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An Emissions Tax in Siberia: Economic Theory, Firm Response, and Noncompliance in Imperfect Markets

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Abstract

The study sets out to discover the most important variables affecting the performance of an emissions tax in the context of a transition economy. An evaluation of the Siberian Pollution database confirms the acute severity of air pollution. Moving from the fact that the region has implemented an emissions charge system, the author examines some of the key theoretical variables explaining the degree of success of an emissions tax. After evaluating these variables, the author finds that most writings have underplayed or missed the most important factor affecting the implementation and functioning of an emissions tax in a transitional economy. Before implementing a market-oriented environmental policy, firms must respond to incentives in formal markets. These sources view the restructuring and environment problem as a one of moving firms closer to formal markets, about which most Western models make their assumptions. However, the author implements a "compliance response boundary" framework, finding that the degree of market orientation of a firm may determine its response to the emissions tax. If firms fall outside of the compliance wedge, policy makers might expect the emissions tax to perform poorly in meeting policy goals of abatement and revenue. In this case, the tax provides few benefits in terms of enhancing efficiency, improving environmental conditions, or allowing "double dividends."

Siberia's unique characteristics--concentrated economic operations around population centers, readily identifiable stationary pollution sources, and a lack of mobile pollution sources—makes it feasible to assess the causes of pollution. The key questions included which groups of chemicals and industries figured most prominently in regional pollution. The majority of all air pollution is generated by large industrial centers, and most of that pollution is deposited within a reasonably near area to those sources.[1] Pollution in the region is highly concentrated, with remote areas hardly affected and populated areas heavily affected in terms of degradation of human health, and environmental health, measured by proxy in terms of forest health. Pollution is not distributed evenly throughout industrial sources, particularly for high-risk emissions such as lead and mercury. The worst polluters, in terms of volume and risk, currently "escape" the emissions charge officially and unofficially. The worst pollution depends on the industrial processes of these heavy polluters, which appear in turn to be a function of the ability of these firms to survive in the current context. If these firms remain viable through bartering and increasing r_i rather than d_i, we can expect a worsened emissions situation for high-risk chemicals. If these firms move towards the markets, they should have an incentive to invest in new production processes that are

[1] Some of course is transported over long distances, but these were outside the scope of this study.

less pollution intensive, if they fall under the compliance response boundary, they may reduce emissions even further.

The author explores the theory of how an emissions tax should work, to further evaluate the strength of the noted variables. Chapter three examines the assumptions of an allocation model, first without, and then with negative externalities from pollution. Because the emissions tax imposes costs upon polluting industry and because pollution imposes constraints on the output of industry (in terms of lower-grade inputs such as labor and natural resources) the model assumes that a tax can promote efficiency and effective abatement. In theory, an emissions charge on firms producing only within formal markets would effectively address a large percentage of Siberia's pollution problems. Siberia's pollution tool does charge higher rates for chemicals with more detrimental human health impacts, roughly reflecting scientific findings. Theory predicts that the charge would successfully impose a constraint upon firms and an incentive to reduce the emission of the most costly types of pollution, such as those in the "high risk" category. Given the assumptions that firms operated only in formal markets where transactions take place based on monetary exchange, the variables of most importance appeared to be the way that policy affected a firm's production function, which assumed that emissions were a joint input of production. In theory, setting the appropriate charge level to equate social and private damage, and the effects of that tax on technological and economic efficiency were primary concerns.

Yet the actual structure of the charge system in Siberia deviates from theory. The program has significant weaknesses; almost every aspect of the policy—from setting charge levels, to monitoring and measurement methodologies, to administrative tangles—appear extemporaneous. No discussion of setting shadow prices for pollution equal to social marginal damage of pollution appears to have occurred. Political reality and the pressing economic concern with survival dictated that key polluting firms are excused from payment obligations, and that the levels charged to other industries reflect the ability of industry to pay more than the actual damage imposed by particular pollutants. These include administrative limitations and obstacles, inflation, and sporadic monitoring and imprecise enforcement of taxes and penalties incurred by firms. Measured against policy goals of revenue collection and pollution reduction to meet human health standards, the policy tool has not yet experienced success. Expected revenues fall drastically short of actual collections, while pollution intensity actually appears to have increased.

Given the weaknesses of the policy implementation, the author further examines possible firm responses to an emissions tax. While a major part of the research assumes that price-taking, privatized firms will respond better to the tax than other forms of enterprises, both theory and experience refute this claim. Under Siberia's particular program parameters, one can expect firms of all types of ownership to respond similarly to the emissions tax. Instead of ownership structure and price levels, the important variable appears to be charge capping, and widespread noncompliance with the emissions tax program. Studies indicate that privatization and the structure of firm ownership does not necessarily reflect that firm's degree of market orientation or the degree of sensitivity a firm will manifest toward market-oriented policies. The status of privatization—enterprise ownership structure—and the level of charges appear less important as explanatory variables.

A framework which accounts for the dynamics of firms moving through the transition either towards or away from formal markets predicts that firms will comply with an emissions tax only under special circumstances, which currently do not apply to the majority of enterprises in the region. Charge levels also play a much less important role in providing incentives for abatement or compliance with the emissions tax. Instead, this framework clarifies what types of firms may comply with the emissions program, and which may not. Using this model, we expect that firms with a high degree of formal market orientation are more likely to feel the constraints and incentives provided by such a market-oriented emissions abatement tool. Viable firms with a higher degree of "relational capital" may choose to balance operations between informal and formal markets. Such firms would have an increased incentive for noncompliance as emissions charge levels rise, because a change in the cost of pollution changes the relative cost of production for formal and informal markets. In this setting, the emissions charge may have perverse effects, causing firms to choose operation in informal markets where no premium is set on pollution rather than paying taxes or abating pollution in formal markets. Cash-shortages and the magnitude of the informal sector, as well as institutional reinforcement of tax evasion or noncompliance, make it unlikely that the emissions charge will impose real abatement incentives or increase environmental fund revenues. In the worst case, the current interaction of informal markets, the tax may actually subsidize further pollution. The ability for firms to act in informal and formal markets simultaneously is the key factor preventing the emissions charge from imposing real incentives. Due to the ease of producing in informal markets where the tax instrument does not reach, firms may have incentives counterintuitive to those intended.

A case study of Tomsk revealed a similar pollution profile to that of Siberia. A handful of industries takes responsibility for almost all industrial pollution. These industries also employ a majority of workers and manifest a relatively low degree of orientation towards formal markets and international trade. Most value-added activities for the natural resources withdrawn in Tomsk occur elsewhere, giving enterprises fewer incentives to invest. Underreporting of emissions appears to be a problem in the oblast, although the emission of high-risk chemicals appears lower in Tomsk than in other Siberian areas. Because an emissions tax increases production costs for formal markets, the author explored labor effects related to this policy. The imposition of an emissions charge has little or no impact upon the inelastic demand for labor in Tomsk. However, price changes due to the imposition of an emissions tax may change the relative costs of production in formal and informal markets, lower the wages of workers, and offer firms incentives to switch production to non-taxed areas. Tomsk enterprises, like many oblasts in Siberia (particularly the most polluting ones, such as energy generation), may economize on cash transactions by bartering tax arrears for needed goods and services. Anecdotal evidence hints at the existence of this phenomena, suggesting that an emissions tax might provide a weak subsidy for polluting activities, rather than an incentive for abatement. The case study pointed out several important "lessons learned" about the Siberian emissions charge program, which have relevance for this policy tool in similar contexts.

A brief comparative study of other transitional economies with similar environmental taxes finds that those countries with greater formal market orientation also showed better results for market-oriented pollution control systems. Successful examples still had problems with tax levels, inflation, lack of sufficient monitoring capabilities. The problems with each individual program spanned a range from formal market institutional problems (administrative, tax level setting, legal questions) to the problem of dominant informal markets and lack of restructuring. While combinations of these problems led to particular outcomes, the most important variable for the success was that country's firms possess formal market orientation and a degree of viability. In general economic terms, Eastern Europe out-performed Russia in its emissions charge policies.

The findings of this dissertation contradict the standard theoretical conclusion that eco-taxes provide meaningful incentives for pollution reduction, due to the economic and institutional weaknesses manifest now in Siberia. The study of Siberia provides key empirical insights into second-best settings for the implementation of such policy tools. The assumptions made in theory about the functioning and incentives provided by eco-taxes are violated in reality in terms of general and firm-specific economic conditions, and institutional frameworks. The principle key for the effectiveness of this program is the ability of firms to remain somewhere outside the formal market system. In addition, as long as noncompliance remains such a large problem, and as long as monitoring and methods for recording and reporting pollution do not improve, the emissions tax system is not superior than other policy instruments in achieving efficiency or improved environmental allocation.

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Koko Warner-Merl

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Executive Summary

Chapter 1: Introduction

This work documents the emerging experience of an emissions tax[2] in Russia's largest region, Siberia. Siberia provides a relevant study of the emissions tax for the impacts and outcomes on its clear pollution and industrial pattern. The current economic challenges facing Siberian "oblasts" (states or provinces) typify in some ways the challenges of transitional economies. The study of Siberia proves relevant for other imperfect economies because of the burgeoning of the informal market—a sort of economic plague that bears enormous consequences for the ability of a market-based policy tool to accomplish its aims. The work moves from an empirical analysis of a pollution and socio-economic database of Siberia provided by the Russian Federation to an examination of the theory of emissions taxes, to an analysis of the actual expected outcomes of the tax in Siberia. Chapter one unfolds with an examination of the major literature dealing with emissions taxes, including theoretical and applied discussions in OECD and transitional economies. The review uncovers the state-of-the art in thinking about emissions tax implementation, and reveals a set of variables, which this work will later examine in Siberia's context. The author provides a brief outline of the major lines of thought devoted to market-oriented policy tools for transitional economies, which include

- Inefficient administration, with understaffed, under-trained, and underpaid personnel assigned to monitor and enforce the policy in an area too vast for continuous control
- Institutional history of the former system such as state-owned firms and soft budget constraints
- Methodologies of collecting and reporting emissions information (Inconsistent measuring and reporting)
- Prices, which appear too low to encourage abatement (reflecting the primary revenue-raising goal of the tool).
- Privatization, which is deemed in most of these pieces to be the key to firm response to the emissions tax. The common analysis is that persistence of state-owned firms encourages widespread lack of clear profit maximization objectives, which in turn reduces the sensitivity of firms to market incentives for pollution control.

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[2] Also referred to throughout the work as a charge.

The author then evaluates these variables, and finds that most writings have underplayed or missed the most important factor affecting the implementation and functioning of an emissions tax in a transitional economy. These sources viewed the restructuring and environment problem as a problem of moving firms closer to formal markets, about which most Western models make their assumptions. The questions which emerge in examining Siberia's case of emissions charges and pollution focus on the following five points:

1. Given the current pollution profile in the region, can an emissions tax address ambient air quality and provide effective incentives for abatement?
2. What are the most important variables that affect the implementation of an emissions tax in imperfect markets?
3. How does the actual program differ from theory and what lessons can be drawn from Siberia's experience with the tax?
4. How do firms react in this economic context to the tax and could the policy instrument achieve multiple objectives?

This study hopes to make four contributions to the literature, which will hopefully fill part of the gap in knowledge about how this policy tool works and the variables which affect its outcome in imperfect settings. It seeks to

- analyze a unique data set about Siberian pollution and economic and social status, which includes the beginnings of a risk analysis in this region,
- illustrate some of the principle issues for a pollution charge system, providing specific data about location-specific environmental and industrial factors, and reveal the severity of environmental disruption and inefficient environmental use,
- assess the revenue potential and abatement incentives resulting from assigning economic constraints to environmental use, and
- evaluate the potential of the emissions charge to achieve pollution abatement in Siberia and the dynamics of the program which affect firm response.

The work is timely and relevant to current academic discussions, and addresses some of the most pressing issues for other developing regions faced with declining ambient air quality. The experience and progress of Siberia towards better economic and environmental performance holds valuable lessons for others. Important similarities exist, which increase the relevance of the Siberian experience in the discussion about emissions charges in imperfect market systems.

This study is unique in many ways. The work makes rare data on Siberia public, both about the pollution status there on an industry-by-industry and town-by-town basis, and allows a fairly accurate pinpointing of pollution sources. It extends a lively debate on the choice and implementation of market-based tools for abatement, and discovers the practical variables that affect program outcome. Its findings challenge the confidence of theory and recommendations of initial research on the implementation of emissions taxes in transitional economies. Its findings differ from the confident statement that "Economic instruments offer considerable promise for improving the integration of environmental and economic policies. Not only do these instruments send better signals to producers and consumers about environmental resource scarcities than more traditional "command and control" instruments, they also promote the technological improvements that will be necessary for improving environmental conditions in the future" (OECD 1994a). The current economic crisis does provide a chance for environmental change and economic change, which is makes the study of these programs so compelling.

Chapter 2: Air pollution in Siberia: A volume and risk-weighted analysis of a Siberian Pollution Database

This chapter provides an empirical overview of the pollution situation in the region. It builds the basis for following chapters by characterizing the particular types of pollution problems found in Siberia, as well as information about the types of firms in subregions which contribute to these types of air pollution. The author analyzes the pattern of emissions in Siberia, including a rough deposition pattern (Nilsson 1998), the most important chemical groups, and industrial polluters. The chapter clusters emissions according to volume and risk, using USEPA methodology. It notes the geographic distribution of pollution in Siberia, and the degree of pollution contributed by industrial sectors. This clustering allows certain policy-relevant conclusions to be drawn in this initial research stage without full risk analyses. The major polluters in terms of volume and risk category bear similar institutional characteristics (history of heavy state involvement, significant exceptions in terms of environmental policy, semi-soft budget constraints, political and economic ties to region-external financial sources/banking). Policy implications for this cluster analysis reveal that the current environmental tax system in Siberia is ineffective in raising revenue for other environmental projects and in achieving abatement. While more toxic emissions face higher taxes, the current tax system does not prove an effective tool, in spite of widespread recent enthusiasm about the implementation of such programs in economies in transition (Bluffstone 1997); (Air Pollution Working Group 1998); (Markandya 1994); (OECD 1994b).

Chapter 3: Theoretical groundwork and evaluation of an emissions tax

Environmental taxes have captured international attention as a cost-effective and flexible policy instrument for air pollution abatement. Studies from prominent organizations began reporting in the early and mid 1990s that environmental and tax policies should be made compatible and mutually reinforcing as a way to improve environmental conditions, raise revenue, and provide a host of other benefits to societies using them. A 1994 OECD report noted that the experience with environmental tax instruments "indicates that tax instruments can also provide 'a rich seam of economic efficiency' for countries in transition to tap for their environmental policies." Although, it continued, "the countries of Central and Eastern Europe face many challenges in adapting existing environmental tax systems to the conditions of emerging market economies and to the goals of the new environmental policies," the report remained positive about the benefits which could accrue from a market-oriented abatement policy. Chapter three offers a theoretical basis for the empirical outline of Siberia's actual emissions charge system that follows, and allows the reader to compare the hoped-for benefits of the policy tool to the apparent outcomes of its implementation in Siberia.

The chapter reviews the assumptions of the model for Siberia and briefly discusses the extent to which the assumptions hold. It next sets the analysis of Siberia's environmental situation in terms of an allocation problem. The model aids in developing a framework to analyze and evaluate air pollution policy in Siberia, particularly its impacts upon human health, the environment, and industrial output. Many distortions exist which lead one to ask about second-best solutions. The chapter formally shows the empirical findings of chapter two: negative environmental externalities associated with industrial production without an effective scarcity price lead to over-consumption of environmental goods. This chapter outlines the classic setting of that scarcity price, and introduces some of the practical problems of setting the appropriate charge level in the region. The focus of the chapter is theoretic, however, even at this stage it becomes apparent that a first-best solution will not apply to Siberian pollution problems. The criteria of the model remain unsatisfied, and the regional economy produces somewhere within the transformation space. In such a setting, a pure Pigouvian-type emissions charge will not function optimally to reduce pollution.

Chapter 4: Outline of Siberia's environmental tax program

The underlying assumption for most of the literary discussions has been that formal markets, which rely on monetary transactions, provide the framework for market-oriented policy tools. Theorists, grounded in the assumptions of Western economic models, provided a host of information to policy makers of transitional economies about the issues that arise in using a tax instrument to achieve environmental objectives. Typical concerns of policy design such as selecting the appropriate target set of pollutants, setting appropriate tax levels and fine-tuning the interaction between taxes and preexisting regulatory frameworks have dominated general discussions of tax instruments for abatement (OECD 1994a); (Klaasen 1994); (Klaassen 1995). Those writings aimed specifically towards the emissions charge in transitional economies focused on inflation indexing and the privatization of ownership structures as determinants of firm response to the tax (OECD 1994b). Yet the literature dealing with market-oriented environmental policy up to this point—and that very literature which analyzes the implementation and impacts of environmental charge systems in transitional economies—has missed the fundamental obstacle to such policy instruments in imperfect market economies.

Chapter four describes and evaluates the implementation of the emissions charge system in Siberia. It shows the historical development of program, noting that the actual establishment of environmental quality standards was a mix between scientific evaluation of "safe" levels of pollution and the ability of industry to meet such standards. Charge levels were set so that industry could possibly attain lower levels of pollution, reflecting the revenue orientation of the abatement program. Next, the chapter outlines the important institutional framework the charge system operates within and some of the obstacles associated with that framework. Finally, the chapter evaluates how close the program comes to meeting its goals of revenue accumulation and pollution abatement. Given the environmental protection priorities defined by law, the program is designed to raise money for an earmarked environmental fund. Due to institutional problems, the program meets neither its revenue nor abatement targets. Economic trauma and decreasing industrial output accounts for lower volumes of emissions. However, rising input-intensities indicate that pollution per unit of output has actually risen since the implementation of the charge system. In the current institutional and economic framework, the emissions charge program neither induces firms to invest in abatement nor pay their emissions charges.

The literature assumes that while evasion and forms of noncompliance exist, formal market institutions are strong enough to constrain most firms to limit the majority of their activities to observable, taxable scenarios. These works largely overlook the growing presence of informal, non-taxable, barter-oriented markets in transitional economies. The ability to “escape” to informal markets where tax arrears are avoided or paid in kind foils the emissions charge system. Siberia’s extreme case illustrates that the institutional framework for formal, capitalistic market activities (and enterprise orientation towards the formal market) must dominate if a policy tool such as an emissions tax is to be effective.

Chapter 5: Enterprise response to Siberia’s emissions tax

Chapter five returns to the cluster methodology to ask how particular Siberian firms respond to the introduction of an emissions tax. The chapter asks if setting a price on environmental goods will actually induce three types of firms represented in the region to reduce their emissions. The discussion reveals that the actual level of the tax plays a smaller role than the likelihood of being caught in noncompliance and the associated penalty. The author compares the theoretical findings with the behavior of groups of Siberian enterprise. The author first analyzes a “typical” profit-maximizing firm in a theoretical framework to estimate the kinds of expected behavior policy makers might expect from such Siberian firms. She next applies the analysis to a non-competitive or monopoly-like firm, which is more realistic for the current pollution situation dominated by Siberian energy and heavy industrial firms. Finally, she relaxes the profit-maximization assumption to estimate the reaction of firms not yet responding to market signals to the eco-tax. Although much of the recent literature discussion emissions charge systems in former USSR economies focus on setting the appropriate tax level, the findings suggest that the tax level itself is a less-important factor in firm response than is the institutional (regulatory) framework. Although the tax level plays a role, firms seem to respond to the system in a type of portfolio management behavior. None of the firms types investigated appeared to respond foremost to an increase in taxes, which actually encouraged greater evasion rather than compliance. In terms of specific pollution types, one of the most significant implications of these findings are that firms may respond less to reduction of high risk chemicals such as lead, which bear a five-fold penalty. Firms may have an incentive to superficially reduce low-risk chemicals such as SO_2 which are easily detected (due if nothing else to sheer volume emitted) but which also bear lower penalties, than to reduce high-risk groups (with lower probabilities of detection) such as lead and mercury. Combined with continuing economic instability and periodic inflation, disregard for taxation systems in general, and misinformation, the current tax levels are not effective in either raising environmental revenues or reducing emissions.

The literature assumes that while evasion and forms of noncompliance exist, formal market institutions are strong enough to constrain most firms to limit the majority of their activities to observable, taxable scenarios. The literature largely overlooks the dual, growing presence of informal, non-taxable, barter-oriented markets in transitional economies. The ability to “escape” to informal markets where tax arrears are avoided or paid in kind foils the emissions charge system. Siberia’s extreme case illustrates that the institutional framework for formal, capitalistic market activities (and enterprise orientation towards the formal market) must dominate if a policy tool such as an emissions tax is to be effective.

Chapter 6: Environmental compliance

As the previous chapter indicated, “getting the prices right” is not enough in transitional economies to reach the sometimes contradictory goals of revenue and abatement. The author analyzes the phenomena in Siberia, and attempts to roughly estimate the magnitude of noncompliance for environmental taxes using established compliance theory methodology and employing Siberian database figures (IIASA 1996a), (IIASA 1996b). After identifying the key industrial sectors where noncompliance appears to occur most often, the author asks how better performance could be achieved. The punishment costs and expected punishment costs for Siberian enterprises are sufficiently low and increase so slowly that the unit tax on reported wastes exceeds the increase in expected penalty in relation to violation size. Data from the Siberian database confirms this pattern of reported wastes. Firms do not usually report zero emissions, which signals noncompliance, but tend to report just under or above maximum permissible emissions.

A modified model incorporating a viability constraint (Gaddy 1999) and a compliance response boundary provides a conceptual tool to think about why firms may or may not respond to market-oriented policy such as an emissions tax. This section is significant because no author has attempted to assign magnitudes to noncompliance by sector, nor attempted to identify economic and institutional barriers to compliance in this region. What results is a “picture” of firms in Siberia which are more or less likely to respond to market-oriented policy instruments. By acknowledging the special economic framework in which transition Siberia is set, including the institutional weaknesses and economic limitations of Siberia’s regional environmental authorities, we gain significant insight about the types of firms which do and do not respond to market oriented policies, and some of the key reasons for that noncompliance.

Although decision-makers expected such instruments to function imperfectly in economies moving towards market societies, the issues excluded by the key assumptions of how tax policy operated became the moving obstacles to effective implementation. The critical assumptions underlying the environmental tax instrument did not hold, particularly in Russia. One of the key obstacles in the implementation of a market-oriented instrument—an emissions tax—in Siberia is that a major part of the economy is demonetized. A barter system exists both to evade taxes and to pay taxes, a situation not dealt with in standard economic models, and one which prevents the potential economic incentives for abatement, as well as the benefits of tax revenue from the emissions charge. Most authors have acknowledged weaknesses but have given relatively positive reports about the policy instrument and its implementation (Bluffstone 1997); (Klaassen 1995). These works have implicitly stressed the idea of an environmental Kuznets curve (Andreoni 1998): that once economic growth takes place, once all firms are privatized, once the emissions tax levels are raised, once the administrative structure is improved the emissions tax will function according to theory. However, we find that if Russia does continue to operate one formal economy based on monetary transactions and one informal economy based on non-monetary transactions, the prospects for an effective emissions tax that provides incentives for Siberian enterprises to reduce emissions is rather dim. Without the market orientation necessary to feel the constraints of a market-oriented tool, Siberian firms will likely not decrease emissions, and may increase emissions as a by-product of wasteful production methods that are part of the distorted economic system.[3]

Chapter 7: A case study of Tomsk

Chapter seven turns attention to the implementation of the emissions charge system in one region in Siberia. Preceding chapters indicate that institutional changes are the important factor in the emissions charge program, rather than (as standard theory suggests) finding an optimal tax level. Throughout this discussion issues of market orientation and its effects upon firm compliance became salient. Chapter seven illustrates the most important issues for the emissions charge system in the context of the economic and social situation in Tomsk oblast.

This case study of Tomsk illustrates the imperfect implementation of a market-based tool for emissions abatement in Siberia. The study shows that an imperfect institutional structure of a Siberian oblast effectively prevents the program from either reaching its revenue goals or its abatement targets. This analysis of the environmental tax system in Tomsk evaluates the impacts of the current emissions charge system and some of the questions regarding the ability of a market-based tool to achieve several objectives (including abatement, revenue raising, and a possible cut in labor taxes) at one time. To accomplish this task, the study

[3] Gaddy and Ickes (1998) refer to such firms as value-destroying.

evaluates Tomsk's pollution profile, including its economic profile (i.e. which firms produce and pollute) and its degree of market-orientation (using the compliance response boundary framework), and estimates the impact of the pollution charge on employment, production output in formal and informal markets, firm emissions output, and the impact on evasion and compliance levels.

This chapter evaluates the emissions charge system within one region in Siberia. It reveals some of the practical, important issues that affect the actual outcomes of market-based instruments in an economic setting where firms vary production across informal and formal markets. This ability to avoid the constraints of formal markets changes the analysis so significantly for Siberia, that the author concludes that the current emissions tax policy will likely not motivate enterprises to either increase abatement activities or investments nor pay their actual environmental taxes. This finding deviates from theoretical work which assumes only formal market participation and positive emissions tax levels.

A closer look at the economic context of Tomsk oblast, including its pollution profile, industrial and employment characteristics indicates that the emissions charge faces significant obstacles to effective implementation. Like other areas in Siberia, Tomsk regional authorities have no greater access to resources or monitoring facilities than others, making enforcement difficult. The standard self-reporting mechanism is fraught with underreporting, intentionally or not, and the charges themselves change frequently within the labyrinth of Russian tax law. This obliges taxpayers to either interpret the charge payments "creatively" or avoid taxation. Journalists in the region have reported cases in which managers would prefer to comply with the tax code, but do not know how because the code is under constant revision (Leiter and Tedstrom, 1997). The opaque and complicated tax system within which the emissions charge is embedded discourages compliance. In addition, any attempts to raise emissions charges in order to increase government revenues and ease the tax burden for labor or corporations may cause increased evasion or avoidance, a decrease in collected revenues, or both. Were the regional government successful in reducing labor taxes, it is very likely that this policy would be strongly regressive, as more wealthy workers might be freed of a tax burden and less wealthy could suffer from reduced access to government funding as government revenues decline. The pollution profile of Tomsk oblast indicated that environmental conditions are likely worse than assumed. However, it is positive to see that only traces of the highest-risk chemicals such as heavy metals are emitted in the region. Health risks associated with Tomsk emissions appear to be most heavily concentrated around pulmonary and skin irritations, which bear a lower political cost than cancer, higher infant mortality, spontaneous abortion, and other acute or chronic disorders associated with high-risk chemicals. While this is good news for the Tomsk population, it suggests that relative to pressing economic concerns, environmental concern and the willingness to pay for environmental damage will likely remain low.

In terms of possible "double dividends" from increases in emissions taxes to fund decreases in labor or corporate taxes, the author found that there are few possibilities to find such a tax mix where firms will not evade the tax, even if taxes are cut elsewhere. Effects upon employment, whose demand appears relatively inelastic in Tomsk and in

Siberia, appear negligible when emissions tax levels change. However, shifts in the price of emissions could raise the price of output in formal markets, lower the wages of workers, and offer firms incentives to switch production into informal markets. In some cases, given possible barter trade of tax arrears, it is even possible that the current emissions charge provides a subsidy for polluting activities. This depends on the enterprises relative position within the oblast. Given that sectors such as oil and fuel, and energy providers monopolize local markets for heat, as well as employment, the emissions charge could feasibly give such firms greater leverage with the regional government. Many authors have noted that clients (including the government) are unable to make cash payments to fuel-related enterprises. It has been observed that such enterprises must engage in barter trade due to the cash crisis, and often tax arrears are also bartered. Instead of paying emissions charges, which go into the environmental fund and are hypothecated for abatement and other environment-improving activities, charges become negative for polluting activities for such enterprises in Tomsk. The effect of the emissions charge on private and public consumption appears ambiguous. Effects upon environmental quality appear neutral.

Chapter 8: Conclusions

This study has deepened understanding for the outcome of the implementation of a market-based tool for air pollution abatement. The findings reflect a new tangent in research on both the outcomes of market-oriented abatement tools and the nature of industrial restructuring in transition economies (Gaddy 1998), (Fischer 1998), (Leiter 1997). Like this new strain of writing, findings from this study of Siberia contrast with earlier theoretical work on the impacts of an emissions tax on an economic system. Rather than increasing cost efficiency and investment in abatement technology—two of the key assumptions about the benefits of the emissions charge—Siberian environmental authorities observe a decline in environmental quality and large-scale avoidance of the tax. In addition, the emissions tax has not generated observable investments in abatement and has not notably increased cost-efficiency in environmental standards enforcement. The conclusions of this study are much more qualified, if not a little pessimistic, about the merits of an emissions tax policy within an economic environment that defies common assumptions of the way market systems work.

The most important lessons learned from this case study differ surprisingly from other research on improving economic instruments in transitional economies. Unlike Bluffstone *et al*. (1997), the author emphasizes the need to first establish the institutional framework for a market-based tool before focusing on important secondary issues such as tax levels, number of pollutants in the charge system, etc. Without the constraints imposed by effective market institutions, an emissions charge will not prove effective.

The market-orientation of the actors involved matters. The compliance response boundary framework and model help us see the principle constraints in the imposition of an emissions tax in Siberia. Because an emissions tax affects the price of operating in formal and informal markets, the initial position and ability of firms to move either towards or away from each respective market will serve as guides to policy makers seeking to understand possible impacts of an emissions tax. In the real world, and particularly in settings where institutional frameworks tend to be very weak, evasion is a constant reality and key problem, monitoring covers only a fraction of pollution instances, and reporting and collection often appear sporadic.

Those enterprises that can avoid performing efficiently in formal markets manifest lower tendencies to respond to market-oriented policy tools. Developing countries with mostly state-owned enterprises might therefore carefully consider other alternatives to air pollution policy than an emissions tax. In this case some regulatory policy may be more effective in abatement. In reality, emissions taxes may prove no more efficient than regulatory tools. At best some combination of tools designed carefully for the economic context of the country of implementation might achieve the best revenue and abatement results.

Privatization is not necessarily an indicator of formal market responsiveness. Officials expressed great initial enthusiasm for privatization as the key mechanism for moving centrally-planned, former USSR economies towards the market. Yet results from studies of Tomsk (Huber 1997).; (OECD 1996); (Radaev 1997), the Russian Federation (Kovalevskii 1995), and other transitional economies have shown that the effects of privatization on restructuring and market performance are ambiguous. Employing market-oriented policy tools within a context where firms, although officially privatized, bear significant non-market characteristics, implies poor firm response. The experience with the emissions charge system illustrates this case.

Initial infrastructure conditions matter. Because emissions charges affect the cost of production in formal markets, initial infrastructure conditions matter. Although the ability for firms that have previously not invested in abatement measures to achieve very high relative returns for initial reduction in pollution, the costs of doing so might be prohibitive. Firms in developing and transitional economies, as well as selected aging industries in better-developed countries, often must undertake a significant degree of industrial restructuring. If a firm can manage to survive by altering its production portfolio to involve informal markets where emissions taxes do not reach, then such a policy will not only miss achieving its goals but may also actually encourage firms not to make the effort to restructure. An emissions charge in such cases might be augmented with an accompanying policy that provides some type of financial assistance that lowers the cost of restructuring and abating. This underscores the need for greater complementarity between policies, and coordination of economic and regulatory rules. Simply selecting a market-oriented tool based on good theoretical reviews will likely elude the achievement of meaningful change in environmental performance or tax collection.

Focus first on building necessary institutional capacity. Before trying to achieve an optimal tax level, maximize efficiency or social welfare, policy makers must establish institutions necessary for proper tax collection and enforcement. Imposing a charge on emissions has not provided a sufficient motivation for most Siberian enterprises—or most other enterprises in transitional economies—to invest in abatement solutions or to otherwise reduce their pollution or pay their pollution taxes. The opportunities for misreporting, outright noncompliance with tax programs, and other forms of avoidance or evasion significantly weaken the current emissions charge program. Emphasis upon improving the institutional framework within which the policy operates will more effectively improve program performance than changing tax rates. The single most important factor for the implementation of a market-oriented policy is the ability for institutions to encourage and enforce economic activity within the sphere of formal markets.

Investment conditions matter. Implementing a market-based tool for abatement assumes the tool provides incentives for investment. This case study of Siberia has illustrated that economic conditions must be stable enough to reduce risk and uncertainty for an investing firm. As Bluffstone and Larson (1997) note, "While most environmental authorities think that their pollution charge systems increase incentives for investment in pollution control, very little evidence exists that charge systems actually do provide such incentives. Investment decisions in these regions take place in highly uncertain market and regulatory environments, and under such conditions the relationships between current charge levels, future charge levels, and investments in pollution control are not simple" (see also (Magat 1978), (McCain 1978), (Pindyck 1991), (Larson 1996)). It is likely that other developing areas face similar challenges in terms of abatement investments.

The study pointed out other important issues, of secondary importance to emissions charge systems and policy design.

Conflicting program goals. The structure of the program in Russia is designed to give firms to an economic incentive to reduce all classes of pollution. However, as in most transitional economies, firms easily avoid or evade charge payments, which are generally too low to induce abatement behavior even if evasion or avoidance is more difficult. If abatement of pollution and an improvement of ambient air quality were the highest-priority goal, then the program would impose higher charge rates, strictly enforce standards, and base rates and penalties upon strictly enforced environmental standards. The current system strikes an ineffective balance between a need to raise revenue and a desire to improve ambient air quality. The framework for tax collection remains weak and abatement incentives low. A possible solution would be to charge an emissions tax on one or two high-volume chemicals such as particulates and SO_2 (Golub 1997). This might encourage a long-term shift towards greater fuel efficiency in Siberia, and possibly in other developing areas that rely heavily on coal and fossil fuels for energy. It might also be easy to target those polluters emitting the greatest amounts of such chemicals and reduce noncompliance.

Hypothecation/environmental funds need close monitoring and disbursement criteria. Close examination of Siberia's fund reveals lack of clarity regarding operating practices, and a lack of evaluation of the environmental and economic effects of the investments made. In cases where pollution charges are earmarked to environmental fund systems, charge revenues are often derived mainly from private sector or public enterprises subject to hard budget constraints. Environmental funds may become politicized and treated as grants rather than loans. The focus on giving gifts rather than overcoming capital market failures means that project appraisal processes generally are not transparent and the reasons for distributing funds are not based on objective environmental and economic criteria. At the municipal level, environmental funds may be treated as part of the general budget and officials often use these resources in ways unrelated to air pollution control. These uses are usually not monitored or controlled. Accountability or a sense of urgency to improve environmental conditions do not mark current earmarking practices. Over time, however, both environmental funds and pollution charges may create identifiable projects for which environmental outcomes are known. This can economize on monitoring and enforcement because these instruments offer incentives for enterprises to reveal private information about their activities (problem with informal market producers). They also provide a set of estimates of abatement costs that can be used to set appropriate charge rates (Zylicz 1994), although this assumes that definitions for environmental investments are broad enough to encompass both end-of-pipe investments and process changes.

Future research will focus on implementing a mix of tools. This and many other empirical studies show no clear advantages of regulatory or market-oriented tools. The theoretical advantages of a charge system such as efficiency and gains in social welfare do not appear to play a significant role, even in advanced industrial countries. Rather, policy tools rely very much upon the context into which they are set to achieve any set of objectives. Future research will investigate the design and implementation of complementary policies to achieve reductions in air pollution. While other objectives may eventually also be accomplished using a mix of policy instruments, it appears most prudent at the outset to focus on improving ambient air quality.

Many other aspects of design become important (Bluffstone 1997). However, the single most important factor in implementing a market-oriented pollution policy tool is the response of firms to that tool. If firms can easily escape the penalties and higher costs of the formal market, policy makers should expect poor results for an emissions tax. If firms operate within economies where market institutions are highly developed, where the costs of operating in informal markets are relatively high and where costs of developing relational capital exceed those of developing market-oriented endowments, the emissions charge has a much better likelihood of succeeding.

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Chapter 1: Introduction

1.0 Introduction

As the transition process from centrally-controlled to market economies began, information about the status of air quality in central and Eastern European countries shocked many observers. Dust emissions in the late 1980s were on average thirteen times higher (dust emissions per thousand dollars GNP) than in Europe. Emissions of other pollutants, exceeded European averages per dollar of output by two or three times. Emissions of heavy metals appeared extremely problematic, with resultant degradation of human health and environmental quality. Since the 1970s, chemical pollution of the air and acid raid have reduced the forest area in Siberia by almost 1.5 million acres and have threatened an additional 2.5 million acres, according to official estimates. In a forest zone near the Norilsk nickel plant, 740,000 acres have died. Near the Bratsk aluminum plant, 345,000 acres have died and in and around Irkutsk, 170,000 acres. Over 270,000 acres have died due to industrial pollution near the Severonikel plant on the Kola Peninsula.

Health statistics only underscore the reality of these statements. According to the State Report on the Environment (Environment 1993), atmospheric pollution is officially responsible for 20 to 30 percent of the overall illness rate of the Russian population. Forty percent more individuals are reported sick in Magnitogorsk, Novokuznetsk, Nishniy Tagil, and Lipetsk—all major ferrous metallurgy centers—than in relatively non-polluted cities (Goskompriroda 1993). High rates of bronchial asthma and skin allergies are blamed on petrochemical and organic synthetic Above-average rates for congenital disorders, spontaneous abortion, heart disease and cancer characterize cities possessing such plants (*ibid*.).

One institute of the Russian Academy of Medical Sciences calculated that only 15 percent of the urban population of Russia lives in areas with "ecologically acceptable levels of pollution" (Goskompriroda 1993). A Russian government resolution of 16 March 1990 identified 43 cities in Russia that required urgent measures to reduce air pollution (*ibid*.). The former Russian Federation minister of health, Dr. A.I. Popatov, stated that "to live longer, [one must] breathe less" (Feshbach 1995).

The central objectives of central planning in Russia—rapid and massive industrialization—encouraged a disregard for environmental regulations and standards, subsidization of environmental destruction, and consequent environmental disaster (Mnatsakanian 1992). At the end of the 1980s, steel production capacity in the Soviet Union exceeded that in the United States by two times, while the economy was one-eighth as large. Promotion of the "commanding heights" of heavy industry, and the necessary large-scale subsidization of energy prices—aided in the distortion of the economic structure, encouraged tremendous inefficiency, and resulted in excessive air pollution. Lack of well-defined property rights further encouraged waste and general neglect of emissions restrictions. The prices of environmental inputs, seen as energy or air quality, had little relevance for industrial consumption and production. Company managers bore no penalties for inefficiency, nor were they generally rewarded for making sacrifices to "do more with less." Since state-owned companies rarely faced punishment for environmental accidents or long-term degradation, they infrequently took adequate precautions to protect populations from these incidents. Although laws required the installation of abatement equipment, many firms did not install the equipment, allowed it to become obsolete, or did not maintain it, reducing the ability of such measures to improve air quality in these areas (*ibid*.).

With the transition from centrally planned to market economic system, many hoped that the most egregious of these problems would disappear. Policy makers began exploring and implementing a host of new market-oriented environmental tools to address the issues mentioned above. Most of these countries chose emissions taxes, for their emphasis upon efficiency, accountability, their cost-effectiveness, and probably most importantly for their promise of revenue. Western economists enthusiastically lauded these moves, suggesting that an emissions tax would certainly avoid the pitfalls of expense and inefficiency which regulation often encounters. Many also hoped that transitional economies which used emissions tax policies would achieve major reductions in emissions at surprisingly low costs (Bluffstone 1997).

This work documents the emerging experience of an emissions tax[1] in Russia's largest region, Siberia. Siberia provides a relevant study of the emissions tax for the impacts and outcomes on its clear pollution and industrial pattern. The current economic challenges facing Siberian "oblasts" (states or provinces) typify in some ways the challenges of transitional economies. The study of Siberia proves relevant for other imperfect economies because of the burgeoning of the informal market—a sort of

[1] Also referred to throughout the work as a charge.

economic plague that bears enormous consequences for the ability of a market-based policy tool to accomplish its aims. Section 1.4. outlines other major goals of this work.

This chapter unfolds with an examination of the major literature dealing with emissions taxes, including theoretical and applied discussions in OECD and transitional economies. The review uncovers the state-of-the art in thinking about emissions tax implementation, and reveals a set of variables, which this work will later examine in Siberia's context. Following the literature review, section 1.2 makes explicit the driving questions of this study. Section 1.3 points out the specific objectives of the work, as well as the information gaps it hopes to fill. This section also links the discussion of Siberia's experience with an emissions tax to ongoing discourse in other imperfect economic settings such as developing countries or regions. Section 1.4 outlines the author's methodology in fulfilling the objectives and answering the driving questions of the research. It outlines the development of the chapters in this work, and points to some possible outcomes. Section 1.5 draws conclusions.

1.1 Literature review

This section reviews some of the most influential literature relating to market-oriented tools and to their use in economies in transition. The review provides a foundation from which to begin discussing the emissions charge in Siberia, and it outlines the central concerns of scholars to date about the set of important factors which affect the outcome of such market-oriented environmental policies. Because Siberia, and transitional economies by definition, do not fully meet all of the assumptions of standard economic modeling, an overview of these important variables and a subsequent review of Siberia's own experience will reveal if and how such an economy differs from the standard discussion. The review suggests the implications that these differences have for the implementation of an emissions tax in an imperfect market context.

The author divides this brief review into three sections: Theoretical literature dealing with economic tools for emissions abatement, including compressed reviews of Pigouvian taxes and the Coase theorem. The discussion then moves on to more recent literature which deals with the economic rationale for using such policy tools, and the subsequent widespread discussion of their impacts. Taxonomies and case studies mark this phase of research, with optimists, skeptics, and those advocating a mix of policy tools demarcating the discussion. Finally, we review the newest literature on the use of emissions charges in economies in transition. This work focuses on the structure, financing, and initial findings of case studies in the Russian Federation and surrounding areas. The study of Siberia's environmental policy provides a direct extension of this work by examining the impacts of an emissions tax in one region of Russia, and investigating the most important variables in program implementation and outcomes.

Research on the use of market-based tools to correct negative externalities, begun early in the twentieth century (Pigou 1932), quickened in the latter part of the century and grew exponentially in the 1980s and 1990s. By 1991, The OECD had advised its member states to “make a greater and more consistent use of economic instruments as a complement or a substitute to other policy instruments such as regulations, taking into account national socio-economic conditions” (OECD 1991). The use of such tools to address environmental problems has increased in the 1990s, as countries seek to capture the static and dynamic gains in efficiency suggested by the literature. This section reviews some of the most important writing on emissions taxes as they relate to transitional economies. It begins with a brief review of the classic thoughts of Coase and Pigou, and then moves to more recent research about the possible boons and boundaries of using this policy tool. The section ends with a review of latest research on the emissions charge system in transitional economies. Due to the program’s newness, and a lack of official data, these studies focus on program structure and objectives. The current study attempts to fill that gap by reporting the results of the emissions tax in Siberia. The case study will allow researchers to see the important factors for success and failure in such an economic setting.

1.1.1 Negative externalities and market tools

The idea of a pollution tax was first suggested by A.C. Pigou (1920), who hypothesized that polluters should face a tax based upon the estimated damage caused by their emissions. His analysis distinguishes between the private and social costs of production and consumption activities. Pollution gives rise to external costs, which drive a wedge between the two types of costs. Social costs of production or consumption consist of private costs plus any external costs. In many cases of pollution externalities, a large number of polluters is involved. The Pigouvian principle prescribes to tax all emissions according to the marginal damage to the environment. However, the optimality of Pigouvian taxes may break down if costs of enforcement are substantial, for example because they are related to the number of agents to be monitored.

That analysis was widely accepted prior to Coase's work in the field. The existence of externalities does not necessarily lead to an inefficient result. Pigouvian taxes, even if they can be correctly calculated, do not in general lead to the efficient result. Third, and most important, the problem is not really externalities at all--it is transaction costs.

R.H. Coase (Coase 1960) noted that if property rights are well defined and transaction costs are low, private parties could internalize an externality. External cost is not simply a cost produced by the polluter and born by the victim. In almost all cases, the cost is a result of decisions by both parties--joint decision-- which produces the cost. A legal rule that arbitrarily assigns blame to one of the parties only gives the right result if that party happens to be the one who can avoid the problem at the lower cost. Pigou's solution is correct only if the agency making the rules already knows which party is the lower cost avoider. The result may be inefficient if the other party could prevent the problem at a lower cost.

One of the arguments commonly offered in favor of using Pigouvian taxes instead of direct regulation is that the regulator does not have to know the cost of pollution control in order to produce the efficient outcome. One sets the tax equal to damage done, and lets the polluter decide how much pollution to buy at that price. Yet one of the implications of Coase’s argument is that the regulator can only guarantee the efficient outcome if he knows enough about the cost of control to decide which party should be considered the polluter (and taxed) and which should be considered the victim.

As long as the parties involved can readily make and enforce contracts in their mutual interest, neither direct regulation nor Pigouvian taxes are necessary in order to get the efficient outcome. A clear definition of property rights and liabilities addresses the problem. If transaction costs are zero then any initial definition of property rights leads to an efficient outcome.

The continued existence of pollution may be efficient if the damage imposed is less than the cost of preventing it. Another possible reason, according to Coase, is that transaction costs of reducing pollution exceed allowing the problem to exist. Coase anticipated public choice economists, such as Buchanan (Buchanan 1969), in arguing that the real choice was not between an inefficient market and an efficient government solution but rather among a variety of inefficient alternatives, private and governmental. In Coase’s words: "All solutions have costs and there is no reason to suppose that government regulation is called for simply because the problem is not well handled by the market or the firm."

Baumol and Oates (Baumol 1971) examined differences between the pricing and standards approach and the Pigouvian-prescription for the control of externalities. The main motivation for adopting the pricing and standards approach is that no exact method exists for determining the optimal Pigouvian tax (equal to the marginal net damage) which leads to Pareto-efficient levels of activities. This is because sufficient information to determine optimal Pigouvian taxes or subsidies is lacking. In contrast, the pricing and standards approach sets predetermined standards for environmental quality and then imposes taxes sufficient to achieve these standards. While this method does not purport to achieve the optimal allocation of resources, it does at least offer some workable way of reducing the level of environmental damage.

Before emissions charge systems and taxes were widely implemented, the focus of the discussion remained on efficiency and the maximization of social welfare. As countries began to experiment with the range of market-based tools, however, the focus shifted slightly. Experience showed that those issues most important in academic circles were not necessarily those of importance to policy makers. Concern remained with efficiency, but new issues such as the range of policy tools available, institutional frameworks, the distributional impacts of the tax, and other variables became important.

1.1.2 Analysis of emissions taxes

In the mid-1980s, countries began to experiment with market-based tools for emissions abatement. Much of the literature provides a sort of taxonomy to characterize the different types of tools available and under what circumstances to use each tool. During this stage of research, scientists manifested a great optimism that, among others, an emissions tax would not only capture "a rich seam of efficiency" (OECD 1994b) but also allow tax restructuring elsewhere to reduce the overall burden on society.

The Commission of the European Communities (Communities 1990) examined the extent and use of economic and fiscal instruments in environmental policy in the European Community. Basic elements of economic instruments, and environmental problems in which economic instruments can be applied are discussed. The report compares various types of economic instruments and describes some successful examples of economic instruments currently applied in Europe. Opschoor (Opschoor 1990) linked the use of economic instruments to sustainable development, noting that economic growth is unsustainable because economic agents shift adverse costs onto others. The author then reviews how policy makers can counteract such behavior, examining in greater depth the prospect for using emissions taxes and charges. Drescher (Drescher 1993) established a set of criteria for the evaluation of environmental taxes and the application of taxes on air and water pollution in different European Countries, the United States of America and Japan. Pearce (Pearce 1989b) reviewed the polluter pays principle, and how it relates to internalizing the costs of environmental damage. His work describes the misunderstanding of the concept of PPP and the methods of internalizing cost, as well as the link between economic tools and sustainability (Pearce 1993b). A comparison of how the principle works in developed and developing countries is made.

An even bolder approach to emissions taxes, Repetto (Repetto 1988), (Repetto 1990), (Repetto 1992), advances the idea that the more industrialized countries can promote sustainable economic progress without sacrificing living standards, possibly even raising productivity and strengthening the global economy. He says that these countries must undertake development of the world economy without environmental degradation. Repetto's proposal to initiate changes includes the reconfiguration of national-income accounting to reflect natural resources losses; the revamping of economic policies to discourage pollution waste; the imposition of fossil fuel taxes to encourage energy efficiency and technology development within a more supportive policy framework for investment, technology transfer, and finance. As Repetto concludes, "The challenge is not so much to discover what must be done to ensure sustainability. The challenge is to discover how to do it."

Andersen's comparative study of the Dutch and Danish efforts to curb surface water pollution distinguishes between the means available for environmental protection and the organizational framework in terms of the agent employed as responsible for the implementation (Andersen 1991). In both cases the agent and means are initiated by the regulating state, so the distinguishing factor is whether the agent and means are operated on market terms or on public sector terms. Perhaps the most pertinent finding of this paper is that traditional command-and-control strategies impede rather than foster the sustainable development of industrial society.

Such studies were followed with surveys of the broad range of economic instruments, which often focused on the several types of charges and taxes available to reduce emissions. In 1994, the OECD released "Managing the Environment," a survey of the use of economic instruments in its member countries (OECD 1994a). Since the first survey, conducted in 1989, the variety and scope of instruments has increased considerably. The work discusses the policy framework and rationale behind economic instruments, as well as a range of economic tools. Country case studies illustrate the practical application of these instruments. Other studies include OECD (OECD 1993) which provides an overview of energy taxes in Austria, Denmark, Germany, Japan and the United States. Pearson and Smith (Pearson 1991) assessed a proposal for a European carbon tax, including a range of likely effects, including distributional effects and the level of revenues that member states might expect to obtain from the tax, and the possible uses of the revenue. The report concludes that market-based environmental policies (such as the carbon tax) are the most effective. Implementation of such a policy will result in fuel substitution away from fossil fuels. However, the authors estimated that unilateral implementation of such an environmental tax could hold serious consequences for the competitiveness of certain industries. They recommended that the six industries that use fossil fuels most intensively should be exempt from the charges, but note the possible flaw in such an act because these exemptions will be permanent. This report provides a brief introduction into the real complexities of an emissions tax when implemented in a non-model setting.

Ayres and Kneese (Ayres 1969) take an initial step towards general equilibrium modeling and, unlike previous economic literature which tended to separate the issue of pollution and general economic activity, incorporates externalities in a general equilibrium framework. In spite of growing caution in pilot studies, further modeling approaches were used to determine the comparative efficacy of policy instruments (Peck 1993). Studies such as Manne and Richels (Manne 1993), using the Global 2100 Model, and Nicoletti and Oliviera-Martins (Nicoletti 1992), which used GREEN; the global, dynamic, applied general equilibrium model developed by the OECD secretariat, to determine the effectiveness of the proposed tax measures and their implications for other countries/regions of the world, showed results close to theoretical predictions. For example, Peck and Teisberg compared three policy instruments, one of which was an emissions tax for the control of CO_2, assuming that the costs and benefits of emission control are known, and assuming that there is uncertainty about these costs and benefits. They found that in controlled circumstances the emissions tax best achieved the emissions target. The results of this study can be compared to those mentioned in Manne and Richels (Manne 1993), since the two models—CETA and Global 2100—are closely related.

Some skeptical voices did emerge, which cautioned the outright acceptance of market-based tools without closely examining the context into which they would be set. As evidence from numerous case studies of emissions taxes emerged, researchers began to advise using a mix of policy tools, the selection of which should depend upon the specific framework in any given area.

Unlike the initial literature which emphasized gains in efficiency and cost-effectiveness, the later literature shows concern for *design* issues within the implementation context: linkage and compliance, firm response depending upon market and production structures, hypothecation, double dividend and pre-existing distortions. The results for many OECD countries might be considered successful in terms of achieving environmental and revenue goals. This study will evaluate whether such gains are possible in imperfect markets, in transition areas where formal market activity is quite imperfect.

Smith (Smith 1992) and other authors continued optimistic reports about the use of emissions taxes and other market-oriented policy tools as more cost-effective methods of pollution control than regulatory policies which are limited by the informational capacity of regulatory authorities. Smith explores the different taxation possibilities for the effective achievement of environmental objectives, the choice of which is a trade-off between the tax in question and the administrative costs involved. The author begins to raise the vital question of when these types of tools work best, and implicitly recognizes that even a market-based tool such as the emissions tax requires an administrative and institutional framework oriented towards formal market activity. The discussion assumes that those countries with good-functioning formal markets will successfully implement an emissions tax for the reduction of air pollution.

Tietenberg (Tietenberg 1992) draws upon economic theory plus empirical and personal experience in implementation of economic instruments, to provide a brief overview of the major lessons he has learned about emission charges and the more traditional regulatory policy. The author concludes that emissions charges work particularly well when the associated transaction costs are high while emissions trading seems to work well for uniformly mixed pollutants. He optimistically predicts that economic incentive approaches should grow in the future since pollution problems fall into the domain where such policies have been most successful. However, by outlining the circumstances in which the policy will have positive results might also implicitly suggest that when these conditions are not met, the charge might not work.

Along similar lines, Stavins (Stavins 1990) examined a range of incentive-based policies for environmental protection. The author concludes that in the long run economic and environmental goals must complement one another if sustainable solutions to today's problems are to be found. Should the environmental policy not “fit” into the larger economic context, the likelihood of reaching program goals will be diminished. Hence, the discussion of economic setting became a central point for discussion in the literature. About the same time, the CCME (CCME 1993) surveyed its members to investigate the barriers to the implementation of economic instruments to promote environmental protection. While the results showed that emissions charges were effective, some of the barriers to implementation which are not considered by the larger theoretical literature could prevent the tax from achieving efficiency or cost-effectiveness. The study indicates that the economic and political setting for emissions taxes play a crucial role in its outcome.

McKay *et al*. (McKay 1990) and de Witt *et al*. (de Witt 1991) began exploring the distributional consequences of emissions taxes. They found that, as with all environmental policies that require changes in the way that business and individuals behave, environmental taxes do incur additional expenses. The costs of changing to more expensive production methods, or to products that appear to offer value for money, are common to both the regulatory and taxation approaches. However, taxation involves further costs, in the form of the tax revenues paid by each business or individual. The authors explore the impact of such taxes on households and the distribution of tax revenues. In spite of a growing uncertainty the authors still recommend tax instruments over conventional regulatory approaches for environmental pollution. Taxes allow firms and individuals to choose to reduce pollution where the cost of doing so represents a saving. Moreover, taxes provide a continuous incentive to develop less polluting products and processes, whereas regulations tend to encourage only minimum compliance.

With research focusing increasingly on tax efficiency and structure, the “double dividend” debate became wide discussed in academic and political circles. The promised ability of an environmental tax to shift the burden from “positive” economic activity such as labor to “negative” economic activity such as environmental degradation excited policy makers and busied scholars trying to assess the parameters for a possible two-fold gain. This literature is very extensive, we mention only a few of the many works here. Owens (Owens 1993) explored how tax measures affect the environment and what tax regime can best produce environmental protection without damaging production are the questions raised in this article. The author identifies failures in the tax system as an important contributor to the problem. Issues such as hypothecation, fiscal neutrality, revenue neutrality and fairness are fundamentals which need to be taken into account when designing a new "environmentally friendly" tax regime. Weizsäcker and Jessinghaus (Weizsacker 1992) also investigate the possibility of ecological tax reform, and find that “nothing short of an efficiency revolution in our use of natural resources is necessary to convert the technologically possible into the economically feasible.” The authors show the viability of these proposals by investigating the impact of the price elasticity of fuel on the transport sector. They propose an ecological tax reform, which moves the tax base away from corporation and income taxes towards ecological taxes in a revenue neutral manner. Kemball-Cook *et al*. (Kemball-Cook 1991) provide an example of such a program, the green budget, which attempts a reformulation of economic policy to incorporate environmental and social goals. Authors increasingly devote research to the possibility of environmental fiscal reform to address problems of unemployment, and other concerns. Some of the important works include Lee and Misiolek (Lee 1986), Oates (Oates 1991), Repetto *et al*. (Repetto 1992), Carraro *et al*. (Carraro 1996), and Carraro and Siniscalco (Siniscalco 1996). In addition, recent work by Bovenberg and de Mooij (Bovenberg 1994), Goulder

(Goulder 1995), Parry (Parry 1994), (Parry 1997), Goulder *et al*. (Goulder 1996), Fullerton (Fullerton forthcoming), and Fullerton and Metcalf (Fullerton 1996) question when the use of taxes will increase welfare in the economy.

1.1.3 Qualified support for emissions taxes

Although, as Jenkins and Lamech (Jenkins 1992) observe, tax incentives for investment in pollution-control equipment are dominant worldwide, perfect market economies do not. The authors conclude that using market forces that integrate economic and environmental decision-making best influence pollution abatement. However, when the forces of the market are flawed, distortions arise and emissions taxes will perform differently than theory predicts. Running parallel to the relative enthusiasm for market-based environmental policies, voices arose which expressed skepticism about the ability of emissions taxes to perform well under less-than-optimal circumstances. Barthold (Barthold 1994) explored the rationale for employing the tax code as a tool of environmental policy but found two problems with taxation. Environmental taxes often deviate from economic theory (and are, thus, inexact); and governments have more frequently used environmental taxes to fund insurance pools or to assess benefit taxes rather than imposing Pigouvian taxes. These problems usually involve a lack of clear identification of costs and benefits and lack of information about tastes, technology and regional impacts. In addition, taxes must compete in the political arena with other environmental tools. Many authors recognized that developing and developed countries alike deviate to some degree from common assumptions of perfectly functioning market systems.

Eskeland and Jimenez (Eskeland 1992) found that only casual evidence exists to show that regulations to protect the environment in developing countries are ineffective or unnecessarily costly. The authors review the design of cost-effective measures to protect the environment from excessive pollution in developing countries, relaxing assumptions of competitive markets, costless transfers, certainty and full information. Instead, they assume that many countries considering the implementation of an emissions tax have a public revenue constraint, are unable to fully monitor emissions and damages, uncertainty, and an imperfectly competitive market structure. Eskeland and Jimenez conclude that indirect economic instruments are more workable and cost-effective than directly targeting externalities.

While markets for pollution permits seem to be an optimal solution, some drawbacks do exist. Laffont and Tirole (Laffont 1993) point out that policy frameworks might fit reality poorly, and that linear prices prevent second- and third-degree price discrimination. Market and regulatory uncertainty also make it difficult for firms to comply with the market-based environmental policy, and affect innovation. Migué and Marceau, (Migue 1993) show that environmental taxes are not as effective as some studies have shown because the aspect of rent seeking has not been taken into account. Rent seeking results because of ill-defined property rights. With incomplete ownership of resources, wealth dissipates. The extent of this dissipation will vary according to the specific incentives created by the taxes adopted. While a market allocation of environmental resources is the superior solution to subsidies, the framework of the tax will influence rent-seeking activities. Incorrect pricing or valuation of environmental resources might cause the tax to operate sub-optimally. Pearce *et al*. (Pearce 1989a) reviews methodologies for appropriate environmental valuation, and uses this as a foundation for the formulation of economic instruments which promote environmental protection. Finding a tax level which promotes better environmental practice may have serious economic and social consequences, while those set too low will have little impact on environmental quality (also see (Pearce 1993a); (Pearce 1995)).

1.1.4 Recommendations for policy mix

The enthusiastic reception of the idea of market-based environmental policy thus gave way to skepticism and further research. As evidence from early case studies of emissions taxes become available, increasingly experts advise finding a mix between regulatory and market-oriented tools to achieve cost-effective, socially and economically acceptable pollution abatement policy. Barbier (Barbier 1989), (Barbier 1992), notes that while economic instruments create the incentives for individuals to choose freely to modify their activities, an important criterion for the selection of an environmental policy instrument is economic efficiency in achieving the desired improvement in environmental quality. The author discusses this criterion with regard to economic instruments and regulations; as well as policy-makers', firms' and individuals' preference for regulations (Bishop 1991). He concludes that instruments and regulations will be used in conjunction in the future.

Bernow *et al*. (Bernow 1993) examines the general logic of pollution taxes, the scope for their efficacy, appropriate structure, and limitations. While pollution taxes can ensure that polluters pay and that cost-effective pollution reduction will ensue, measuring environmental problems is complex. Thus, complex environmental issues will require multi-dimensional policy responses. Cost-effective pollution reduction will likely involve a combination of standards, economic incentives, and programmatic instruments. Likewise, Cassils (Cassils 1991), (Cassils 1992), finds that in considering various policy tools and their incentives, each situation will demand a different response. In most cases, a mix of incentives and economic instruments may be needed.

1.1.5 Importance of endogenous factors

Finally, a string of scholars began reporting that the policy mix implemented for pollution abatement depends upon a variety of endogenous factors. Some areas may meet necessary criterion for pollution control policies that nearly mirror "pure" market incentives. Some will rely more heavily on regulatory approaches. The institutional and economic frameworks of the countries or regions involved plays the key role. Bernstein (Berstein 1993) explored some of these alternative approaches to pollution control. The discussion focused on how developing and developed areas employ such policy instruments. Bernstein concludes that the fundamental challenge will be to determine the most appropriate mix of instruments by taking into account endogenous factors. These cover a complex range, such as a desire for economic efficiency; compatibility with existing administrative, political, and judicial frameworks, economic conditions and tax structure; political acceptability of instruments; complexity of application; ease of monitoring and enforcement; consistency with overall environmental policy; and compliance with relevant international agreements or principles. The Ontario Ministry of the Environment (Environment 1991) had similar results in a review of case studies comparing traditional regulatory approaches with market-based approaches: a combination of "command and control" and economic instruments contributes significant gains in economic efficiency without minimal problems in monitoring and administrative costs. Sterner (Sterner 1996) asked a series of questions about local conditions when designing an appropriate policy mix. He noted the importance of competitive markets, the availability of technology, cost-efficiency, administrative, transaction and information costs as well as factors such as pollution distribution which may affect regional distribution of income with an emissions tax.

Most recently, Cole and Grossman (Cole 1999) refute the prevailing view that command-and-control environmental regulations are inevitably inefficient or less efficient than economic instruments such as emissions taxes. They argue that this is an inaccurate interpretation in both theory and practice. Command-and-control environmental policy can be nominally efficient and may under certain circumstances be more efficient than economic approaches to air pollution abatement. They emphasize variables such as historical, technological, and institutional endowments that can determine the comparative efficiency of alternative regulatory regimes.

1.1.6 Emissions charges in transition economies

Regardless of the flaws of individual programs, the above literature engendered confidence and support among governments of Eastern European and former Soviet economies in transition. The majority of these countries implemented pollution charge systems, many before general economic restructuring had occurred. After nearly a decade of experience with such charge systems, results and analysis becomes possible. Although data is limited, the existing literature provides a basis from which to build.

Opschoor (OECD 1994a) summarized the developments in the use of economic instruments in OECD countries, and concludes that although the use of such instruments has increased, their performance has not been spectacular. Charges have had better showings, but the incentive impact of these instruments are under-represented in the empirical literature, which tends to focus on revenue generated by charges and taxes. Following heavy initial research by the OECD, scholars saw the applicability of pollution taxes for transitional economies. World Bank papers also began analyzing the structure of taxation in such economic contexts (de Melo 1992); (Bogetic 1993); (Easterly 1992); (Rajaram 1992).

Several environmental economists wrote persuasively that environmental policies in formerly centrally planned economies should offer enterprises both incentives and flexibility to solve environmental problems in cost-effective ways (Dudek 1992). They discouraged the use of command-and-control instruments and incorporated the notion of cost-effectiveness into the conventional wisdom of air pollution policy for transitional economies. A background note to the Environmental Action Programme for Central and Eastern Europe endorsed pollution charges as a way to exploit lower costs and higher revenues in the early 1990s. It concluded "There is a unique opportunity to bring about major environmental improvements in the course of economic transformation and industrial restructuring, and every effort should be made to promote policies which will encourage this process in the most efficient manner possible."

Russian studies about the ability of the market-based tools to accomplish abatement and raise revenue for other environmental purposes were optimistic, and largely reflected a nearly wholesale importation of Western economic ideals. Golub and Gofman (Golub 1993) reported that a Baumol-Oates charge—essentially a mix of standards and pricing mechanisms—had been implemented Russia to address air pollution problems. Palmisano and Haddad (Palmisano 1992) reported that Russians have been experimenting with the use of economic incentives to induce environmental responsibility. The authors report that in Russia, command-and-control measures have generally been hijacked by corruption and bureaucratic red-tape while the costs of ecological-economic modeling are prohibitive. This leaves market-based incentives as a viable option. This study reviews two recent experiments with pollution charges and fees and maintains that these experiences are becoming common place in the new Soviet Union. The authors do not deal with problems such as noncompliance; assuming that market-oriented policies are less affected by these factors. Experience in transitional economies will likely show that these authors missed a key point of discussion.

Markandya and Lehoczki (Markandya 1994) reviewed the experiences of several OECD and transitional economies with pollution taxes and defined what they thought to be the most important variables in program success. Realizing the near-impossibility of reaching an optimal level of pollution and social welfare where the marginal cost of abatement and marginal damages of pollution are equal, and suggest some of the issues that arise with alternatives. The authors note that the most important variables for the implementation of a charge include finding the appropriate level for taxes, the implications of the environmental taxes for other types of taxes (double dividend), and the use of emissions tax revenues. The authors conclude that a large scope exists for shifting the overall tax system to include more environmental taxes and less of other taxes; and the levels of the environmental taxes should be based more closely on information about efficiency and damage aspects.

Another key study, "Taxation and environment in European economies in transition," (OECD 1994b) indicated that although environmental taxes could provide a cost-effective and flexible policy instrument, the countries of Central and Eastern Europe face many challenges in adapting existing environmental tax systems to the conditions of emerging market economies. In particular, economic and institutional uncertainty curtail the potential incentive effects of tax instruments—uncertainty such as future institutions and rules, major economic variables such as prices and interest rates, and about the rights and responsibilities of economic actors with respect to pollution. For this reason, the financial dimension of tax instruments dominates arguments of efficiency or economic incentives. This revenue-raising role is likely to persist for some time, given economic constraints to raising tax levels or increasing environmental authority. One key finding of the report suggests that macroeconomic stability in the framework of a formal market economy appears important for the development of tax-based environmental policy. As Russia, and Siberia as an extreme case, has experienced high inflation and dramatic drops in industrial output, this aspect will be of special interest in this study. The OECD report ends on an confident note, stating that in spite of the many problems facing emissions charge systems in the mid 1990s, environmental taxes promise a mechanism for countries in transition to integrate economic and environmental policies. "With judicious use and appropriate reforms, environmental taxes and charges provide an opportunity to pursue and effectively integrate environmental objectives in the economic restructuring process."

Subsequent studies on emissions charge programs in transitional economies focused on finance and program design. In an effort to promote environmental protection in Europe, a series of conferences were held from 1991 to 1995 with ministers of the environment from transitional economies. These meetings motivated the gathering and reporting of information on the new emissions charge systems, and provided the basis for further analysis about the important variables for program success in transitional economies. Klaasen and Smith (Klaassen 1995) reported on the financial aspects of several emissions tax programs, including the Russian Federation. The authors identified a central concern for all countries involved that market and institutional failures—the legacy of centrally planned economies—were the fundamental stumbling blocks for the charge system. Monitoring and evaluation, ensuring accountability for the use of environmental tax funds, and a host of factors such as high transaction costs, risk and uncertainty, and imperfect competition all prevented the charge system from attainting the hoped-for efficiency assured in theoretical discussions (Lehoczki 1995); (Lovei 1994).

A review of the research to date on the implementation of emissions charges in transitional economies reveals several common themes. Bluffstone and Larson (Bluffstone 1997) provide the most comprehensive overview of the recent experience of implementing pollution charges in ten transitional economies. The work focuses on controlling point-source air pollution, describing and analyzing the experience of implementing pollution charges and fines, and the interactions of these fiscal instruments with systems of pollution standards and permits. The authors draw general conclusions for the implementation of pollution charge programs in imperfect economic contexts. While the work assembles a great amount of expertise, as late as 1997 specific results were not fully clear. Data remained distorted, unavailable, or difficult to interpret. The underlying causes of program success or failure, with the exception of the Polish case discussed briefly in chapter eight, remained obscure. With the passage of time, increased experience and reporting on the impacts of the environmental charge systems in these countries, and increased data availability, it now becomes possible to build upon the foundation provided by these authors to assess the relative importance of variables in the outcome of pollution charges. This work contributes to the literature by analyzing a rare data set provided by the Russian Federation Statistical Committee (Goskomstat) on air pollution and social and economic data in Siberia. Combining this information with other data about the institutional and market framework, the research now moves beyond an analysis of program structure to report the early outcomes of the pollution charge system.

Another seminal group of papers provides an important foundation for the current work. Since 1993, the Harvard Institute for International Development (HIID) has worked with Russian environmental economists and policy specialists to examine and evaluate emissions policy. HIID carried out numerous studies, including non-Russian pollution programs in Latvia, Lithuania, Poland, and Estonia. These studies included descriptions of current Russian system of stationary-source air pollution permits and charges, as well as cursory suggestions for the improvement of these systems. The project produced a number of reports presenting the methodology and results of individual studies (Air Pollution Working Group 1998); (Larson 1998); (Zylicz 1995); (Farrow 1997); (Ensmann 1995); (Ubelis 1997); (Golub 1997a); (Golub 1997b); (Larson 1997). The current work builds upon these studies by providing an in-depth look at the structure and impacts of the pollution charge system in industrial areas in Siberia. It takes the analysis one step further in exploring the successes and failures of the program, and exploring possible reasons why the pollution charge has not been as successful as the theoretical literature would have suggested.

1.2 Driving questions

What are the important variables that have led to the outcome of Siberia's charge system reported here? Many of the works implicitly assume that an environmental tax program can attain cost-efficiency and an optimal allocation of social and environmental welfare. Yet when these assumptions do not hold—the case for almost all real-life scenarios explored so far—several variables become important to the outcome of the second-best situation. Although the following are not exhaustive, authors of the above-cited works tend to mention several variables of importance for the outcome of emissions charge systems implemented in the early 1990s. These include

- inflation and unstable macroeconomic conditions
- tax levels, also related to macroeconomic conditions and price levels
- enterprise response to emissions taxes and the impacts upon monopolies

- restructuring of tax systems to achieve double dividends and faster market adjustments
- institutional frameworks for general economy and environmental authorities

This study of Siberia’s pollution charge system evaluates the implementation of an emissions tax in Siberia. It asks to what extent these variables are the driving factors that determine the success of the emissions program in

- reducing air pollution,
- raising tax revenues,
- providing firms effective economic incentives to restructure production activities or invest in abatement technology.

The current work asks a series of questions and attempts to answer these questions in individual chapters. For example, many note the severity of economic and social problems in Russia, and ask if air pollution warrants such widespread attention. Chapter two addresses the seriousness of pollution in Siberia, and assesses the possible environmental and social impacts of damage. Chapter eight returns to the question and asks if the case of air pollution policy—the damages incurred and the use of an economic tool to correct those distortions—has application to other situations in the region.

Another relevant and driving question involves the way that an emissions charge system functions in an imperfect economic situation. Chapters three and four contrast the theoretical and practical prospects for the emissions tax, and advances the investigation of what variables play the greater roles in the outcome of the pollution charge in such a setting. In addition, the study addresses firm reactions to the emissions tax, again contrasting theory and practice. Chapters five and six ask whether the structure of firm ownership or market share plays a role in their reactions to Siberia’s environmental charge instrument, and explores some of the variables unique to the transition period which have relevance to other countries. In its in-depth analysis of one market-based policy, the study addresses questions such as why and how the level of industrial restructuring and activity in formal markets affect policy performance. Chapters two and seven seek to answer the question of which firms are more likely to respond to market-oriented tools and what variables explain this. With this question a host of others unfold, such as how pollution charges might affect older industries which do not restructure, and whether the pollution charge alone can provide incentives to polluters to reduce their emissions. The study addresses the most basic questions of the ability of, and the degree to which, a market-based tool can address environmental problems in a transitional economy.

1.3 Objectives and contributions

Because of the recent implementation of emissions charges in these countries, publications tend to focus on program structure, pitfalls, and issues in implementation rather than results. With the unique data provided by the Russian Federation about Siberia's pollution inventory and indicators of social and economic performance, this study fills a gap in the literature by reporting some of the outcomes and impacts of the region's air pollution policy. Although data problems do exist, the analysis will provide additional insights into the use of emissions taxes for a range of objectives in a transitional economy setting.

This study hopes to make four contributions to the literature, which will hopefully fill part of the gap in knowledge about how this policy tool works and the variables which affect its outcome in imperfect settings. It seeks to

- analyze a unique data set about Siberian pollution and economic and social status, which includes the beginnings of a risk analysis in this region,
- illustrate some of the principle issues for a pollution charge system, providing specific data about location-specific environmental and industrial factors, and reveal the severity of environmental disruption and inefficient environmental use,
- assess the revenue potential and abatement incentives resulting from assigning economic constraints to environmental use, and
- evaluate the potential of the emissions charge to achieve pollution abatement in Siberia and the dynamics of the program which affect firm response.

The work is timely and relevant to current academic discussions, and addresses some of the most pressing issues for other developing regions faced with declining ambient air quality. The experience and progress of Siberia towards better economic and environmental performance holds valuable lessons for others. Important similarities exist, which increase the relevance of the Siberian experience in the discussion about emissions charges in imperfect market systems.

- Like transitional economies, developing countries aspire to and some have achieved rapid rates of economic growth and integration into the world economy.
- Developing countries have similarly weak environmental institutions and underdeveloped legal systems and lack monitoring and enforcement capability. Easterly and Rebelo (Easterly 1992) showed that many developing countries have advanced taxation programs on paper; however little revenue is collected due to loopholes, lax enforcement and control.
- Large shares of informal market activity and pervasive poverty or unprofitable businesses characterize such economies. Corporate taxes play an important role in transitional and developing economies, which have a harder time collecting personal

income tax, but tax levels may be so oppressive that compliance might prove problematic (Sterner 1996).

- Like transitional economies, most developing countries, facing formidable fiscal and financial constraints, and cannot afford the high cost of rigid regulatory systems or the fiscal consequences of large environmental investments (Dudek 1992).
- Developing countries share with Central and Eastern European countries and the newly independent states an abundance of win-win investment opportunities and low-cost solutions that can be exploited with the right policy environment
- Developing countries, especially those with high growth rates, are undergoing rapid structural transformation and quick turnover of their capital stock, which offers unique opportunities for institutional change, new rules of the game, and new instruments to shape the expectations of investors and advance pollution prevention over end-of-pipe solutions.

1.4 Methodology

The author attempts to answer the questions and make the contributions discussed above by following a chapter-by-chapter plan. The first vital step, the author analyses a pollution database from the Statistical Committee of the Russian Federation (Goskomstat) for Siberia from the years 1992 and 1993, and a socio-economic database spanning the years from 990 to 1995. The author uses two rudimentary risk analysis methods to analyze emissions and to identify possible abatement strategies. The first simply identifies the volume of given pollutants in given administrative regions (oblast, kray, republic), in specific towns, and in specific industrial sectors. The second approach applies a risk-weighting factor to help identify those chemicals that, regardless of total volume emitted, have higher destructive potential than the majority of reported pollutants. Based on this analysis of available data, the author employs cluster methodology for industrial and pollution groups.

The author then characterizes Siberia's environmental situation in terms of an allocation problem. Chapter three briefly reviews theoretical approaches to Siberia's pollution problem and reviews assumptions underlying a model of environmental allocation. The model analyzes Siberia's transformation space with respect to private goods and the public-good, environmental quality. The author applies this model to enterprises in Siberia, and explains some of the observed behavior under the pollution charge system when firms can evade the tax and when imperfect competition and non-profit maximizing firms also operate in the economy. Chapter four contrasts the theoretical model with the actual structure of Siberia's emissions charge system. This chapter analyzes the variance between theory and practice in Siberia's regional economy. The author reviews the modeling of calculations of pollution charge levels. The chapter then contrasts and compares the theoretical setting of a shadow price for pollutants (an emissions tax) and the actual setting of standards and charges in Siberia.

Chapter five explores how Siberian enterprises respond to the emissions tax. This chapter uses the theoretical framework of the simple model to consider how producers react to an emissions tax, first, under a partial equilibrium analysis for a given commodity price and for perfect competition (assumptions which do not consistently hold for Siberia). Next, the author employs a general equilibrium framework in which the emissions tax also affects the relative price and in which the demand side of the economy is considered. This chapter outlines the actual rather than theoretical nature of the allocation problem in Siberia. It outlines the practical problems associated with the emissions charge system in Siberia and suggests that firm ownership and market structure are less important variables. The author explores theoretical limitations and introduces a new model to account for what appears to be the driving variable for firm response to a market-based policy tool such as the environmental charge. Chapter six explores this model and uses discrepancies in deposition accounting and officially reported depositions to estimate the shortfall in reporting and tax payments. The author then calculates the divergence between reported and evident emissions and compares the tax gap between expected and collected revenues, and identifies patterns of the firms most likely not to comply with emissions fees.

The author explores the impacts of the emissions charge system in Tomsk oblast upon unemployment, the environment, and industrial performance. Elasticities of demand for labor and inter-industry linkages are discussed to evaluate dynamic effects of the pollution charge in this oblast. The author evaluates possible “double dividends” resulting from a shifting tax base and the efficacy of the policy in meeting abatement goals. Chapter eight draws conclusions and points towards further areas of research.

1.5 Conclusions

This study is unique in many ways. The work makes rare data on Siberia public, both about the pollution status there on an industry-by-industry and town-by-town basis, and allows a fairly accurate pinpointing of pollution sources. It extends a lively debate on the choice and implementation of market-based tools for abatement, and discovers the practical variables that affect program outcome. Its findings challenge the confidence of theory and recommendations of initial research on the implementation of emissions taxes in transitional economies. Its findings differ from the confident statement that “Economic instruments offer considerable promise for improving the integration of environmental and economic policies. Not only do these instruments send better signals to producers and consumers about environmental resource scarcities than more traditional "command and control" instruments, they also promote the technological improvements that will be necessary for improving environmental conditions in the future” (OECD 1994a). The current economic crisis does provide a chance for environmental change and economic change, which is makes the study of these programs so compelling. Whether or not the emissions charge and accompanying market forces will provide incentives for the restructuring of industry and for a swifter move towards environmental (and economic) soundness depends upon a host of variables—some surprising—discussed in the chapters which follow.

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Chapter 2: Air Pollution in Siberia

A volume and risk-weighted analysis of a Siberian Pollution Database

2.0 Overview and principle findings

Air pollution from industrial centers in Siberia pose observable environmental threats. Siberian ecosystems have begun to show stress from the accumulation of pollution depositions that come from cities and industrial plants. While some uncertainty exists as to the long-term effects of air pollution upon forests, in measurable terms such as human mortality and incidence of disease, forest species decline or forest die-back, observable impacts indicate that there is cause for concern. Industrial emissions from large production centers regularly release toxins into the air, pollutants that find their way into forest soils and water systems. The risk-ranked and volume based chemical profiles here provide insight into the possible threats posed to the environment in specific regions and by specific compounds. More dynamic models must come forward to account for accumulation of pollutants, environmental response, and effects upon biodiversity in these areas.

This chapter analyses a pollution database provided by the Russian Federation for Siberia from the years 1992 and 1993. It reveals a pollution profile with acute spots of emissions exposure and large areas of less-affected environments. The report uses two methods to analyze emissions and to identify possible abatement strategies. The first identifies the volume of given pollutants in given administrative regions (oblast, kray, republic), in specific towns, and in specific industrial sectors. The second approach applies a risk-weighting factor to help identify those chemicals that, regardless of total volume emitted, have higher destructive potential than the majority of reported pollutants. A clear industrial source pattern emerges. This analysis suggests that Siberian policy makers could use cost-effective steps such as an implemented emissions tax to reduce emissions and environmental threat in the region, while helping to improve industrial performance and the international competitiveness of Siberian enterprise.

1. Using volume-based emissions data, excluding SO_2, CO_2, and NO_x for which Nilsson *et al*. (Nilsson 1996) already provided analysis, the following pollutants appear to pose the greatest threat to Siberian environments, in order of reported volume emitted in 1992-1993:

Table 2.1 Most notable volume-based emissions in Siberia, inorganic and organic 1992-93

Inorganic compounds	**Organic compounds**
V_2O_5	Benzol (benzene)
Carbon soot	Xylene
Ammonia	Styrene
Manganese	Toulene
Lead	Methanol
Chromium hexavalent	Phenol
Nitric acid	Butazulene
Hydrogen chloride	Ethyl acetate
Sulphuric acid	Formaldehyde
Flouric gasses	Acetone

Source: (IIASA 1996)

These compounds appear in almost every administrative region (the main exception being regions in the Far East) in volumes exceeding 10,000 tons *per annum*. Particular areas have varied pollution profiles in which some chemicals appear to play a more dominant role than others in posing risk to the environment.

By introducing a risk-ranking methodology which couples toxicity information with sheer volume of pollutants emitted, the analysis changes significantly. Using a human-health based risk ranking, the following pollutants appear to pose the most serious threat to Siberian environments, in order of toxic rank in descending order (below). These inorganic compounds are all ranked absolutely and relatively higher than organic compounds in posing risk to human health. These metals are categorized in this report in “high” and “medium” risk groups. The organic compounds above rank in the “medium risk” group.

Table 2.2 Most notable risk-ranked emissions in Siberia, inorganic and organic 1992-93	
Inorganic compounds	**Organic compounds**
Tetraethyl lead	Furfural
Cresol	Acetone
Mercury	Toulene
Carbon tetrachloride	Styrene
Arsenic	Hexane
Hexavalent chromium	Formaldehyde
V_2O_5	Naphtalene
Hydrogen sulfide	Phenol
Hydrocyanic acid	Ethyl ether
Manganese	Xylene

Source: (IIASA 1996)

The chemical that emerges as the single most toxic and environmentally threatening emission using risk-ranked analysis is tetraethyl lead. Because of its high toxicity, lead dominates the pollution profile of every administrative region and poses the most significant risk for human health. Initial research upon the toxic effects of lead upon various species of trees shows reasonable evidence that lead, combined particularly with acidifying compounds, can cause an array of developmental distortions and damage. Applying risk thresholds to lead may, however, be inappropriate given research indicating that lead in any dose may have toxic effects on living organisms. The author employs human health in order to determine environmental risk posed by various chemicals in Siberian environments.

2. Using a volume-based analysis, the industries associated with energy production such as large and small coal burning plants, oil extraction and refining contribute the greatest quantity of pollutants into Siberian environments. Policy makers concerned with reducing weight of emissions released could focus upon regulating or taxing the energy sector to reduce the types of emissions of greatest concern there (SO_2, CO_2, and NO_x).

3. Following the risk-ranked analysis of air pollution in Siberia, a much different distrubution of industries appear to be the top culprits responsible for potential environmental damage from air pollution. Energy production is notably absent, while the polymetallic industry (because of its relatively high releases of lead), machine building, and machinery and tool industry command the highest risk emissions.

   In the current situation of economic transition and adjustment, when economy-wide regulatory mechanisms and political institutions may not bear a full reform of current environmental policy; it may be most efficient to use risk ranking to target the chemicals of most concern. If human health, and environmental quality (proxied by forest health), is a high political and economic priority, following a policy which focuses on reducing emissions at the source (typically a small handful of mega-sources in industrial complexes) will abate the riskiest compounds.

4. Areas at risk from significant damage from air pollution: East Siberia tends to have the highest (th. tons) levels of emissions and the Far East the lowest. Following an observed

pattern, emissions tend to be highest around the major centers of industrial production, with the highest levels of atmospheric emissions in the southern-central part of Siberia in the regions of Irkutsk, Krasnoyarsk, and Novosibirsk.

Two areas register as Siberia's most polluted areas in terms of volume: Tyumen oblast in West Siberia and Krasnoyarsk Kray in East Siberia. Anthropogenic activities here contributed over two times the volume of pollution as any other area in Siberia, amounting between 1992 and 1993 to just under six million tons. The next-worst polluted areas are Irkutsk oblast and Kemerovo oblast, again located in East and West Siberia respectively. After these most-polluted areas comes a large gap in volumes emitted.

5. Recommended policy approaches: The natural resources of Siberia stand at long-term risk from air pollution, but much hope remains if policy makers act quickly to abate the emissions that threaten forests, human health, and ecosystems. Policy makers must first decide if toxicity or volume of emissions is most important to set abatement goals. This consideration will be based upon the key weight which two possibly conflicting, current policy goals take. Under the Russian Federation'sl pollution charge system, industries pay fines for emissions exceeding acceptable levels. The first goal is to use pollution charges to fund other environmental programs. The second goal is to use pollution charges as a deterrent for industries to continue polluting above specified levels. It appears as if the revenue goal dominates the current policy scenario. However, if abatement takes on higher value, risk-related information such as that presented in this report will become more relevant in shaping policy. Specifically, identifying general regions of environmental risk, identifying the chemicals of most concern (either by volume or risk-rank), and identifying the key industries that serve as source points are necessary steps preceeding the formulation of a sustainable environmental policy for pollution abatement.

   This report indicates that focusing on a few administrative regions such as Krasnoyarsk Kray, Irkutsk, and Novosibirsk may envelope up to 80% of total emissions and total risk-weighted emissions. An efficient policy will first target these areas, and focus on abatement in the major point sources, such as the polymetallic industry for metal emissions and oil processing industries for soot and SO_2. Given the clear pollution pattern in Siberia, it seems that an emissions charge might feasibly address specific industrial sectors, limited administrative resources, and the need for tax revenue. If industrial sectors respond as expected to the incentives provided by the emissions tax, then Siberia should be able to achieve improved ambient air quality in a cost-efficient way (the hypothesis tested throughout the remaining chapters). The use of a market-based policy tool for abatement is a testing ground for the use of such policies to attain hoped-for outcomes. If firms react to the emissions charge in Siberia, indicating that they respond to the incentives and constraints of the formal market, policy makers can expect that a range of such tools can shape enterprise behavior in an emerging market system.

2.1 Introduction

As Russia positions itself for a new phase of economic development based upon its vast natural resources, assessing the environmental status of Siberia becomes increasingly important. The extraction of forest products, in addition to oil, natural gas and mineral wealth, promises new sources of prosperity for the region. However, without a policy that ensures the long-term survival and use of both renewable and finite resources, Russia may exhaust its bounty and create an environmental disaster with global consequences.

Under the auspices of IIASA's Sustainable Boreal Forest Resources project, a team of researchers has already investigated several topics related to Siberia's environment. Kiseleva (Kiseleva 1996) provided a general overview of environmental conditions in Siberia in respect to atmospheric emissions, upon which the present study expands. Nilsson *et al.* (Nilsson 1998) calculated critical loads estimations for acidification from SO_2, and NO_x, while other researchers have performed numerous studies on Russian forestry, industry, and oil extraction.

To provide an overview of air pollution in Siberia, this chapter analyzes the levels and potential risks to human health and forest ecosystems of organic and inorganic compounds. The data upon which the analysis is based was recorded by the Russian Federation, which identified the chemical compounds of interest and measured emissions of these by administrative region, city, and industrial source for the 1992 to 1993. The author assesses the spatial distribution of toxic inorganic and organic emissions in Siberia--divided into three subregions: West Siberia, East Siberia, and the Far East--which facilitates estimating potential environmental risks and impacts for the area. The author has attempted a preliminary risk ranking of the most toxic pollutants in specific areas, which in future research may yield more concrete details about the risks posed to environmental resources in the region. Following a general overview, the study presents a more detailed look into each region, its industries, and the pollutants that could create the highest risks and impacts upon Siberian environments. Within this report one finds descriptions of the most polluted and most pristine areas in the region, as well as major industrial polluters and the toxic chemical compounds they emit. One of the primary objectives here is to provide a baseline report on the pattern of organic and inorganic emissions and potential environmental risks.

Future research will reveal specific, direct toxic effects on identified endpoints. This report provides a point of departure for general conclusions about the threats to Siberian ecosystems from atmospheric emissions, based on a stylized weighted risk assessment which identifies by toxic potential some of the most critical pollutants in the region.[1] The author does identify several endpoints to assess the potential environmental impacts and risks to the environment in Siberia. While most emphasis is given to forest

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[1] Possible endpoints for future assessment may include biological production, for which forest productive capacity could serve as a proxy. For example, researchers could assess the proportion of a region devoted to biological production that is lost or lost from production due to chemical exposures (controlling for other factors) (trees).

ecosystems (for which tree health stands as a proxy), consideration is also given to human health in polluted regions.

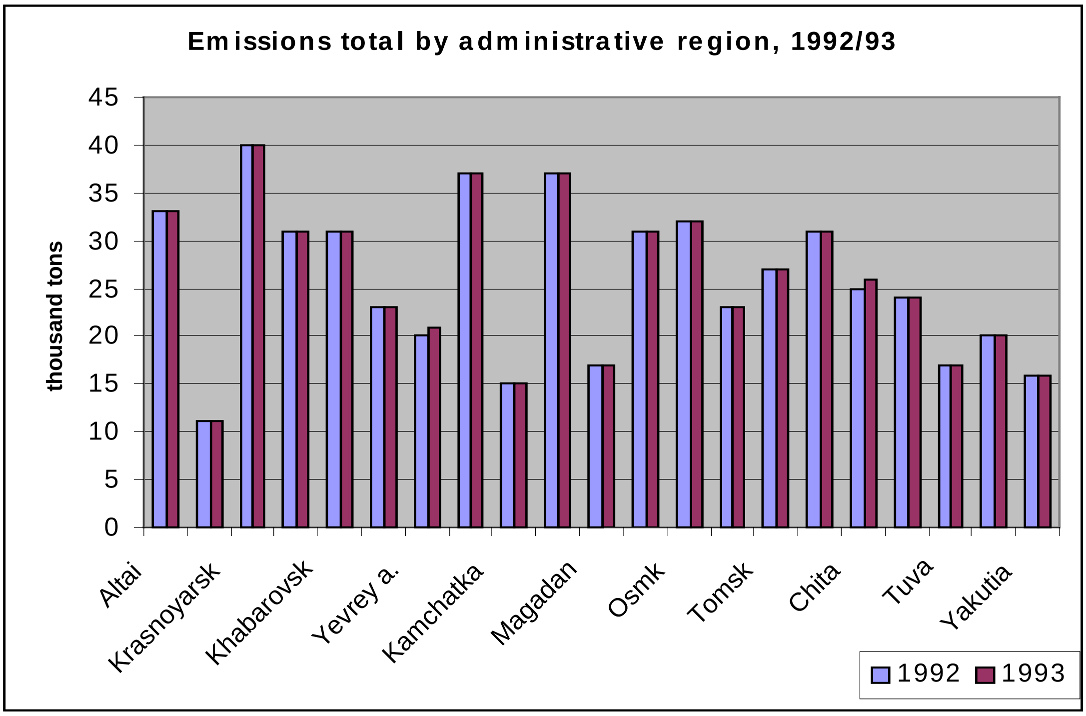
The greatest challenge in using the database to make inferences about Siberia's actual production and pollution profile is incomplete data. By cross-checking data sources with other Goskomstat records on aggregate industrial development (among other indicators), it is possible to conclude that a limited degree of information on Siberian industrial output and inputs, as well as pollution outputs, is missing (Huber *et al.* (Huber 1996) estimated approximately 0.05% to 1.0% for industrial data). Because this is a small number, the author feels secure that the database provides an accurate picture of the regional industrial structure and pollution output for the given time period, as long as the data was recorded and reported correctly. Some problems do occur with the data, which make certain types of risk assessment more difficult. The data does not indicate seasonality of emissions releases. Background pollution levels for reported chemicals are not given, nor are depositions of these chemicals measured in Russian studies. "Expert opinion" seems to have played a role in some data, and discrepancies occasionally appear between regional estimates and those from Moscow. In addition the study covers only a two-year period of emissions, rendering time series analysis of air pollution less meaningful. To estimate possible environmental risks, the author has used proxy methods to assess emission impacts. These drawbacks do not, however, obscure the importance of the information presented here about the Siberian region.

Following this introduction, section two outlines the parameters of the Siberian air emissions database upon which this analysis has its basis. The two methods of volume-based and risk-weighted pollutant ranking are described. Section three provides a pollution profile of the Siberian environment, based on both volume-based and risk-weighted analysis. Regions at risk are broadly described, and cities and specific industrial centers that appear to be the culprits for the majority of target pollutants are discussed. Section four reviews current research on the effects of various toxins on forest ecosystems and points out the various stress factors to forests which can be augmented by such chemical compounds. Section five outlines policy suggestions for the development of a sustainable, viable abatement program for the region and concludes with suggestions for future research.

2.2 Siberian emissions database

The emissions database upon which this report is based contains information about the volume of emissions in thousand tons for 22 inorganic compounds, 54 inorganic compounds, and numerous other particulates such as solid and liquid emissions, dust, flue gasses, filter residue, and recycled residue. The author focuses here upon the potential impacts of inorganic and organic emissions upon Siberian environments. These pollutants are also aggregated into eight general categories (solid, gaseous and liquid, SO_2, CO_2, NO_x, volatile organic compounds (VOCs), hyrocarbons without VOCs, and other gaseous and liquid compounds) for a broader overview of emissions. While the dispersion of these chemicals throughout the region remains unclear, initial reports estimate that a majority of pollutants deposit in a relatively near vicinity to their emission source. This creates a unique pattern in Siberia of areas of acute pollution damage and larger areas of lower risk. Figure 2.1.indicates the aggregate level of emissions in Siberia in 1992-1993.

Figure 2.1 Total volume emitted by administrative regions in Siberia, 1992-93
Source: (IIASA 1996)



Total Russian Federation emissions for the years 1992-93 were approximately 157,470 thousand tons and 138,200 thousand tons, respectively. During the transition period in which many industries slowed or stopped production, pollution also decreased in some locations. The total amount of pollutants from stationary sources in West Siberia 1988 was estimated at 19.3% of Russia's total, while just five years later the amount was 11,769.25 thousand tons (8.51% of Russia's total). Decreasing patterns prevailed for East Siberia and the Far East, where pollution from stationary sources measured in 1988 at 12.5% of Russia's total and 5% of Russia's total, respectively. 1993 levels were estimated at 8,515.56 (6.16 % of Russia's total) and 2,586.08 thousand tons (1.9% of Russia's total). These figures are subject to much "expert opinion," however there is reasonable certainty that they generally reflect reality as industries reduced production to meet the economic rigors of the transition phase. The situation in the past few years as industries have recovered has nevertheless changed the pollution balance again towards higher emissions. As the map below indicates, the pattern and distribution of emissions (by volume) vary significantly throughout Siberia. The map shows that, considering only pollutant by sheer volume, SO_2 appears to be one of the most serious threats to the natural environment in Siberia, particularly around Norilsk. In Western Siberia, SO_2, CO_2, and NO_x contribute more equitably to environmental degradation.

This map does not identify single pollutants that may pose particular threats to the environment. In order to move to this phase of the analysis, the author has employed a risk ranking methodology to distinguish and group the individual contaminants in the Siberian pollution database posing greatest environmental threat.

2.2.1. Toxicity rank of database chemicals

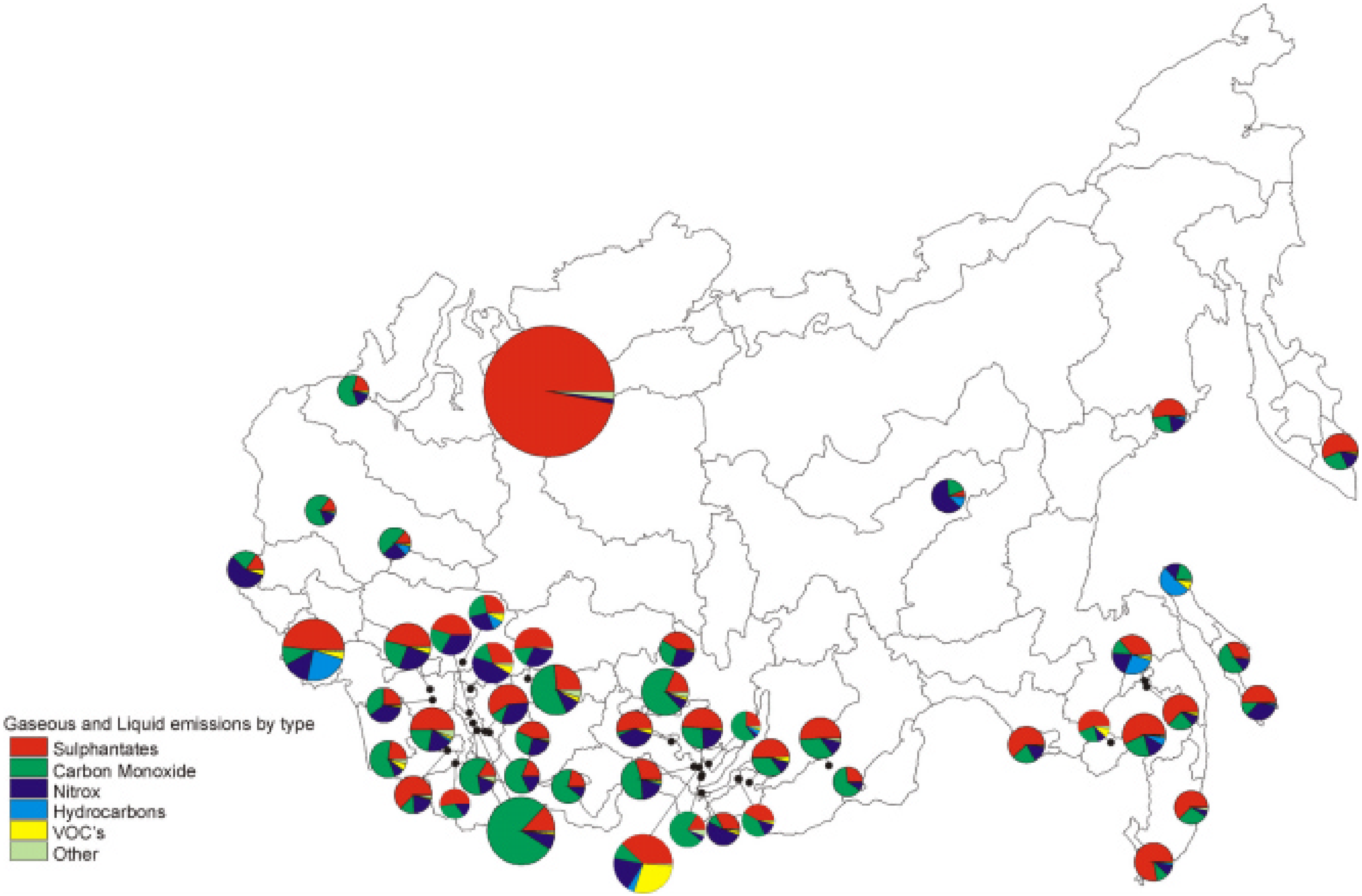
This study of organic and inorganic emissions reveals a pattern of particular importance for the development of a sustainable development policy for the Siberian region. While total volume of pollutants certainly concerns policy makers, of more importance will be to establish which pollutants correlate with the most environmental disturbance or damage. While it is useful to compare total volumes of chemical compounds emitted by given industries, knowing the toxic potential of the various compounds adds depth to the discussion of where emissions must be lowered, and what the potential risks for various endpoints may be.

Given the quality of the data which reports only volume quantities of emitted compounds, creating a risk ranking to determine which chemicals pose the greatest risk in Siberia becomes methodologically difficult. With more information from Russia, it would be feasible to follow the pattern set by the EPA in developing media-specific benchmark values for those chemicals commonly found in surface water, sediment and soil samples at sites (values for soil are still under development). The values are referred to as Ecotox Thresholds (ETs), and are defined as media-specific contaminant concentrations above which there is sufficient concern regarding adverse ecological effects to warrant further site investigation. ETs are designed to provide Superfund site managers with a tool to efficiently identify contaminants that may pose a threat to ecological receptors and focus further site activities on those contaminants and the media in which they are found.[2] In the future, a methodology such as that for calculating ETs could prove helpful in assessing risk from pollutants in Siberia.

Until such information becomes available, the author has employed the following methodology as an example of what could be used to estimate emissions risk in Siberia. The approach, which uses human health as an endpoint for determining the toxicity rank of the chemicals provided in the IIASA's Air Pollution database, does not accurately represent the threat to Siberian environments. Comparatively more data exists for the analysis of toxic impact upon humans than for any other environmental endpoint, yet the analysis does move towards the general goal of assessing environmental impact. The

[2] Such an approach is most useful for screening a particular site, rather than for setting regulatory criteria, site-specific cleanup standards, or abatement goals. The approach may set thresholds too high at some sites for chemicals with the potential to bioaccumulate to toxic levels in upper trophic wildlife (e.g., methyl mercury, PCBs, DDT, dioxins, and lead).

Map 2.1 Emissions by volume, location, and type in Siberia. Source: IIASA, Sustainable Boreal Forest Resources



report illustrates which chemicals appear to play the most important role in air pollution in Siberia and points to future areas of study for the region.

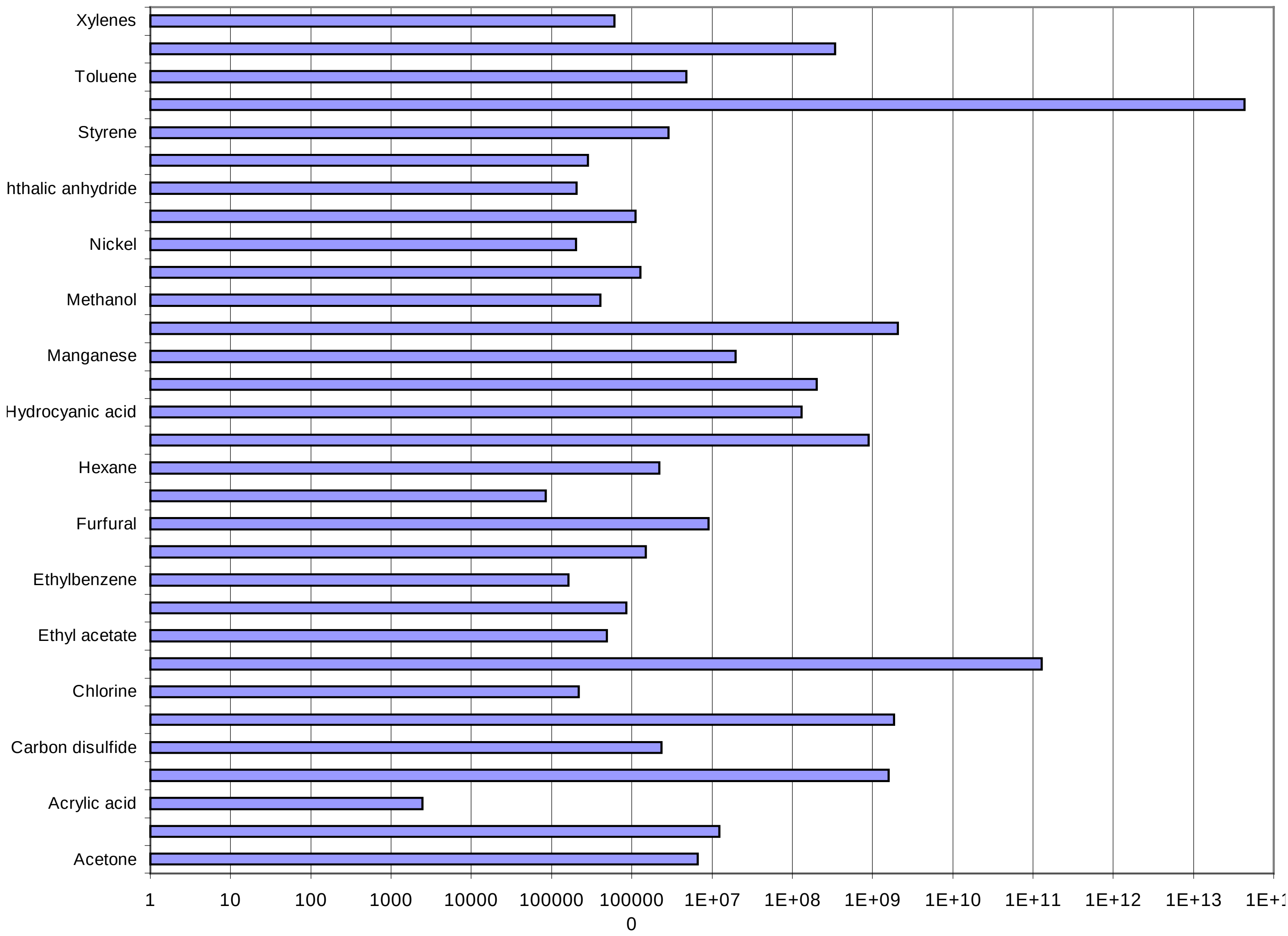
As for the impact upon humans from exposure to harmful compounds, given low population densities in Siberia, exposure risk for humans to this set of atmospheric emissions appears relatively low for individuals living outside of industrial centers. Exposure risk for plants and animals, however, could be more significant. More detailed information about populations, exposure pathways, toxic impacts upon different environmental endpoints, and a variety of other chemical data is needed to carry out detailed impact assessments from air pollution in Siberia.

Using the volume of emissions by site for each compound, the author combined reference dose information for each identified compound with the volume of emissions by site for each compound. A reference dose (RfD) is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Multiplying RfDs for each chemical by total volume of each chemical emitted yields an estimate of the risk value for human health for each pollutant. Figure 2.2 illustrates the compounds which, following this method, appear to have a highly toxic impact upon humans at a given dosage (the RfD).

Risk ranking in this way allows one to divide Siberian emissions into high, medium, and low risk groups. Knowing which chemicals pose greatest threats to human health (and by way of proxy to forest health), policy makers can more cost-effectively focus on specific abatement goals. For example, the most toxic compound which appears in this analysis is tetraethyl lead, which not only appears consistently throughout the region, but also has some of the most dangerous health impacts for humans. The use of leaded fuels and lack of lead regulation in industrial processes could be responsible for high levels of lead in atmospheric emissions.[3] Other toxins that fall into this “high risk” category include mercury, cresol, arsenic, and carbon tetrachloride. Many chemicals fall into the “medium risk” category, including V_2O_5, toluene, styrene, phenol, naphtalene, manganese, hydrogen sulfide, hydrocyanic acid, hexavalent chromium, hexane, furfural, formaldehyde, carbon disulfide, acrolein, and acetone. In the “lower risk” category fall compounds such as xylene, pyridine, phthalic anhydride, nickel, methanol, hexahydro 2H-azepin-2-one, ethylbenzene, ethyl ether, ethyle acetate, chlorine, and acrylic acid. While these rankings are limited to human health, they do illustrate which chemicals pose greater threats when introducing a dose indicator such as the RfD.

[3] The author acknowledges that risk ranking may not be appropriate for chemicals such as lead and mercury. Current research indicates that exposure to such heavy metals may prove toxic at any level.

Figure 2.2 RfD Ranked toxins based upon emissions in Siberia, 1992/93



Source: (IIASA 1996)

The present risk-ranking methodology uses human dosage to assign toxic risk to the Siberian pollution database. Future research in the effect of emissions upon specific endpoints such as boreal forests, soil organisms, and animal life will give more insight to the present analysis. Because large areas of Siberia are covered primarily by coniferous and deciduous forests, such measurements would prove more appropriate to measure negative effects of atmospheric emissions. The present study indicates which areas have a higher probability for risk from excessive exposure to high-risk toxins, and what the potential and observed effects upon forest ecosystems are for Siberia and its subregions.

2.3 Pollution profile of the Siberian environment

In this section the author outlines findings of two analyses of IIASA's Siberian pollution database. The first identified problem areas by total volume of pollution emitted in a given year, by administrative region (oblast, kray, or republic), by town and by industry. This approach revealed a geographically distinct pollution pattern in the region, without indicating which chemicals might pose greater environmental risk. The second approach applied a risk-weighted scale based on reported chemical toxicity. Using this method, the author pinpointed specific industries and chemicals most likely to threaten Siberian forests and human populations in the vicinity of the emission sources. The results are presented first as a general overview of regions at risk, followed by a look at which industries can be closely associated with high-volume and high-risk emissions.

2.3.1 Regions at risk

Spanning over 597 million hectares (forested area), some 94% of which fall under state forest management, Siberia encompasses a globally unique set of ecosystems, industrial economy, and environmental challenges. Controversy has raged over the degree to which both aggregate and singular areas are threatened from anthropogenic disturbance. This report finds that large areas of Siberia are indirectly exposed to high-risk ambient toxins, while some acute areas sustain significant short- and long-term damage from air pollution.

The unique geography of Siberia, enclosed largely by mountains on all borders has allowed pollution to remain relatively localized in many areas. The air pollution problem from organic and inorganic emissions appears in many cases to be a regional problem, with some notable instances of long-distance air pollution. For example, Tyumen Oblast receives pollution from the Southern Ural industrial zone, and Canadian scientists began reporting in the 1980s that the massive industrial Norilsk complex contributes markedly to arctic haze, acid rain and marine pollution (via the Yenisey River) (Saunders, 1990). American scientists have identified suspended particles in central Alaska as consistent with nickel and other heavy metals from Norilsk, indicating that some Siberian air pollution may correlate with trans-oceanic problems (Shaw 1982). Environmental degradation in terms of forest damage and death occur in greatest magnitude along a southern corridor in West and East Siberia, the Norilsk complex in northern East Sibera, and along coast of the Far East region.

Pryde (Pryde 1994) reports that 23 regions in Siberia have 'very critical' environmental conditions. Seventeen of these are located in East Siberia and the Far East. Industrial cities are the main producers of atmospheric emissions; the areas surrounding these cites are most at risk for environmental damage. Ongoing studies have assessed many of these cities and have reported extensive damage from toxic emissions in terms of natural loss such as tree die-back, and human loss such as higher incidences of disease caused by exposure to toxic emissions. Poor air and water quality, severe health problems, and deterioration of natural ecosystems characterize environmental degradation in these regions. In contrast, emissions remain low in areas far from industrial centers. Estimates about the environmental damage due to air pollution varies widely; however, this assessment shows that the environmental damage due to air pollution varies significantly by location.

For the entire territory, the Geographical Institute of the Academy of Sciences of the former USSR identified around 290 areas of acute ecological situations, occupying an area of 3.7 million km^2, or about 16 percent of the total territory. Of these areas, damage from air pollution accounted for all industrial sites and some non-industrial sites (Markuse 1993). Air pollution in 1992 around major Siberian industrial cities adversely affected approximately 160,878 km^2 of land, caused an estimated 86,000 deaths from respiratory diseases and 300,000 deaths from cancers (many of which appear related to air-born toxins), and destroyed 431,877 hectares of forests (Kiseleva 1996); (Doklad 1990). The estimated economic costs resulting from environmental damage amounts to at least 50 billion Rubles *per annum*. However, such estimates do not currently employ "green accounting" methodology to value externalities of such as clean air and complex forest ecosystems. The loss in terms of human quality of life is difficult to put into economic terms, or remains inestimable.

2.3.1.1 Regional emissions by volume

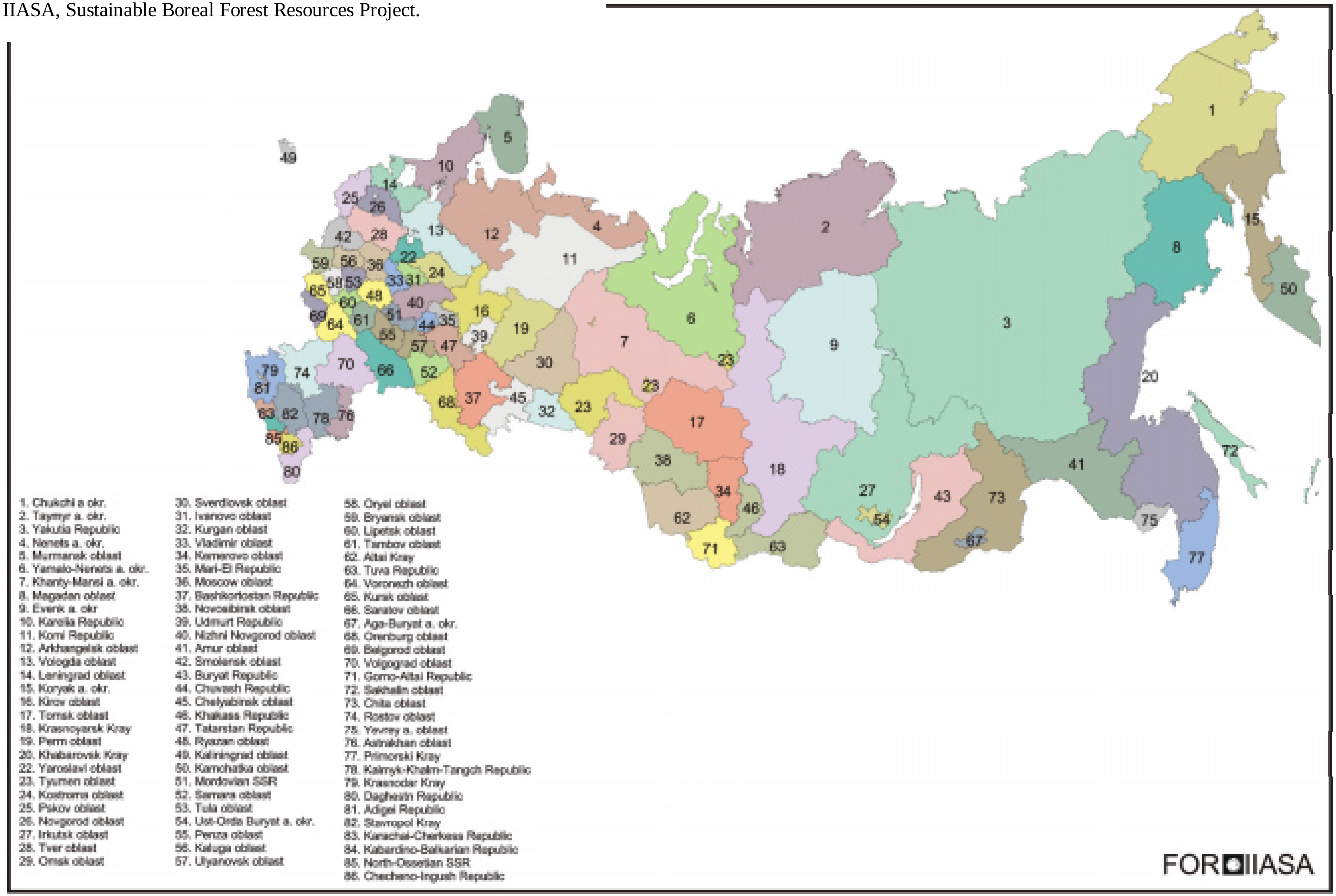
East Siberia has the highest volume of total emissions and the Far East the lowest. Following an observed pattern, emissions tend to be highest around the major centers of industrial production, with the highest levels of atmospheric emissions in the southern-central part of Siberia in the regions of Irkutsk, Krasnoyarsk, and Novosibirsk. Map 2.1 illustrates the level of emissions by general category by region (indicated by relative size of each pie figure). The pattern of emissions becomes clear, with industrial centers serving as the principle sources of air pollution. The visual presentation also indicates the importance of applying risk weighting to pollution analysis in Siberia, for this analysis has shown that sulphur, nitrates, and carbon monoxide have less toxic impact than heavy metals and some organic compounds not shown in this aggregate by-volume map.

Two areas register as Siberia's most polluted areas in terms of volume: Tyumen oblast in West Siberia and Krasnoyarsk Kray in East Siberia. Anthropogenic activities here contributed over two times the volume of pollution as any other area in Siberia, amounting between 1992 and 1993 to just under six million tons. The next-worst polluted areas are Irkutsk oblast and Kemerovo oblast, again located in East and West Siberia respectively. These industrial cities contribute a high percentage of total pollution by weight. The cities in Kemerovo oblast contribute 100 percent of solid emissions, carbon monoxide and nitrates, as well as volatile organic compounds. In Novosibirsk, industrial cities account for 90 to 100 percent of solids, sulphur, and carbon monoxide.

The remaining administrative areas contribute relatively little to overall atmospheric pollution in Siberia. The areas in the Far East emit the lowest volumes of the inorganic and organic pollutants studied here, between 100 thousand tons to 1,800 thousand tons of waste during the 1992-93 period.

Areas relatively free from environmental risk lie most often in the Far East. Vast Yakutia Republic sprawls across 3,103.2 thousand km^2, a third of the total land area of Siberia, and hosts few industrial activities. Here forest ecosystems appear to sustain the lowest levels of total emissions (averaging less than 600 thousand tons *per annum*) in all Siberia. The greatest anthropogenic threats appear to be from imprudent forestry practices. Such techniques strip permafrost soils of vegetation, exposing it to warming. At this intersection such practices become problems of atmospheric emission. As permafrost melts, potentially vast areas of once-forested areas could turn into methane and carbon-emitting swamp lands. Barring such a dramatic situation, the area appears pristine. Overall the Far East appears least harmed by atmospheric emissions, with the exception of Primorsky kray, where a well-developed transportation infrastructure, fishing, and forestry industries contribute to higher emissions weight. The Primorsky area may be of significant interest for its wealth of biodiversity and economic resources, but may be equally threatened as easier access exposes natural areas to human-related stresses (Newell 1996). Map 2.2 provides a reference for the following discussion, which focuses upon the pollution patterns and the locations in which they are manifest in Siberia.

Map 2.2 Political Map of the Russian Federation.
Source: IIASA, Sustainable Boreal Forest Resources Project.



Map 5.1 Political Map of the Russian Federation (Source: IIASA, Sustainable Boreal Forest Resources Project)

2.3.2 Cities, industry, and chemical patterns

Of immediate concern, the large industrial complexes negatively impact surrounding environments. Using a volume-based analysis of pollution, it appears that West and East Siberian industrial centers threaten surrounding natural areas, while the majority of the region sustains drastically lower impacts from organic and inorganic emissions. A similar pattern emerges in the Far East when applying volume-based analysis. Such an approach indicates that points of concentrated environmental degradation, at least in the short-term, pose low risk levels for the majority of ecosystems for the entire area.

Distinct patterns of pollution emerge from this analysis. Both volume- and risk-ranked analyses of the pollution database indicate broadly that a wide band ranging from Tomsk to Vladivostok along the 50^{th} to 60^{th} parallels sustains relatively higher risk from emissions than do other areas in Siberia. Four northern-lying exceptions exist: Norilsk, Yakutsk, Magadan, and Kamchatsky. Data from the Natsionalynyi Doklad indicate that areas around some of the largest Siberian cities and industrial centers may be chronically polluted. Areas manifesting the most significant damage in terms of square kilometers are found in Irkutsk, Krasnoyarsk, and Novosibirsk. The largest areas of damage according to this data are found in Abakan-Minusinsk and Kansk, areas around which iron ore, coal and mineral extraction contribute to emissions. The pollution emitted from Abakan industry contaminates an estimated 40% of the total land area in the Kemerovo oblast.

Figure 2.3 indicates the chronically polluted area as a percentage of the total area of administrative regions in Siberia in thousand km^2. Of note, while many areas surrounding industrial sites are chronically polluted and could be classified as “sacrifice zones,” areas lying outside them may also be affected by long-term effects of pollution such as tree die-back, increases in tree die-back due indirectly to pollution (such as weakening which leaves boreal forests more susceptible to disease and pests), and soil degradation indicate that Siberia faces greater threats from anthropogenic pollution than now estimated.

Figure 2.3 Chronically polluted areas by administrative region in Siberia, km^3					
Administrative Region	**Total area of administrative area, km^3**	**Chronically polluted area around industrial centers, km^3**	**Total polluted area in admin. area, km^3**	**% Total polluted area in admin. area**	**%Chron. polluted area in admin. area**
Altai Kray	169.1		1.79		
Barnaul-Novoaltaisk		1.79		1.20%	1.20%
Gorno-Altai Republic	92.6				
Krasnoyarsk Kray	710		19.78		2.78%
Krasnoyarsk		10.72		1.51%	
Achinsk		1.54		0.22%	
Norilsk		7.52		1.1%	
Primorski Kray	165.9				
Khabarovsk Kray	788.6		6.65		0.84%
Khabarovsk		2.53		0.32%	
Komsomolsk-na-Amure		4.12		0.52%	
Amur oblast	363.7		3.89		1.067%
Blagoveshensk		1.81		0.5%	
Tynda		2.08		0.57%	
Yevrey a.oblast	36				
Irkutsk oblast	745.5		34.94		4.69%
Irkutsk		31.24		4.19%	
Baikalsk		0.7		0.09%	
Bratsk		3		0.4%	
Kamchatka oblast	170.8				
Kemerovo oblast	95.5				
Novosibirsk oblast	178.2		13.02		7.3%
Novosibirsk		13.02		7.3%	
Omsk oblast	139.7		4.58		3.27%
Omsk		4.58		3.27%	
Sakhalin oblast	87.1				
Tomsk oblast	316.9		2.02		0.64%
Tomsk		2.02		0.64%	
Tyumen oblast	161.8		4.43		2.74%
Tyumen		4.43		2.74%	
Chita oblast	412.5		1.54		0.37%
Chita		1.54		0.37%	
Buryat Republic	351.3				
Tuva Republic	170.5				
Khakass Republic	61.9		38.56		62.29%
Abakan-Minusinsk		38.56		62.29%	
Yakutia Republic	3103.2				
Total area, km^3		131.2	131.2	approx. 1.5% total area	
Source: *Obzor Sanitarnogo Sostoyaniya*, 1994.					

Less dramatic but still significant, Irkutsk city pollutes about 4% of the total area of Irkutsk, one of the larger administrative units in East Siberia. Norilsk industry appears to damage approximately 1.06% of the total land area in Krasnoyarsk kray. It is generally accepted that the Norilsk industrial complex is a main contributor to forest die back and earlier stages of forest decline for at least 7,520 km^2, potentially more when considering transport capabilities of the many heavy metals emitted from its heavy industries. Information in this figure, though incomplete, does indicate that industrial emissions claim about 1.05% of Siberia's total area in what the Russian Federation calls "chronically polluted areas." Other locations may be affected from pollution from industrial sources as well, but the above reported appear most serious.

Analyses using diverse methodologies and with varying pollutant subjects have uniformly indicated that the areas most at risk for environmental degradation in Siberia center around the central-southern corridor of large industrial complexes (Bashkin 1993), (Kiseleva 1996), (Nilsson 1998). Pollution is worst in West and East Siberian locations. Other areas in these two regions appear less at risk. Depending upon the transport capabilities of the heavy metals and organic compounds emitted from southern towns, central and northern Siberian forests could exist almost undisturbed. However, while large tracts of land in both West and East Siberia lie far from industrial centers and may thus be at lower risk, these areas may sustain damage from: long-distance air pollution, weakening due to combined effects of pollution and natural factors, and degradation from new economic developments which can produce higher emissions. Gaps in the data prevent risk analysis for Khanty-Mansi a okr. and Yamalo-Nenets a okr. in West Siberia and Taymir a.okr, Evenk a.okr, Ust-Orda Buryat a.okr and Aga-Buryat a.okr in East Siberia.

Risk-weighted analysis adds some depth, identifying chemicals with the most destructive potential.

Risk-ranking analysis reveals that industrial centers focusing upon the production of chemicals and petrochemicals, steel, and the polymetallic products located mostly in East Siberia and centers like Norilsk and Kemerovo put those areas at higher relative risk than other industrial centers. However, because of the particular set-up of industrial complexes in Siberia, many major centers have all of the industries which tend to emit the most toxic chemicals.

2.3.2.1 City-source emissions of toxic substances

While the industries located in various Siberian cities determine the pollution profile there, almost all cites manifest a few similar characteristics in types and volumes of chemicals emitted. Carbon soot is emitted in large quantities in all areas, evidence that fossil fuels make up the base of energy production. Coal burning, oil combustion, and by-products from oil refineries, among others, release about 1,336,460 thousand tons of carbon soot into the air per annum in the average East Siberian industrial town (the amount rises to 2,061,510 thousand tons for Ulan-Ude in the Buryat Republic). All Siberian cities are sources of vanadium pentoxide, manganese, and chrome. Some of the major sources of chrome in Siberia are Krasnoyarsk, Novosibirsk, Barnaul, Osk, and Irkutsk. Irkutsk, the most significant producer of Cd in Siberia, discharged more than 100 tons of this, one of the most toxic identified metals. Norilsk and Belovo (Kemerovo oblast) emit tetraethyl-lead in the largest quantities, while Norilsk generally occupies first place for heavy metals emissions.

A handful of key industries appear to emit the majority of toxic emissions in Siberia by weight and by risk. These industries are located in four or five administrative regions in Siberia, with the remaining areas emitting low volumes of reported pollutants. The dominant industries for total volume of emissions in Siberia are related to energy production and the burning of fossil fuels. These include energy production, large coal-burning energy and power stations, the fuel industry and oil dwelling (with Tyumen contributing by far the largest. The following figures show industrial contribution to emissions *by volume* in Siberia: the polymetallic industry (with industry in Krasnoyarsk the biggest polluters), and the steel industry (Kemerovo leads in emissions).

In 1987, four areas in Siberia ranked among the top ten Russian regions of industrial output. These were Sverdlovsk (27.28% cumulative share of total output), Tyumen (22.85%), Chelyabinsk (15.36%), and Bashkortostan (8.74%). Five years later after the Russian political and economic crisis, six of the top ten Russian regions of industrial output were located in Siberia, namely Tyumen (with 41.35% cumulative share of total industrial output), Sverdlovsk (35.06%), Chelyabinsk (21.05%), Bashkortostan (17.25%), Krasnoyarsk (13.56%), and Kemerovo (3.21%). The policy implications which come from this break down of industrial contribution to air pollution in Siberia include a necessary shift to increased scrubbing or away from fossil fuels and a new, less-polluting energy policy.

The analysis changes when applying a risk-weighting factor into the calculation of emissions and environmental impact. Based upon RfDs for human health, the destructive effect of heavy metals such as manganese or chromium hexavalent exceeds that of carbon soot by many magnitudes. Industries emitting smaller quantities of more harmful compounds, then, become the targets for abatement policy and reveal a pattern of pollution more serious than initially expected in Siberia.

Figure 2.4 Contrubution by Industry Type to Air Pollution in East Siberia (IIASA 1996)

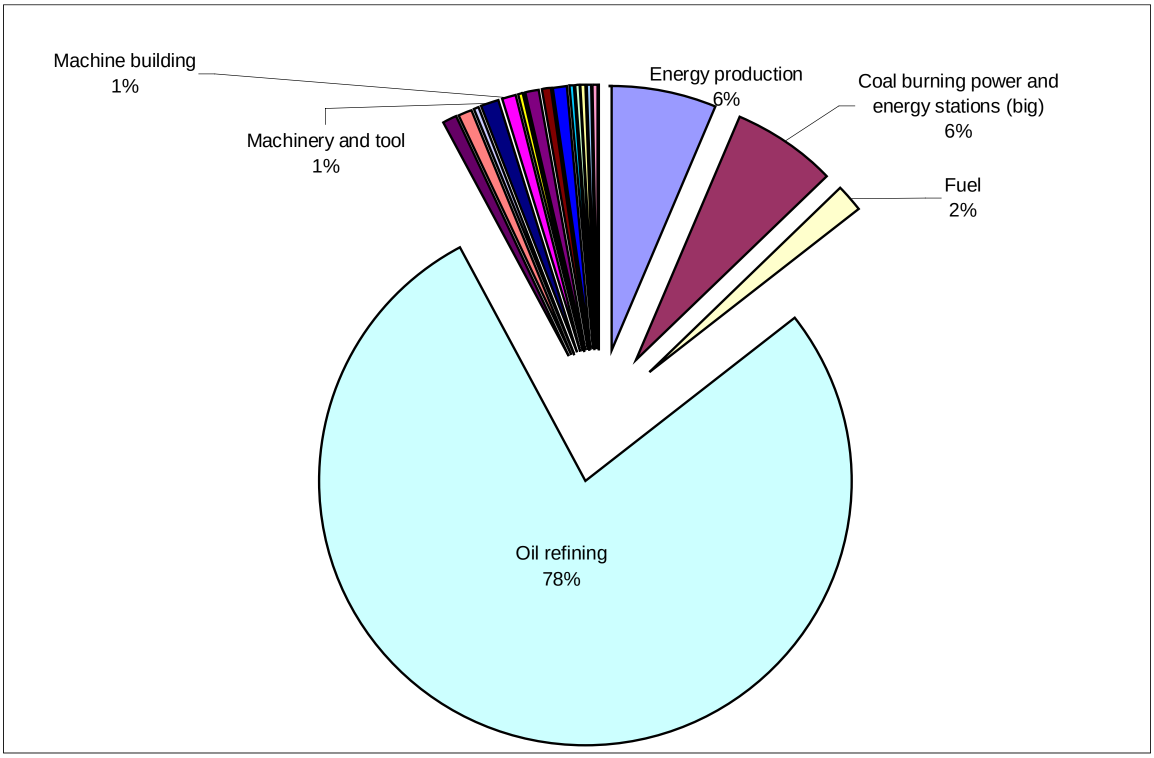


Figure 2.5 Contribution by Industry Type to Air Pollution in the Far East (IIASA 1996)

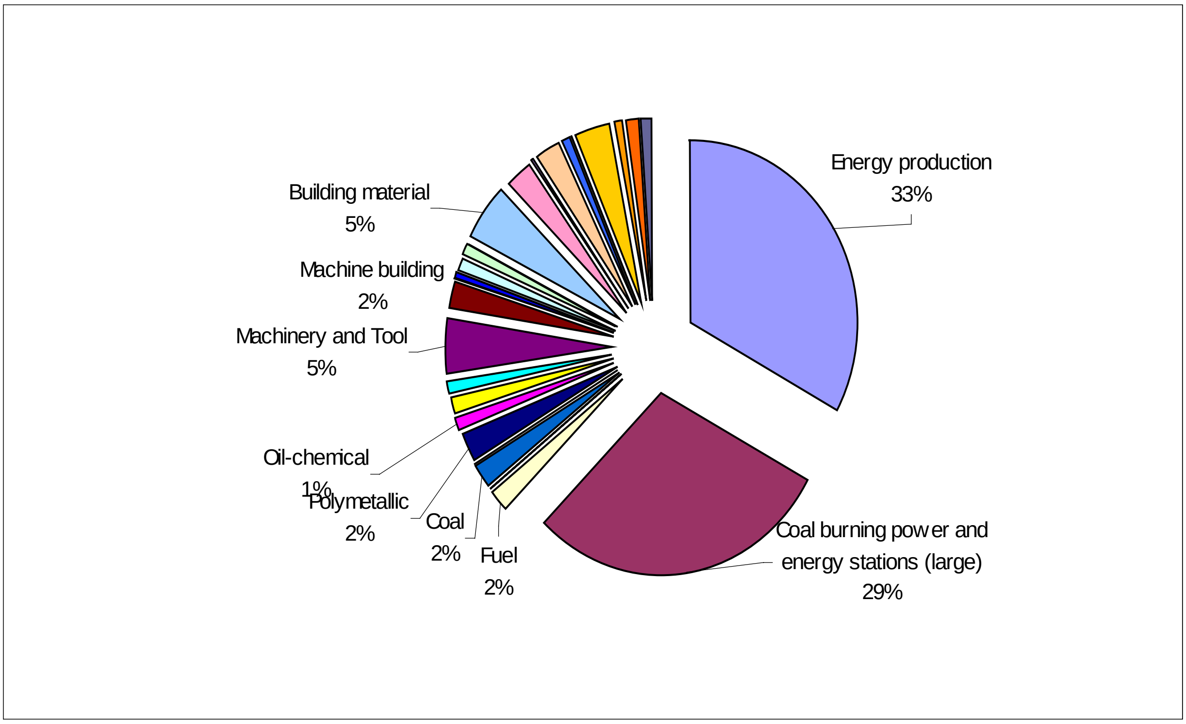
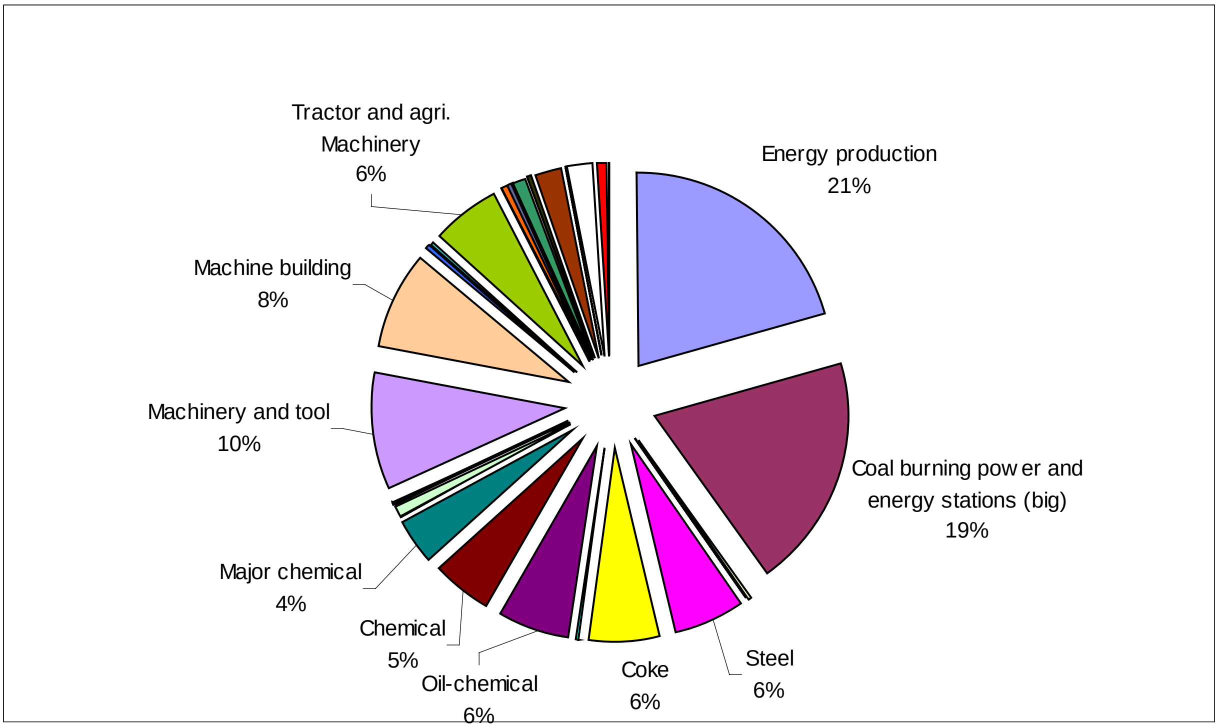


Figure 2.6 Contribution by Industry Type to Air Pollution in West Siberia (IIASA 1996)



Some surprises emerge. For example, a random analysis of Siberian industrial cities showed that the city of Dalnegorsk was at higher risk for toxic compounds (particularly the polymetallic industry's lead emissions) than Omsk. Following Omsk, Vladivostok, Juzhno-Sakhalinsk, and Khabarovsk appeared to emit the highest risk-ranked volumes of lead in the region, indicating that environmental impact from lead depositions could be highest in the near vicinity of these points.

Industrial centers which emerge as the most serious points of emissions generally reflect those noted above for total volume emitted. Tetraethyl lead dominates the profile of toxic polluters, for which (in descending order) Irkutsk, Chelyabinsk (both significantly higher emitters of "high risk" toxins than Moscow), Krasnoyarsk (including Norilsk), Primorsky, and Novosibirsk (five magnitudes below Primorsky Kray).

Figure 2.7 Volume-ranked emissions by industry

Compounds	**Associated industries in Siberia**
V_2O_5	Steel, chemical, polymetallic industry, oil refineries
Carbon soot	Coal combustion, transport, widespread industry, agriculture, chemical, paper and pulp, steel, oil refining, machinery, fuel industry
Ammonia	Energy production
Manganese	Steel, polymetallic industry, chemical
Lead	Widespread industrial use, leaded petroleum fuels, military, chemical, polymetallic, oil-refining
Chromium hexavalent	Polymetallic, chemical, widespread industrial use
Nitric acid	Energy production, large and small coal-burning energy plants, chemical, agriculture, military, fossil fuel combustion
Hydrogen chloride	Energy production, military, polymetallic industry, chemical
Sulphuric acid	Coal combustion, oil refining, polymetallic industry, wood and paper production, steel, military, chemical, agriculture
Flouric gasses	Military, polymetallic industry, chemical, cement, steel, fuel industry, agriculture, widespread industrial use
Source: (ATSDR 1993)	

Although emissions by volume are higher in Norilsk, the largest emitter of metallic nickel and other metal compounds, industrial centers to the south including Irkutsk, Angarsk, Bratsk among others rank three magnitudes higher in terms of risk. Because of the extreme toxicity of lead and its low reference dosage, the analysis of significant pollutants changes significantly when lead is excluded. Figures 2.7 and 2.8 compare volume-ranked emissions by industry in Siberia and risk-ranked emissions by industry in Siberia, excluding lead.

To isolate and reduce the detrimental effects of lead upon human and forest health, figure 2.8 indicates that focusing upon the polymetallic industry (which emits up to 34% of risk-ranked pollutants in Siberia, of which lead dominates due to its extreme toxicity), the machinery and tool industry, and the machine building industry would prove most effective. Of note, other industries such as energy production, large and small coal production plants which contribute high volumes of soot and SO_2 do not contribute even one-percent of risk-ranked emissions.

Figure 2.8 Risk-ranked emissions by industry

Compound	Associated industries in Siberia
Hydrogen sulfide	Oil refineries, chemical, iron smelters, coke ovens, food processing, agriculture, oil-chemical
V_2O_5	Steel, chemical, polymetallic industry, oil refineries
Arsenic	Polymetallic industry, coal-powered energy plants, agriculture
Nickel	Steel, coal-powered energy plants, polymetallic industry, chemical, oil-chemical
Carbon disulfide	Chemical
Hexavalent chromium	Steel, chemical, polymetallic industry
Mercury	Chemical
Manganese	Steel, polymetallic industry, chemical
Hydrocyanic acid	Polymetallic industry, chemical, mining, oil-chemical
Source: (ATSDR 1993)	

Of interest, when risk-ranked analysis is applied to industrial emissions data in Siberia, the following industries do not appear: gas, coke, coal, small coal-burning energy plants, major chemical industry, oil dwelling, military or transport. While the data may prove unreliable in some instances, the industries which appeared as the high-risk polluters (Pb excluded) were chemical (15% of high-risk emissions) the oil-chemical (15%), steel production (12%) and polymetallic industry (11%). Medium-risk industries included pulp and paper (8%), paper and wood (8%), energy production (6%), and large coal-burning energy stations (5%).

In the volume-based analysis, the energy sector appeared as the main culprit for total pollution emissions by ton. This lead-dominated analysis reveals that policy makers must first define the level of risk associated by individual pollutants for identified endpoints and then target specific sectors to reduce emissions. The distribution of industries contributing risk-ranked toxins into Siberia's environments changes when lead, with an RfD several magnitudes higher than the next most toxic substance, is excluded. Figure 2.8 indicates that for the reduction of chemicals such as inorganic arsenic, carbon disulfide, chlorine, chromium (IV), hydrogen cyanide, hydrogen sulfide, manganese, metallic mercury, metallic nickel, and V_2O_5, policy makers may find an economy-wide approach more effective than focusing on a specific sector.

This analysis reveals the aggregate contribution of risk-ranked emissions and indicates that a handful of industries pollute in high volumes, others in terms of high-risk emissions, and a few such as the chemical, polymetallic, and steel industries both in high volume and high-risk chemicals. Unlike the volume-based analysis, energy production and most oil-related activities do not appear as the major sources of particularly toxic substances.

While millions of tons of carbon soot and other petroleum fuel-related byproducts pose problems for Siberian environments, according to this analysis they may pose relatively less risk than initially thought. According to a risk-weighted analysis of the data, heavy metals and a handful of organic compounds could impose the most significant risks for Siberian ecosystems and human populations.

2.4 Emissions threat to forest ecosystems

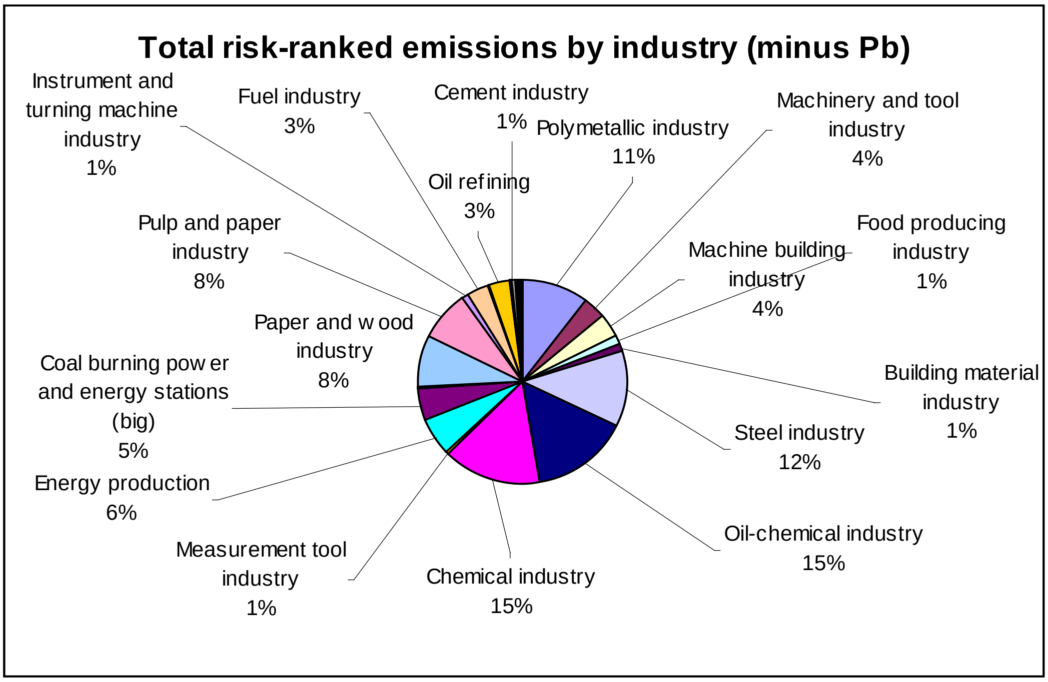
Atmospheric emissions pose serious health threats to forest ecosystems. Michaelis (Michaelis 1997) reported the significant role which air pollution plays in forest damage, stating, “Slightly damaged trees may occur due to natural causes…but more severe damage or even the death of trees [has been] attributed to anthropogenic causes such as direct effects of air pollutants on plant organs, acid deposition, soil acidification and impairment of the mineral budget.” According to official reports forest die-back resulting from air pollution accounts for 95% of all anthropogenic factors (Forestry 1994) and areas of loss appear concentrated along corridors of industrial activity. Forest die-back, increased susceptibility to disease and insect attacks, and simplification have all been linked with emissions in Siberia. Acidifying pollutants, heavy metals, and organic pollutants may also damage the lower plant forms of the tundra which form the food base for many animals and migratory birds (artic moss).

When a severe pollution stress is imposed for a long duration or in a particularly high intensity, the forest ecosystem may experience a retrogression characterized by reduction in structural complexity, biomass productivity, and species diversity (Whittaker 1975). Abating pollution, particularly the high-risk chemicals identified in this report, would not only have a high certainty of improving forest health and preserving a valuable economic asset, but it might also halt possible forest simplification and reduction of biodiversity. Thus discovering the levels and potential risks of emitted chemicals associated with industry in Siberia becomes a priority for forest protection. Present research focuses upon estimating critical loads and their exceedances for single and combined chemicals for the regions various ecosystems (Nilsson 1998).

In spite of a pattern of localized pollution, the extent of destruction in terms of total area percentage can be significant. Of most concern, up to 28% of the total area of Krasnoyarsk Kray appears to be chronically affected by toxic emissions coming from industrial centers within this administrative region (Kiseleva 1996). Although the *Natsionalynyi Doklad* does not clearly define “chronic,” the immediate effects upon forest die-back correlate strongly with these figures. Of a total area of 71,000 km^2, approximately 19,780 km^2 sustain damage from air pollution. These areas are in the immediate vicinity of Krasnoyarsk, Norilsk, and Achinsk. Between 1988-1993 approximately 130,000 ha of forest died due to emissions in the Norilsk industrial complex alone (Kasimov 1993). While these numbers are significant, insufficient data may encourage official reports to underestimate damage to forest. The Russian Federal Forest Service primarily measures forest die-back rather than early stages of forest decline which may have some relation to atmospheric emissions. Combined with knowledge about the weather patterns and pollutant accumulation capabilities of the region, damage caused to forests and other parts of the environment in Siberia may concern larger areas than now estimated. In the longer term, atmospheric emissions from Siberian industrial centers could pose a serious threat to forests ecosystems far afield, weakening and destroying valuable economic and natural resources.

Primary and secondary pollution in the form of direct exposure to emissions such as sulphur dioxide, lead, and other toxic chemicals occurs on a broader level than earlier assumed in Siberia (Nilsson 1998). Exposure to particulates such as industrial dust, soot, lead particles, magnesium oxide, and sulphuric acid have clinically proven adverse affects on tree growth and may so affect Siberian forests, which receive moderate to high dosages of these emissions in local areas. Severe injury to woody plants may also occur in the area of large polymetallic complexes in eastern Siberia due to exposure to heavy metals, dusts and flourides. According to both volume and risk-ranked analyses below, there is reasonable certainty that forests sustain damage from these sources of industrial air pollution. The problems associated with acidification of the Siberian forests have been discussed elsewhere (*ibid*.); this report, therefore focuses on the potential adverse effects of risk-ranked chemicals (the most important of them heavy metals) upon forest health. The major sources of heavy metals in the Siberian environment include emissions from large industrial sources such as the steel industry, the chemical industry, and the polymetallic industry (including primary and secondary base metal smelters and refineries).

Figure 2.9 Total risk-ranked emissions by industry (minus Pb) (IIASA 1996)



2.4.1 Effects of metals on forest decline

Needle and root damage and nutrition imbalances have been observed in some areas in Siberia (Nilsson 1998) and acid rain may liberate metals in the soils, the most commonly accepted hypothesis on the mode of metal pathogenicity in forest trees. Constantinidou and Kozlowski (Constantinidou 1976) reported how air pollutants induce adverse metabolic changes and injuries in plant cells, warning that "eventually pollutants affect entire forest ecosystems by inducing reduction in structural complexity, biomass, productivity, and species diversity. Growth reduction by pollutants has been shown by measurements of height growth, leaf growth, xylem increment, dry weight increment of roots, stems, and leaves, relative growth rate, and reproductive growth. Air pollutants inhibit reproductive growth by decreasing the physiological efficiency of foliage, influencing mechanism of flowering and fruiting and directly injuring reproductive structures.

Kozlowski and Constantinidou (Constantinidou 1976) note that, "the rate of photosynthesis in polluted plants is adversely affected in the short term by changes in stomatal aperture, occlusuion of stomatal pores, chlorophyll breakdown, and by changes in photosynthetic enzymes, phosphorylation rate, and buffering capacity. In the long term photosynthesis is adversely affected by reduced photosynthetic surface resulting from leaf necrosis, abscission, and inhibition of leaf formation and expansion." Although current emissions levels have decreased since the height of industrial production under the Soviet regime, one may assume with some certainty that Siberian forests have been exposed to at least low-level, long term compounds such as SO_2 and nitrates, Pb, Mn, chromium hexavalent, and other high-risk chemicals.

Findings on the effects of metals on forest health provide few definitive answers about tree damage and the presence of identified emissions. Although Finnish studies have found no positive correlation between the degree of tree damage and metal concentrations, evidence exists of less direct effects of metal pollution on tree health. These Finnish observations give no evidence for a general absence of such a correlation, but do indicate that researchers have found no relationship between tree damage and metal concentrations in areas of relatively low pollution levels (Ahti 1988). However, Finnish studies have noted *less direct effects* of emissions upon forest health. In the observation area of Kotka, Ahti (Ahti 1988) found a correlation between the damage caused by *Blastophagus piniperda* to pines and concentrations of Cd and Zn in *Hypogymnia-physodes* in those pines. Ahti also found a positive correlation between the damage caused by *B.piniperda* and the levels of Fe and Zn in the needles. In addition, the degree of metal concentrations correlated with the degree of damage to lichens in the study.

Metal pollution appears to cause complex ecotoxicological disturbances in forest systems that should not be overlooked even when the volume of aggregate emissions appear to be low in large parts of Siberia. Volume-based analysis leads to the assumption that large tracts of Siberian ecosystems have relatively low exposures to air pollution because reported volume of emissions in these regions are low. Risk-ranked analysis reveals that, although levels of pollution may be relatively modest, the chemical makeup of the aggregate pollution (particularly if high risk chemicals such as metals mentioned here) may put even remote locations at risk for environmental degradation. Both methods of analysis, however, suggest that areas surrounding industrial centers sustain anthropogenic damage.

Lerman and Darley (Lerman 1975) indicated that foliar injury (necrosis, chlorosis, and abscission) to forests is attributable to metal particulate exposure. Several studies have shown the destructive potential of heavy metal emissions on forests surrounding near power plants, smelters, and polymetallic industries (Scheffer 1955), (Scurfield 1960), (Miller 1975), (Linzon 1978), (Smith 1981), (Kim 1982), (Pandey 1983), (Ulrich 1983).

In the vicinity of industrial centers (located primarily in south central Siberia) the damage to trees and other types of life forms from the high risk chemical group appears acute. The impact of lead on forests is not yet fully understood, however developmental damage can occur in trees. Studies in the 1980s showed that lead accumulated in the soil as a consequence of rising acidification, dissolved below pH4, and that this process was enhanced by high concentrations of sulphate and chloride in the soil solution (Brümmer 1983), (Herms 1984). Godbold (Godbold 1984) showed that the availability of just 0.1ppm of lead reduces the growth of fine roots of spruce seedlings by more than 50%. The presence of increasing acidification in Siberian forests, combined with such industrial emissions therefore poses significant threats to forests. The effects of mercury, cresol, arsenic, and carbon tetrachloride, compounds identified as “high risk” in this report, also have negative impacts on various stages of tree growth, but more research is required to determine threshold values for specific species. Research shows that Siberian vegetation manifests damage in areas where heavy metal emissions are highest (Ruhling 1978), (Ruhling 1984), (Tyler 1984), (Beyer 1986), (Mankovska 1986), (Folkeson 1987), (Jansen 1987), (Kazmierczakowa 1987), (Braniewski 1988), (Beyer 1988), (Oyler 1988), (Pacha 1989).

2.4.2 Natural factors combined with anthropogenic pollution

Apparently low levels of emissions may disguise environmental risk by obscuring the effect of weather patterns on deposition and accumulation of toxic emissions over time. In Siberia, weather patterns combine with geographical formation to make large areas of the Siberian territory barely capable of ridding itself from toxic chemicals from air pollution. The low potential for self purification makes technogenic smog in the wintertime, and pollutant accumulation in general, common (Doklad 1991). The situation is even worse around cities, where unfavorable atmospheric conditions such as anticyclones and air inversions trap toxic fumes in valleys. The forest damage appears most critical in Krasnoyarsk, where toxic clouds form as water evaporates from the massive Krasnoyarsk water reservoir.

While the presence of insects, forest fires, and disease occur naturally in the region, the presence of anthropogenic air emissions may augment the degree of damage caused by these factors. The southern area of Siberia is characterized by warmer weather conditions which allow insects to develop. Kiseleva (Kiseleva 1996) reports that the highest density of insect loca was observed in the Altai region, Novosibirsk oblast, Tuva republic, and Primorsky Kray, all areas lying in the southern part of the region. However, the highest losses of forest due to insect activities from 1989-1993 occurred in industrialized areas of Irkutsk, Tomsk and Tyumen oblasts, with relatively high damage from insects also occurring in Kemerovo and Omsk oblasts, as well as the southern region of Krasynoyarsk kray. These areas also appear sustain the largest forest die-back resulting from air pollution (Sostoyaniya 1994).

Dust, emitted in large quantities from Siberian factories of all types, can also severely weaken trees and make them susceptible to multiple forms of stress that contribute to tree die-back. Dust may be a locally important stress factor for trees (Nuorteva 1990). Dust pollution causes mite outbreaks but also kills some species of small insects on trees (Alstad 1982). Studies reveal that damaged trees with characteristic symptoms of forest die-back are clearly concentrated around industrial centers and major roads.

2.4.3 CO_2 and the role of Siberian forests

One key pollutant, CO_2, surprisingly not included in the database upon which this analysis is based, deserves mention here. Carbon dioxide emissions in Siberia are of particular interest in light of intense discussions prior to and following Kyoto about green house gasses, Siberian industrial emissions, and the role which the forestry sector can play in emissions abatement or augmentation in terms of volume, are unique (see, for example, (Kohlmaier 1988)). CO_2 is the main polluting substance in the Siberian region (Danilov-Danil'ian 1993). As of 1990, the Russian Federation contributed 10.7% of the total global CO_2 emissions (ICRFCCP 1995), much of which is a result of either direct consumption of fossil fuels or as a result of fuel extraction and processing of those fuels in energy-rich Siberia. Figure 2.10 illustrates 1990 levels of green house gases in the Russian Federation. Taking into account the significant carbon sink provided by Siberian forests, net emissions in 1990 were still 451 million tons of CO_2, over three times the carbon sink potential (estimated at160 MtC/yr).

Figure 2.10 Anthropogenic emission of greenhouse gases in the Russian Federation (RF) 1990

Gas (Mt)	RF Emission/RF Sink	Global emission, Mt/yr[1)]	RF share in global emissions, %
CO_2	651/200	6100	10.7
CH_4	27	375	7.2
N_2O	0.82	8.2	10.0

Source: (ICRFCCP 1995) Interagency Commission of the Russian Federation on Climate Change Problems, 1st National Communication, Moscow, Russia.
1) IPCC data

The patterns of emissions in European Russia and Siberian Russia vary significantly, with transport and individual motorized traffic playing a significant role in the west, and primarily industrial and forest sectors playing a significant role in Siberia. Although the Kyoto Convention dealt primarily with emissions levels as of 1990, it is important to note that because of the transition, many industrial sources of CO_2 actually reduced their emissions. For example, the city of Novokuznetsk experienced a roughly 50% reduction of CO_2 and other major airborn emissions between 1987 and 1992 (Pryde 1991). However, increased use and potential abuse of Siberia's vast forest resources, in addition to growth in the use of low quality materials and fuels, could offset this downward trend and exaccerbate the CO_2 problem.

The distribution and magnitude of carbon dioxide emissions also vary, according to both anthropogenic and natural forces in the region. Following the pattern of emissions seen above, CO_2 is emitted heavily in industrial pockets, particularly those where the energy sector dominates (available data indicate that the industrial corridor of south-central Siberia including cities such as Novisibirsk, Novokuznetsk, Kemerovo, Tomsk, Krasnoarsk, Irkusk, and Bratsk manifest the highest emissions of carbon dioxide). CO_2 appears to have more stationary source points than other chemicals, primarily because of widespread energy extraction and production activities, and because of the energy inefficiency of Siberian industry. Russian experts estimate that 460-540 Mtce could be saved (currently 40-45% of current energy consumption) through more effective use of energy resources. Over a third of these savings could be made in the energy production sector alone, which would lead to a 0.35-0.4% rise in national income (ICRFCCP 1995).

Unlike the body of the analysis here which points towards chemical, steel, and other metals-related industries as the prime culprits of risky emissions, the fossil fuel industry accounts for 98% of CO_2 emissions in Siberia. In contrast, industrial production accounts for only 1.7% of technogenic carbon dioxide (ICRFCCP 1995). Although energy consumption per capita declined from 8.46 tons of coal to 6.7 tons in 1995, and from 104 million tons of motor fuel to 74 million tons in 1995, consumption levels are forecasted to rise again to (near) their 1990 levels by the year 2000 for all major types of energy (OECD 1996). Figure 2.11 shows the distribution of emissions according to specific features of the fossil fuel composition in Russia. Targeting energy production, particularly coal-based, as well as the use of oil and gas for fuel after processing, might make the greatest initial inroads towards carbon dioxide abatement in Siberia and the Russian Federation.

Figure 2.11 Types of fossil fuels and contributions to CO_2 emissions.

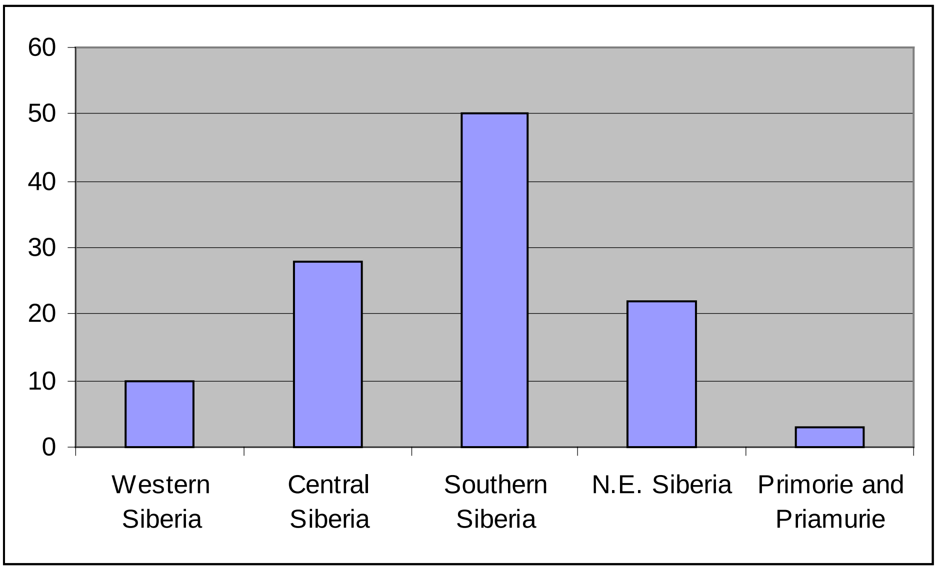
Fuel type	**% of CO_2 emissions**			
	Direct transformation to electric and heating energy	Use as a fuel after processing	Needs in industrial and technological processes, and other needs [1)]	Total
Coal	58.5	21.2	20.3	100.0
Oil and gas condensate	0.5	99.4	0.1	100.0
Natural gas	64.4	1.0	34.6	100.0

Source: (ICRFCCP 1995), Interagency Commission of the Russian Federation on Climate Change Problems, 1st National Communication, Moscow, Russia.
[1)] Including direct use as a fuel in industry and other branches of the economy.

Siberian forests are at risk from CO_2 pollution, but with wise management, they also provide a key to CO_2 abatement. Depending upon the natural climate, it is estimated that Siberian forests have the potential to absorb a significant amount of global greenhouse gasses, with European and North American forests the IPCC estimated the CO_2 mitigation potential of between 12 and 15% (Kohlmaier 1988).

An increase or decrease in the carbon stock of Siberia‘s forest ecosystems depends upon many factors, among them: changes in land use and forested areas, changes in the age and species structure of forests (caused by harvesting, planting, or natural reforestation), and the influence of climate changes and other external forces on forest growth and decomposition of forest matter. In 1993 up to 100MtC/yr were emitted as a result of harvesting and decaying roots and branches. Anthropogenic stresses mentioned above exacerbate insect and disease attacks, the risk of forest fires, and forest growth itself, and could cause transformations of Siberian forests away from their natural roles as CO2 sinks. The special role of Siberian forests in CO2 abatement, and the current challenges facing the forestry sector in Siberia, underscores the need for prudent management and use of forest resources.

Figure 2.12 Distribution of the total carbon sink by natural climate regions, MtC/yr
Source: (IIASA 1996)



2.5 Conclusion

The natural resources of Siberia stand at long-term risk from air pollution, but potential solutions might be found if abatement measures are implemented quickly and effectively. Policy makers must first decide if toxicity or volume of emissions is most important for Siberian abatement goals, and whether raising revenue exceeds the value of abating emissions. Identifying general regions of environmental risk, identifying the chemicals of most concern (either by volume or risk-rank), and identifying the key industries that serve as source points are necessary steps to take the appropriate environmental policy.

The pollution profile of Siberia has special parameters that set it apart from cases in OECD countries, in which pollution emanates from millions of point sources, particulary mobile sources. The regional analysis performed here, both by volume and by risk rank has shown that up to 80 or more percent of high-risk emissions come from a handful of identifiable sectors clustered in large industrial complexes. A policy that can take into account these pollution “hot spots” while creating incentives for protection of less endangered Siberian areas should accomplish abatement. For these reasons, policy makers chose to implement a pollution charge system, based on its theoretical ability to impose incentives for firms to reduce emissions and invest in abatement technology, and its hoped-for ability to raise much-needed revenues for other environmental uses. The following chapters assess the performance of the emissions charge system in Siberia.

The empirical analysis illustrates the direct relationship between industrial production and emissions. In addition, the data revealed that a few major sources emit a majority of pollution in terms of both volume and risk. The following chapter fits this empirical pattern into an emissions abatement model by Siebert (Siebert 1998) to show that pollution is an allocation problem, where appropriate economic tools can change the allocation of pollution and improve air quality. Following chapters evaluate the extent to which Siberia's experience follow this model and explore the important variables which influence whether the most polluting firms identified in this empirical analysis respond to the market-oriented pollution charge system in the region.

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Chapter 3: Theoretical groundwork and evaluation of an emissions tax

3.0 Overview

With a comprehensive weight and risk-ranked analysis of Siberia's pollution profile, the analysis moves to regional pollution abatement policy. Chapter two revealed human health and the environmental risks from industrial emissions. This chapter extends the discussion by placing Siberia's economic and environmental relationship within a theoretical framework, which reveals the strengths and weaknesses of an emissions tax for pollution abatement. Chapter three formalizes the link between pollution and economic activity, and outlines the central issue of concern in most of the literature—finding the appropriate environmental tax level. The ensuing chapter links theory with experience of how Siberian regional governments have attempted to address the heterogenous goals of pollution abatement.

In the burgeoning literature on tools for abatement, scholars have devoted much energy to scrutinizing the relative merits of command and control and market-based approaches (Kohn 1984); (OECD 1994); (Jorgenson 1995); (Sterner 1996); (Parry 1997); (Roodman 1997), (Farzin 1998); (Cohen 1998).[1] Somewhat ironically, centrally planned economies moved towards the use of market-based policies such as the pollution charge system discussed here, while market-based economies (OECD countries) struggled to reduce air pollution mostly through regulatory measures (Markandya 1994). Chapter

[1] This dichotomy, although traditional, is contrived. In reality, a range of tools exist which vary in degree of market and government involvement. Many of the most effective tools combine elements of both market and regulation under situation-specific conditions.

three presents a theoretical framework and justification for the market-based approach to pollution abatement. Based on the preceding analysis that identified patterns of pollution, it appears in theory that economic incentives rather than regulation might best address Siberia's problem. In practice, the emissions charge is an add-on to a standards and permit system. The current chapter examines the theoretical potential of an emissions tax to resolve some of the worst environmental and industrial distortions in the area.

Section 3.1 outlines the assumptions of the model for Siberia and discusses the extent to which the assumptions hold. Section 3.2 sets the analysis of Siberia's environmental situation in terms of an allocation problem, following Siebert (Siebert 1998). The allocation model presented below aids in developing a framework in which to analyze and evaluate air pollution policy in Siberia, particularly its impacts upon human health, the environment, and industrial output and performance. Section 3.3 continues the discussion of the region's transformation space. The analysis indicates that—when assuming negative environmental externalities associated with industrial production—too many environmental goods and services will be consumed, as indicated in chapter two. Section 3.4 discusses the setting of a shadow price for the environment. Finally, section 3.5 draws conclusions about the theory of the emissions charge for Siberia's environment. The most important theoretical issues differ greatly from the most important practical variables for Siberia's air pollution policy.

3.1 Assumptions and framework

A variety of scholars have laid out the economic theory of pollution control (Mills 1986); (Oates 1992); (Tietenberg 1992). Bluffstone and Larson *et al*. (Bluffstone 1997) outlined what they saw to be the transition-relevant elements of the pollution tax theory. To clarify the general framework in which Siberian's pollution policy operates, the author briefly reviews these elements here. First the author reviews key assumptions of a basic model for air pollution abatement, then a short analysis of what assumptions hold and do not hold for the region. Following this, the author establishes the allocation problem of Siberian emissions by using a simple model to show the relation of pollution to production possibilities (Siebert 1998). Chapters four and five continue the discussion of this model by examining the impacts of emissions charges on polluter behavior in a transitional economy.

3.1.1 Model Assumptions and Framework

The following simple framework outlines the assumptions and functions that determine pollution levels in a society and determines whether those levels exceed a socially acceptable threshold. Formalized in following sections, the demand or damage function for pollution by firms is analogous to any other demand function because generating pollution provides benefits to firms in ways similar to the way that labor or energy inputs generate benefits. Reducing pollution reduces benefits to the firm while increasing benefits to society. The abatement costs therefore equal the cost of reduced benefits of pollution. The supply of pollution from productive activities defines social costs of pollution (and the marginal benefits of abatement). At least seven assumptions should hold in order to arrive at an optimal supply and demand of environmental goods and services (Bluffstone 1997). If these are not met, some second-best solution must be found.

Link inputs, outputs and emissions that define D_p

A. A set of production processes generates pollution.

B. Enterprises can accurately measure pollution—either by direct monitoring or using indirect estimation methods—without excessive costs.

C. Enterprises seek to optimize some objective function.

D. Enterprises clearly understand the relationship between production and pollution.

Increases control options, & responsiveness to charges

E. Key markets function well, particularly financial markets. Firms operate in formal markets based on money exchange (as opposed to barter).

Adds cost element, helps define SC, MSC, damage.

F. Pollution creates social costs through environmental damages that can be translated into the same units as the benefits of pollution.

Allows enforcement and definition of policy.

G. Environmental authorities can observe pollution without excessive costs either through direct monitoring or indirect estimation methods.

Clearly for the Russian Federation, and for Siberia's regional economy in particular, all of these assumptions do not fully hold, and sometimes not at all. The most interesting aspects of this study emerge where the above assumptions of this model do not hold. To improve clarity, however, the work first reviews what should or could occur under an ideal pollution tax, and then review the "interesting and perverse Siberian reality" in subsequent chapters. Sections 3.2 through 3.4 discuss and formalize these assumptions as they apply to Siberia, particularly as the empirical issues of pollution and abatement were raised in chapter two.

Assumption A, based on the mass balance principle, fits with the empirical analysis in chapter two and seems to hold for Siberia. The following discussion assumes that emissions are joint outputs of production and treats environmental quality as a variable in the production set. Below, we discuss Siberia's transformation space in a simple model. A convex relationship exists between industrial output and environmental quality, which correlates with assumption A. Therefore, addressing industrial processes will affect pollution output.

Assumption B is less likely to hold for most enterprises in Siberia. The lack of modern pollution monitoring equipment, outdated or inappropriate estimation methods, and a possible aversion to measuring pollution means that enterprise knowledge of the link between actual production and expected pollution may be very loose. Regardless of good environmental intentions, enterprises may not know their exact levels of emissions nor the dependability (if present) of filtering devices. According to one survey performed in 1988-89, only 35.8 percent of enterprises in Siberia were equipped with some sort of emissions filtering or purification device (Doklad 1990). On average, such devices intercepted about 78 percent of total pollutants by volume in facilities where they were installed. The interception for gaseous and liquid substances was much lower, comprising about 31 percent of this type of pollutant intercepted. The worst performance for emissions interception were power plants (1.2 percent) and coal mines (0.6 percent) in the region (Goskomstat 1989). Often, existing purification facilities function poorly. An inspection organized in 1987 by the Goskomstat and an official committee for hydrometeorology showed that for the large industrial enterprises which were included in the inspection, 11 percent of total emissions was due simply to low efficiency and malfunctioning filter equipment. Up to 23 percent of these enterprises did not clean gases to the standards for which they were designed, 21.2 percent were in operation less than 5 years, 28.3 percent from 5 to 10 years, and over half more than 10 years (*ibid*.). In addition, given the low economic priority afforded to environmental law in Siberia (noncompliance appears high) firms may have less incentive to accurately estimate or monitor pollution levels. When self-monitoring is present, enterprises in Siberia manifest a tendency to underreport emissions to avoid paying charges.

Assumption C appears to hold for Siberia. Polluters are divided into two broad categories, which roughly respond to pollution output and firm characteristics in the region. Even though most enterprises in Siberia have undergone some form of privatization, the assumption that they try to optimize an objective function doesn’t necessarily mean profit maximization or cost minimization. The state, for example, still plays an important role in Siberia’s energy sector, sometimes skewing profit motivations and behavior. A pollution demand function can be determined for non-profit maximizing firms. In addition, assumption C does not require perfect competition in Siberia’s economy. It applies to pure competitors, monopolists, or oligopolists alike as long as each firm involved seeks to minimize the private cost of producing whatever vector of outputs it selects and has no monopsony power (i.e. no influence on the prices of inputs). Chapter five discusses the behavior of such firms as they respond to the implementation of an emissions charge system.

Assumption D does not hold in Siberia’s context of imperfect competition and asymmetric information. Siberian industry often lacks experience with the available abatement technologies and their costs and benefits. In an ideal situation, firms will not only be fully aware of all of their abatement options, but they will also have access to complementary markets, particularly financial ones. The actual environmental performance of firms receiving credit for abatement projects to date appears poor, due, as Smith and Zylicz (Smith 1994) note, to

> “…a low level of awareness of various technological options for pollution control, and their associated costs and benefits. This is partly a result of the lack of past contact between western suppliers of pollution control and other technologies, and individual enterprise managers.”

As later chapters show, assumption E fails in Siberia. Capital markets in Siberia are either not sufficiently developed to support a wide variety of credit packages to enterprises or markets that are still too thin to include the financing of environmental projects. If credit isn't available for pollution reduction projects then the demand for pollution will be higher and less responsive to price signals. Cash availability in the Russian Federation has decreased dramatically, and rationing now takes place. Banks appear reluctant to loan money for projects, which will not directly generate cash, which abatement investments do not. Politically powerful, the energy sector has a large say in the direction of credit, which depending on the circumstance could lead to crowding out for other firms or to a more hopeful situation. Partly to address this failure, the Russian Federation chose a pollution charge system whose primary goal is revenue generation. Local and national environmental funds draw principally on funds generated by pollution charges; however, the efficacy of the funds is questionable. Work on guidelines has proceeded but actual implementation results remain unclear (Lehoczki 1995), (Lehoczki 1994); (Lovei 1994).

A type of dual economy appears to exist in which large, formerly state-owned industries in Siberia make up a "virtual economy" while numerous smaller firms are beginning to form a "legitimate" market economy. This poses a challenge for our analysis, in that only half of the firms examined in the two-sector model react to abatement policy in profit maximizing ways. Some firms (coincidentally the heaviest polluters in the author's dichotomy) optimize some objective other than profits, such as perquisites. Many market-based abatement instruments assume pollution prices, which equal shadow prices for environmental consumption and profit-maximizing firms within perfectly competitive frameworks. Analysis of firm behavior before and after transition in Siberia reveals that firms did not behave as profit maximizers under the old system, and may still not fully respond to market signals in the newly privatized economy. In the period of massive economic transition, some firms are still learning to behave under market conditions. While restructuring efforts do encourage smaller firms to respond to the economic incentives of an emissions tax, behavior of sectors for which the objective function is not clear may differ depending upon institutional arrangements. Such industries (particularly the sectors of most interest to the present study) appear to operate in a space between market and state allocation of economic goods and services.

Measuring the social costs of pollution has improved, particularly in terms of human health and negative effects on the forestry sector (Bridges 1996), (Nilsson 1998). Although appropriate valuation remains an obstacle, assumption F appears to hold and provide for this simple model a cost element that allows one to define a social cost function (environmental damages), as well as a marginal social cost function (pollution supply function).

Finally, the ability for regulators to monitor and enforce air pollution policy on enterprises in Siberia is constrained by geographical distance and limited financial means. In fact, atmospheric emissions from industrial enterprises are as a rule not directly measured but calculated on the basis of "special non-direct means" (Goskomstat

1989). Measurement is fraught with methodological difficulties and plagued by "expert opinion," which often amounts to fixing the numbers until they fit the expected or hoped-for results of managers, environmental authorities, or regional political or business interests.

Siberia does not fully meet the criteria of the above framework, failing in what appear to be the most critical assumptions upon which effective implementation of the environmental tax relies: E (firm responsiveness to economic incentives such as the pollution tax), and G (effective monitoring of actual and reported emissions). The key question is the degree to which firms respond to the opportunities and costs imposed by a market-oriented policy tool in Siberia's framework. Before discussing these issues, the author lays the theoretical groundwork for later comparison.

3.2 Theory of environmental allocation in Siberia:
The transformation space and static allocation

Siberia's current environmental problems stem directly from an economic and political system that placed a low priority on such issues. Although federal law placed continual emphasis on environmental protection measures, it had limited capabilities to implement ambitious plans. Low levels of environmental investment, a lack of incentives to ensure compliance with strict air quality standards, and an apparent desire to conceal information regarding the extent of environmental degradation in the area indicate that environmental protection threatened the development interests of economic and political priorities of Siberian officials. Exacerbated by a state planning system in which the price mechanism played a very small role,[2] the institutional setting of a zero or even negative price for the environment correlates with environmental overuse and a severe regional decline in environmental quality in Siberia. The private and social costs of production and consumption diverged significantly and prompted the government to officially require the introduction of a limited "polluter pays" principle in which polluting industry paid victims for exposure to pollution. Even after the transition to market-based economic activities, the top polluting Siberian industries continue to produce in ways which do not represent the true opportunity cost of their production processes. Input prices are inefficiently fixed, both for labor and critical energy inputs, and pollution-intensive activities proliferate and disturb the allocation optimum. This section outlines the nature of the allocation problem in Siberia, and suggests a framework for analyzing the issue, which assumptions hold and which do not for the region.

[2] This might explain the chronic weakness of assumptions E, F, and G in the above framework.

3.2.1 Production theory

The first step in building the model for air pollution abatement in Siberia is to establish the correlation between production processes in the region and the output of pollution. Following this discussion, we will move to the demand and supply functions for Siberia's regional economy. Below, the author presents a theoretical model, which shows that pollution is a by-product of the production process. This supports the empirical findings of chapter two which point out that pollution distribution in Siberia parallels the spatial locations of major industrial centers (refer to Map 2.1).

Based upon the outcome of the inquiry into Siberia's pollution profile, which revealed a pollution bias heavily skewed towards five major industrial sectors, we "cluster" industry into two simplified sectors, one pollution intensive (including the five major polluting sectors discussed in the preceding chapter) and one non-pollution intensive sector. To further simplify the model, the author assumes that both sectors emit just one identical pollutant. Notations for the following discussions are as follows:

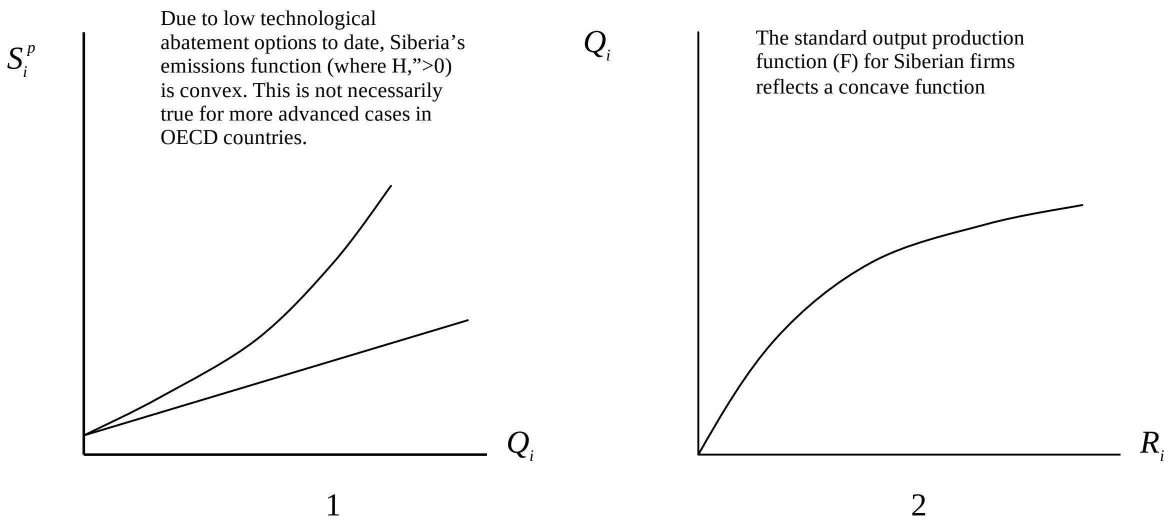
(3.1) $$S_i^p \geq H_i(Q_i) \qquad H_i^{'} > 0, H_i^{''} \geq 0 \qquad \text{for } i = 1, 2$$

At a given technology, the quantity of pollutants S_i^p increases proportionally or progressively with output Q_i.[3] The figure below depicts the emission function for the cases $H_i^{''} = 0$ (linear curve) and $H_i^{''} > 0$ (convex curve). This production function assumes a declining marginal productivity and does not distinguish between different production factors. In addition, (3.2) implies that no negative externalities are generated during production processes, an assumption relaxed later in the discussion to account for Siberia's actual situation. The model introduces only one type of resource *R*. The important assumption is that the total production function is made up of the standard production function and a waste-generating production function: during the production process the mass balance concept states that some waste is generated.

The two panels below depict emissions in terms of pollution supply given industrial output (panel 1) and the level of industrial output given a certain resource (panel 2)

[3] The emission function excludes the case in which the quantity of pollutants increases regressively.

Figure 3.1 Pollution, industrial output, and resources



(3.2) $Q_i = F_i(R_i)$ $\quad F_i^{'} > 0, F_i^{''} < 0$

Expression (3.1) and (3.2) suggest that emissions are dependent upon the resource input. Pollutants can also be considered as joint producers of the input, shown in (3.1a).

(3.1a) $S_i^p = H_i[F_i(R_i)] = Z_i(R_i)$ $\quad Z_i^{'} > 0, Z_i^{''} \gtrless 0$

One could formulate a model using (3.1a) instead of (3.1). Total output is a function of both production output and an environmental externality.

$$Z_i^{'} = H_i^{'} F_i^{'} > 0.$$

Applying the mass-balance concept to the production function, a concave production function implies a convex emission function. Below the model denotes $Z_i^{'}$ as the quantity of emissions that occurs if a resource is used in sector *i*. Let α and β designate the quantitative content of resources in commodity 1, and let S_i^p be the joint product.

$\alpha Q_1 + \beta S_i^p = R_1$ so that

$$S_i^p = \frac{1}{\beta}\left(R_1 - \alpha Q_1\right) = \frac{1}{\beta}\left[R_1 - \alpha F_1\left(R_1\right)\right] = Z_1\left(R_1\right)$$

Because the function F is concave, the emission function Z must be convex. The mass-balance concept and a concave production function imply $Z_i'' > 0$. We assume such an emission function in the following analysis. Note that $Z_i'' = H_i'' F_i'^2 + H_i' F_i''$, so that $Z_i'' > 0$ implies that $H_i'' > 0$.

The pollution abatement indicates that pollutants can be reduced by an input of resources in abatement R_i^r, where S_i^r represents the abated quantities of the pollutants. Declining marginal productivity also prevails in the sector-specific abatement function, and implies residuals of abatement activities.

(3.3) $$S_i^r = F_i^r\left(R_i^r\right) \qquad F_i^r < 0, F_i^{r''} > 0$$

In reality, abatement can result from various events. New production technologies develop which may reduce emissions, although this model assumes that polluting firms use only one technology. In addition, firms may cease production or expire entirely (particularly in Siberia's troubled economic climate) and investment in cleaning devices may prevent emissions from entering the environment will reduce emissions.

Precise diffusion functions discussed by numerous authors (Dennis 1978), (Pruchnicki 1977), (Berlyand 1974), and (Antonovski 1991) account for meteorologic, environmental, and pollution assimilation differences across the region. For this discussion, (3.4) defines pollution ambient in the environment as S, which is equal to emissions S_i^p.

(3.4) $$S = \sum S_i^p - \sum S_i^r$$

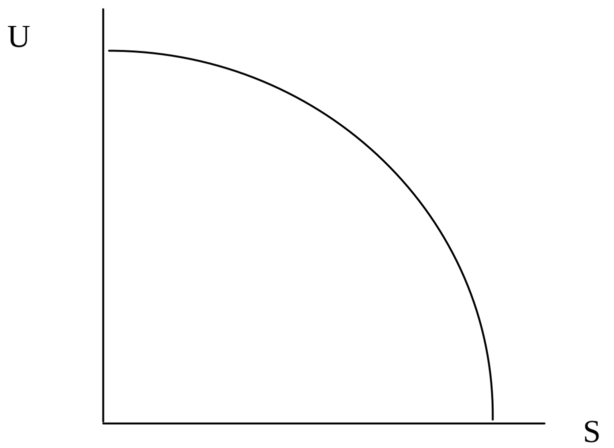
In this simple presentation, the function degenerates into a relationship in which ambient emissions equal the total quantity of emissions. In reality, particularly with accumulating high-risk toxins such as lead and mercury, ambient pollutants may not dissipate at the end of the period and accumulation occurs. Discussed briefly in chapter two, some elements of uniquely "Siberian" emissions such as nickel from Norilsk metallurgy plants may contribute to transboundary pollution problems. To remain within the scope of the current research, however, the author leaves these critical issues for future inquiry.

With this simplifying assumption, we can now build a pollution demand or damage function by specifying how pollutants S affect environmental quality in Siberia. The previous chapter established a correlation between the presence of above threshold value emissions (as indicated by the critical load mapping performed by Nilsson *et al*., 1996) and degradation of forest and human health endpoints. Now we formalize this physical relationship by creating an index of environmental quality in terms of pollutants.

(3.5) $U \leq G(S) \qquad G' < 0, G'' < 0$

Where U represents the public good (environmental quality) and G represents environmental degradation. The figure below illustrates the concave damage function of U and G.

Figure 3.2 Concave damage function of environmental degradation and pollution



Environmental quality decreases over-proportionally with increased emissions, due in part to accumulation of compounds, Siberia's particular climate which is adverse to assimilation of waste, and absent or poorly functioning given technology. While other damage functions could be considered, such as damage to quality of inputs in the production process, financial losses incurred due to pollution, etc., here we consider emissions damage to the environment.

Having established a relationship between production and pollution (pollution supply) and total emissions and environmental quality (pollution demand or damage), we place a physical constraint upon Siberia's economy by restricting resources. This limits the production and abatement possibilities of the economy.

(3.6) $\overline{R} \geq \sum R_i + \sum R_i^r$

3.2.2 The transformation space with environmental quality

Equations (3.1) through (3.6) describe the production possibilities of the economy. Assumption A above is verified in that if, at a given technology and with full resource utilization, a sector wishes to produce more, emissions will increase and the quality of the environment will decline. The emission function shows that emissions rise as output increases. In addition, in order to produce more at full resource utilization, resources currently employed in abatement will be redirected towards production. Environmental quality declines for two reasons: more emissions from increased production and reduced abatement activity, assuming a given technology. On the other hand, an improvement of environmental quality under the same assumptions is possible only if more resources are diverted from production towards abatement. The environment is used in two competing ways: as a public consumption good and as an assimilative recycling medium for waste and pollutants. If all resources are not currently employed, it could be possible to achieve abatement without compromising production. Nevertheless, even though Siberian firms do not use resources efficiently and could make substantial improvements in both production and abatement activities, following chapters will clarify the traditional bias against diverting resources into environmental protection measures and away from production.

Chapter two showed a correlation between areas of extreme critical load exceedances, high volume- and risk-ranked pollution output, and the existence of forest die back, which the author treated as a proxy for environmental damage. In addition, health statistics for chronic and acute human health disorders related to exposure to specific emissions indicate that production using a given technology does compromise environmental integrity. The following discussion formalizes these relationships.

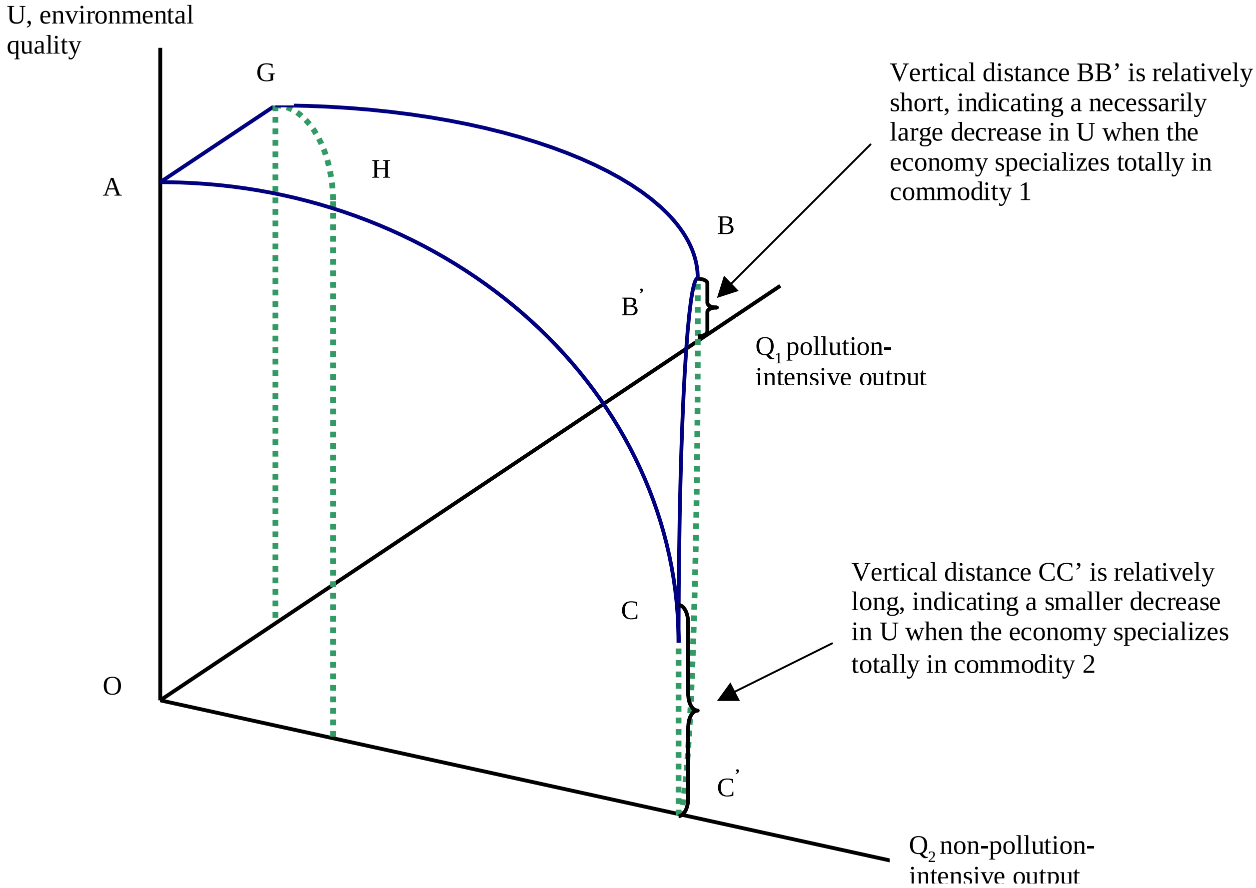
The model assumes that only one type of abatement activity exists, and R_3 denotes the resource input in abatement. The condition

(3.7) $$Z_i^{'} = H_i^{'} F_i^{'} = \frac{\partial S_i^p}{\partial Q_i} \frac{\partial Q_i}{\partial R_i} = \frac{\partial S_i^p}{\partial R_i}$$

expresses what quantity of emissions occurs if a resource is used in sector *i*. Thus, $H_i^{'} F_i^{'}$ can be interpreted as the marginal propensity of the resource input to pollute. Condition (3.7) states that the marginal propensity of the resource input to pollute in sector 1 is higher than in sector 2. Sector 1 is the pollution-intensive sector.

The figure below represents the transformation space for Siberia's economy, described in previously for a two-sector economy. Each sector produces one good, with Q_1 representing a pollution-intensive output (such as steel, chemicals, or fuel in Siberia) and Q_2 a non-pollution-intensive output (such as a good or service). In the figure below, because the vertical distance BB' < CC', the reader sees that Q_1 is the pollution-intensive output. According to the analysis of chapter two, Siebert's (1998) allocation model fits Siberia's case suitably. The figure illustrates the maximum production possibilities for commodities 1 and 2 and the public good U, environmental quality in Siberia. Other points on the graph help illustrate different levels of production and potential impacts upon the allocation of environmental quality and industrial output. Equation $U = \phi(Q_{1,} Q_2)$ presents another way to express the model's restrictions up to this point. We now examine the characteristics of this transformation space, noting the relationship between production, abatement, and environmental quality.

Figure 3.3 The transformation space and environmental quality



When both sectors produce no output, the economy achieves the natural, pristine environmental condition, or maximum environmental quality (*OA* in figure 3.3). Holding Q_2 at zero output and expanding the production of commodity 1 to an output correlating with G illustrates a resource allocation (R_1, R_3) such that all pollutants produced at this level of output quantity for commodity 2, when Q_1 = 0, maximizes environmental quality. Except for the curve *GH*, the horizontal roof represents a situation with maximum environmental quality and underemployment.

Now expand the production of commodity 1 at point *G* for Q_2 = 0 by 1 unit. Then the quantity of emissions increases progressively because $H_i'' > 0$. Because environmental quality decreases over-proportionally with increased emissions, environmental quality has to fall over-proportionally as a consequence of the increase in production of commodity 1. With an increase in production of commodity 1, additional resources are used in production rather than abatement or the non-pollution intensive sector 2. The quantity of abatement falls and environmental quality declines. We know that as a result of each unit of input withdrawn from abatement, the unabated pollution increase commensurately, reflected in a decreasing marginal productivity in abatement. According to the law of declining marginal returns, each additional unit of commodity 1 produced requires an increasingly larger share of resource inputs. For a shift from *G* to *B*, the quantity of pollutants has to increase progressively as inputs are reallocated from abatement to the production of commodity 1. Environmental quality must decrease progressively. The curve *GB* is concave.

The distance BB' denotes that quality of the environment which results from a total specialization in the production of commodity 1, given full employment and no abatement (this parallels the Soviet goal for massive Siberian industrial development). The distance CC' represents the quality of the environment which corresponds to a total specialization in commodity 2 with no abatement (less emphasis was historically placed on the development of light industry and consumer goods and services). Because $CC' > BB'$, one sees that commodity 1 is the pollution-intensive commodity, defined in terms of marginal propensities to pollution.

Define $\alpha = \frac{Q_1}{Q_2}$ and hold α constant. Consider a point on the curve *GH*. A unit of resources is withdrawn from abatement and put into the production of commodities 1 and 2 with the quantitative relation α of both commodities remaining constant. The quantity of emissions rises progressively in both sectors; in abatement, the quantity of unabated emissions rises decreases progressively, since the marginal productivity of disposal activities increases with a lower factor input. A reallocation of the resources in favor of production, given a constant proportion of commodities α, thus causes the emissions to rise progressively. Concurrently, marginal productivity does not increase as much in production.

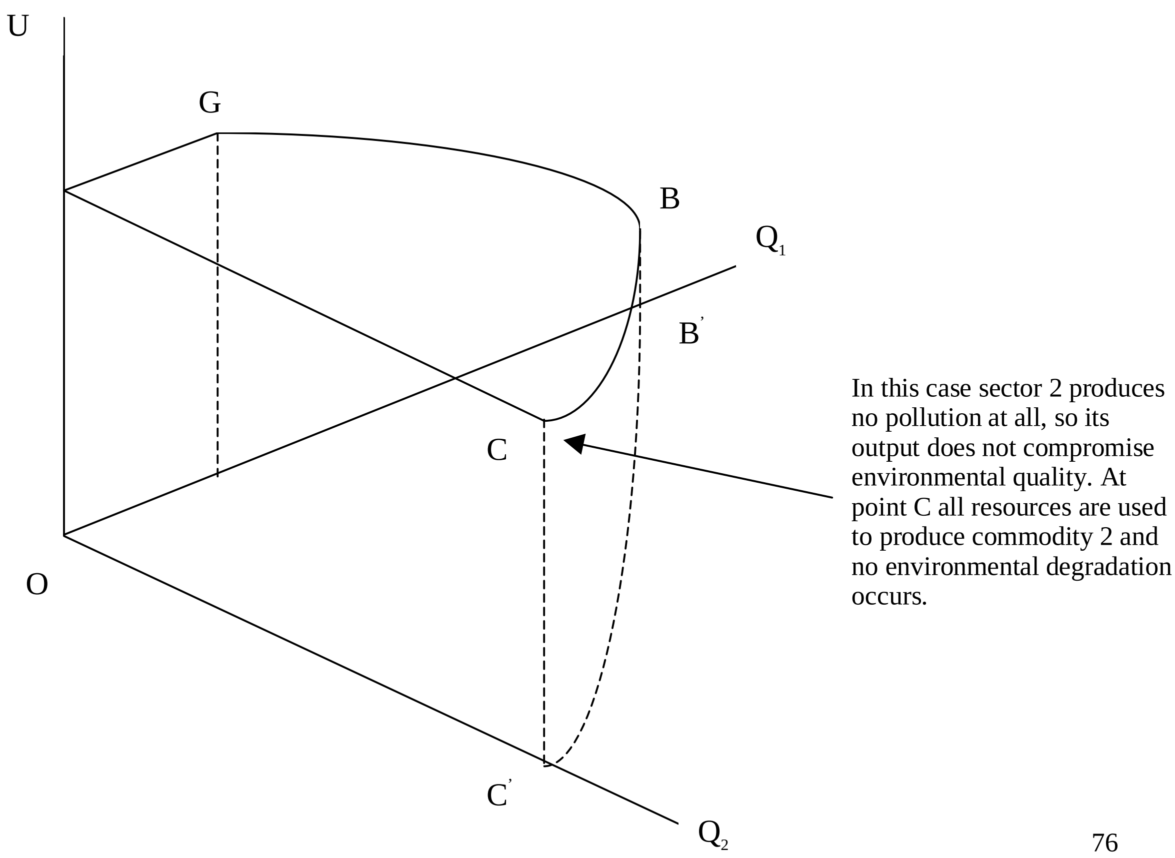
Curve *BC* represents the transformation problem for the case of resources not being used in abatement (R_3 = 0). The projection of the curve *BC* into the Q_1, Q_2 plan, (the curve *B'C'*) is the production possibilities curve. In a situation without environmental policy, the economy is located on curve *BC*. Point *X* on the transformation curve, the vector of goods and the factor allocation $\{R_1, R_2\}$, is determined by the relative price p_2/p_1.

This reasoning and formal analysis shows a tradeoff between the production of commodities and the provision of environmental quality. If higher output is desired some degree of environmental quality will be sacrificed. This implies that as Siberia's economy recovers, if little resources are devoted to abatement or other environmental investments, one can expect disproportional declines in already-deteriorated environmental quality. We now formally illustrate that declining environmental quality may also lead to declines in output in terms of both quality and quantity in the two sectors in this model.

If environmental improvement is the goal, output must be reduced. We expect that if the hypothesis that environmental taxes will induce firms to reduce output or invest in abatement is true, then we will see empirical verification in Siberia. If the economic chaos resulting from the transition period in Siberia has lead industrial output to decline and we observe decreasing actual emissions levels, then the emissions tax must have an expected impact in the region. We will expect to find evidence of lower incidences of acute distress for various diseases and disorders for humans as presumably air quality has increased. Subsequent chapters examine the empirical evidence.

The above analysis shows that several variables affect the form of the transformation space: resource endowment of the economy, pollution intensity of the two sectors, and productivity in production and abatement. Altering these variables for Siberia allows us to analyze the shape of the transformation space under different scenarios. Below we examine briefly three cases for Siberia.

Figure 3.4 Pollution intensity and industrial production

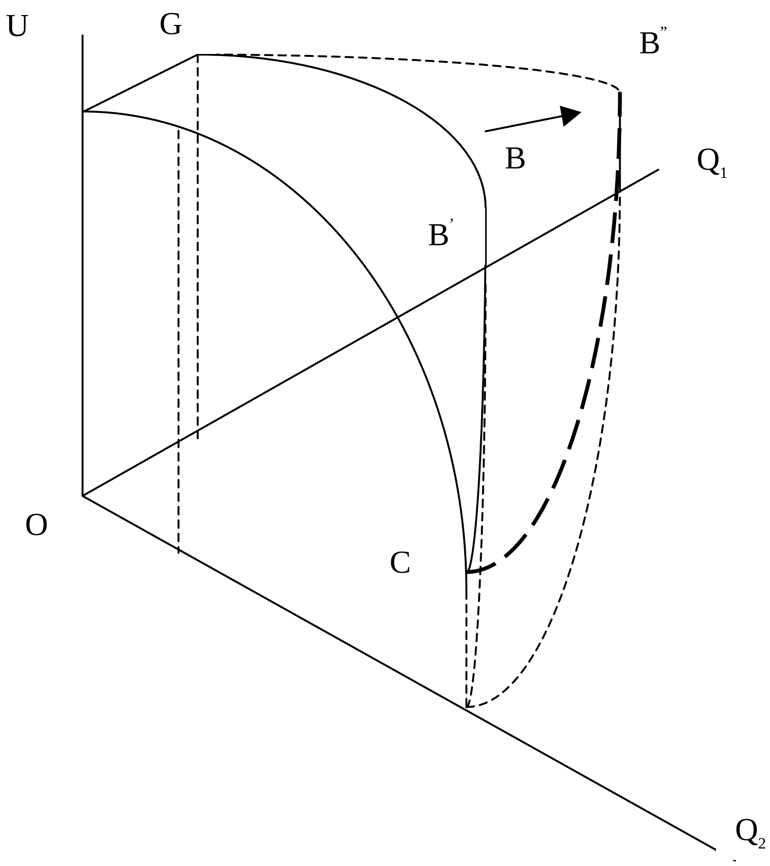


In figure 3.4 we assume that sector 1 represents the pollution-intensive industrial sectors discussed in chapter two (energy, steel, chemical). We also assume that sector 2 represents all other industrial sectors, and that it does not produce pollution to the extent that it causes negative environmental externalities. Point *C* represents the situation in which all resources are used in the production of commodity 2 and no environmental degradation occurs.

Some policy implications emerge from this inquiry. From both an environmental conservation and economic perspective, Siberia should focus on developing those industries which are not pollution intensive, which produce more efficiently vis-a-vis resource inputs, and which are more competitive globally. Coal, steel, petrochemical production, and energy need modernization and much investment before they can meet globally efficient and competitive standards. Given limited investment means in the current economic situation, Entrepreneurs and investors in Siberia may find quicker and richer payoffs in what we characterize here as “sector 2,” if other key assumptions hold.

Now we examine a case in which, due perhaps to technical progress in the production of commodity 1 leading to an abatement of emissions or to some other form of direct abatement activity in sector 1, the transformation space changes. In this case the curve *GB* shifts outward to GB''. This implies sector 1 is no longer pollution intensive, or that the economy has experienced an increase in resource endowments (which would cause the entire transformation space to shift outward). This analysis assumes (refer to (3.2)) that no negative externality exists.

Figure 3.5 Shift in transformation space due to technological change

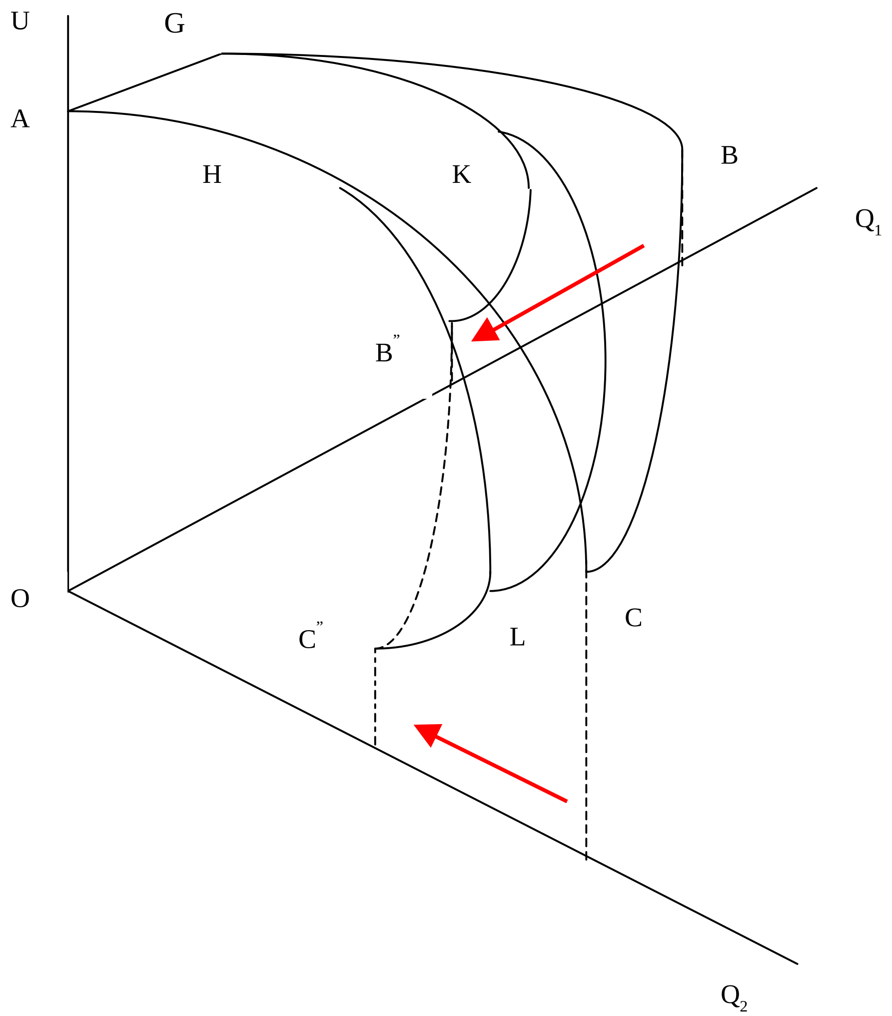


Now consider the implications of industrial output, which may cause the transformation space to contract rather than expand. Introduce negative externalities and begin to examine the effect upon the transformation space for Siberia when industrial activity can compromise environmental integrity *and* production itself. Figure 2.3, for example, illustrates the correlation between chronically polluted areas, tree die-back, and industrial production centers in Siberia. This led to the conclusion that industrial activity in Siberia reduces the output of at least one economic sector, forestry, by creating emissions that damage Siberian stands. With this conclusion we must now reformulate our production function from (3.2) in a way that shows the negative impact of polluting activities.

(3.8) $Q_i = F_i(R_i, S)$ with $F_{12} < 0, F_{122} < 0$

Here, output in a given sector is not only a function of the resource input but also of pollution supply. $FS < 0$ indicates that pollutants have a negative productivity effect. In addition, $F_{122} = dF/dS < 0$ says that the negative productivity will become smaller in absolute terms. If (3.8) holds for Siberia's economy, increased production means both a decline in the quality of the environment and an (eventual) reduction of output since pollutants will have a negative impact on output. Numerous empirical examples of this negative relationship confirm that (3.8) holds true for Siberia. Human health statistics for labor in Siberian industrial areas suggest not only a strong negative externality for labor and pollution, but also imply that labor as an input to Siberian industry is of lower quality and lower productivity when exposed to high levels of pollutants. With a larger stock of pollutants, the transformation space may contract (illustrated by curve GB'' in figure 3.6).

Figure 3.6 Transformation space with negative productivity effect



What could occur in Siberia if negative externalities did exist in relation to emissions? A negative productivity effect exists, and affects the transformation space. Assuming the production function presented in (3.8), the inverse defines the input requirements for production

(3.9) $R_i = \phi(Q_i, S)$

where the properties of the inverse are determined by the assumption on the production function. Substituting (3.9) into (3.1) and (3.3) through (3.6),

3.10) $U = G\left\{\sum H_i(Q_i) - F_3\left[\overline{R} - \sum \phi_i\left(Q_i, G^{-1}(U)\right)\right]\right\}$

implicitly defines a function between *U* and Q_i, or. the transformation space when negative productivity effect is present. From (3.10) we see the concavity of the transformation space with negative production effect looks like

(3.11) $\frac{\partial U}{\partial Q_i} \begin{smallmatrix}<\\>\end{smallmatrix} : \phi_{1S} + \phi_{2S} \begin{smallmatrix}<\\>\end{smallmatrix} \frac{1}{F_3'}$

where ϕ_{iS} indicates the inputs required to compensate for the effect of negative productivity caused by one unit of pollution, if output in sector *i* remains constant. The term ϕ_{1S} + ϕ_{2S} denotes total inputs required to maintain constant output in both sectors. From equation (3.11) we have

(3.12) $\frac{\partial U}{\partial Q_i} \begin{smallmatrix}<\\>\end{smallmatrix} 0 \Leftrightarrow \phi_{1S} + \phi_{2S} \begin{smallmatrix}<\\>\end{smallmatrix} \frac{1}{F_3'}$.

The right hand side of inequality (3.11) indicates resources used for abating one unit of pollution. If the inputs required to compensate for the negative productivity effect caused by one unit of emissions are smaller than those required for abating one unit of emissions, then curve *GKB''*, or $\frac{\partial U}{\partial Q_i} < 0$, figure 3.6 has a negative slope. Inversely, if more resources are needed in order to compensate for the negative productivity effect caused by one unit of pollution than those required for its abatement, curve *GKB''* will have a positive slope. When S rises, the absolute value of ϕ_S^i also rises. In addition, F_3' will fall and 1/ F_3' will rise. Note that $\frac{\partial U}{\partial Q_i} > 0$ holds true in section *C''B''KL*, meaning that environmental quality has positive opportunity costs. One can increase environmental quality and production at the same time. There is no tradeoff between environmental quality and private outputs within this space.

Compare the transformation space *AGB''C''H*, in which negative externalities in production exist (equation 3.8), with the case *AGBCH*, in which they do not exist (equation 3.2). One expects that negative externalities in production will shift the transformation space inward. Points *G* and *H* are identical in figures 3.3 and 3.6 since there is no negative productivity effect at maximal environmental quality. In addition, the transformation space may not be concave in the case of negative externalities. This may raise theoretical questions since one assumes concavity of the transformation space when analyzing the existence of equilibrium or the properties of optimality in a state of competitive equilibrium (Siebert 1998).

Properties of the transformation space are affected by the intensity of the negative productivity effects of pollutants. This is due both to the nature of various chemical compounds (illustrated by the risk-ranking employed previously) upon endpoints as well as the production structure of industries involved. For example, the agricultural sector will likely experience greater declines in productivity as pollution intensity increases than will the chemical industry, assuming that various forms of inorganic capital makes up a greater share of production output than labor. If the negative productivity effect is small or negligible, then the transformation space will not curve inward. If sector 1 is strongly affected by pollutants, then the inward bend will be stronger for sector 1 than for sector 2. With this relationship now made formal and illustrated through various examples from the preceding presentation of an air pollution database for the region, we now examine forms of ownership—public or private—which facilitate environmental improvement or degradation.

3.3 Defining use of the environment in Siberia

We have formally established the production possibilities for a simple model of the Siberian economy, incorporating the environment as a constraint to that production. The discussion now begins to examine the actual and possible assignment of environmental use in that economy. Russian policy makers have moved through two broad phases in their approach to assigning environmental allocation. The first, relatively unsuccessful approach (measured in terms of the magnitude of coinciding emissions-related environmental problems) involved government regulation of what was interpreted as a public goods problem, with a resulting false assignment of shadow prices and over-consumption of environmental goods and services. The second, still largely experimental approach has been introduced with other transition policies and has attempted to assign property rights and prices to environmental goods. A similar outcome mispricing and over-consumption occurs in this framework. During the middle and late decades of this century, command and control approaches have been the typical approach to controlling the kind of pollution manifest in Siberia (from large industrial sources) in OECD countries. Critics may ask why the Russian Federation would experiment with market-based abatement tools in the current period of extreme economic hardship and rapidly deteriorating environmental quality. However, several arguments present themselves to justify the current economic incentives approach:

- In Siberia, command and control approaches did not provide a source of revenue as market mechanisms supposedly do. Under the Soviet institutional constellation, command and control approaches proved administratively nontractable due to great distances, and limited government resources. These institutional aspects persevere into the current period with the emissions tax.

- Siberia had some of the highest air quality standards in the world prior to the transition, yet the command and control system in the USSR failed to achieve abatement due to the widespread understanding that offenders would not experience punishment and a general lack of direct accountability for environmental degradation.
- If Siberia develops economically along Western consumption patterns, the pollution profile may shift from large industrial sources, to multi-source pollution—harder to control through command and control mechanisms. Implementing economic tools for abatement now may lay the ground work for future pollution control through market forces. The most important variable is the degree to which firms would respond to such a tax.

It is unclear to what extent Russian policy makers employed theoretical criteria (compare for example (Mas-Holell 1995); (Rawls 1971); (Fisher 1981)) such as Koopman's efficiency, social welfare functions, or Pareto efficiency in their formulation of acceptable environmental use policy in the past or present. However, one can analyze the problem using various theoretical approaches. The private property and public good approach, although departing from different points, arrive at the conclusion that policy makers need assign some (effective) price to the environment's assimilation of emissions. The central problem of excluding consumers from the environment as a waste receptacle plays an important role in Siberia's allocation problem. The success of current and future abatement policy can, in light of this analysis, depend on the extent to which market or regulatory tools actually prohibit excessive environmental consumption.

3.3.1 Property rights

The first approach involves assigning and defining property rights for the use of the environment. By the early 1980s, the Soviet government had become increasingly involved in environmental monitoring and intervention, with meager success. In light of the current transition, administrative limitations noted elsewhere, and very few funds for environmental programs, the Russian Federation tried to tackle the problem of air pollution based on property rights and the use of the price mechanism to encourage abatement and raise revenue. This program will be discussed at length in the coming chapters. Here we discuss the general approach as it applies to Siberia.

Furubotn and Pejovich (Furubotn 1972) define property rights as a set of rules specifying the use of scarce resources and goods, in this case Siberia's environment and its waste assimilating capabilities. The set of rules includes obligations and rights, either codified in law or institutionalized through social norms or other mechanisms. Framing the environmental allocation problem of air pollution in Siberia using the property rights approach allows one to link economics (the pollution charge system as a market-based abatement tool) and the search to internalize the negative externalities revealed above. Prior to the last two decades, the concept of property rights in the Soviet Union was rarely employed in questions of allocations. Until the revelation of the catastrophic environmental conditions in many industrial centers in Siberia, the environment was assigned no property rights. Over-consumption and acute deterioration of the environment due to air pollution resulted. Markets did not fulfill the environmental allocation function under the centrally planned economy, and the resulting production structure remained distorted.[4] For decades the negative externalities of heavy metal emissions went unobserved. As the traumatic long-term health effects of exposure to impure air became evident, a correlation was drawn between faulty allocation of environmental goods, and the economic processes associated with pollution creation. Government institutions placed a low priority on pollution abatement and proved ineffective in the execution of strict air quality standards. By the late 1980s, regional and federal governments were prepared to experiment with a property rights approach, which assigned economic incentives for producers, who in turn were thought to find the optimal economic and environmental outcome.

This approach more clearly defined constraints for using the environment and attempted to change the common property characteristic of Siberia's ecosystems. The federal government attempted to prevent overuse of the environment at zero cost by introducing a scarcity cost. The method by which these prices were determined is discussed in the following chapter. Through this mechanism regional governments hoped both to generate revenue for other environmental programs (the central objective and principle weakness of the current pollution charge system) and transform the environment to a private good with a positive price and a new set of rules governing its use.

3.3.2 Public goods

Clearly the private property approach, while offering theoretical benefits, makes assumptions inappropriate for Siberia's current economic and environmental situation. We now turn attention to the public goods approach as an alternative to solving the environmental allocation problem. Under the central planned economy prior to transition, Siberian regional governments attempted to allocate environmental goods and services, viewing markets in general as inappropriate and adversarial to central government goals and objectives. This section looks at theoretical issues surrounding how a government determines desired environmental quality. The author outlines the actual development of this process, along with shadow prices and actual prices for emissions taxes, in chapters four and five.

[4] Some market-like environmental policies were implemented as early as the mid-1970s; however in the accountability-free framework of the Soviet industrial enterprise, these had very little effective value.

The discussion distinguishes between the cases of public and private goods. Table 3.1 summarizes the two key characteristics of these two types of goods: rivalry of use and excludability in property rights.

Table 3.1 Characteristics of Public and Private Goods

	Private good	Public good
Use of good	Rivalry in use $C^1+C^2+\ldots+C^n = Q$	Nonrivalry in use $U^1 = U^2 =\ldots=U^n = U$
Rights for good	Exclusive property rights	Nonexclusive property rights

Assuming that the environmental services of the various Siberian ecosystems are a public good, individuals and industry may take the position of free riders unwilling or not required to contribute to the costs of consumption. In the absence of a functioning market for the public good, the government must establish some sort of allocation mechanism for the environment to prevent excessive (environmentally degrading) free riding.

Environmental authorities then faced the task of assigning appropriate access to various consumers of the environmental good. Theoretically diverse methods present themselves for the appropriate analysis of this problem. Among others, policy makers can use social welfare functions in which environmental quality is included as an independent variable, determined by maximizing the social welfare function. Another more pragmatic approach involves a benefit cost study of environmental policy, which produces information to determine environmental quality. The Lindahl solution proposes that the government base target values on individual preferences and assign individualized prices for environmental quality (Lindalh 1919); (Head 1974). However, in a political economy of central planning, it is not surprising that the choice for environmental allocation fell to a series of environmental legislation from Moscow. The legislative acts formulated general rules for environmental exploitation, set environmental protection goals, and assigned the execution of environmental protection to various ministries and organizations.

The government, treating the environment as a public good, began by assigning standards and targets. This process established a value and penalty for the public good in the form of a shadow price. In accordance with the 1969 Public Health Act, the Ministry of Public Health was obliged to establish and adopt environmental quality standards. Current ambient standards (Ministers 1980) played a central role in the system of standards, which was based on maximum permissible concentrations (MPCs), of hazardous substances.

3.3.3 Shadow pricing and optimal environmental use

The Russian Government autonomously introduced value judgements to determine its desired set of industrial and environmental production levels. To arrive at a theoretical understanding of the process, we begin in the context of Pareto optimality with two entities (1, 2) whose utilities depend on the quantity consumed of two private goods and on the public good, environmental quality. We define environmental quality (U, where both entities experience nonexcludability and nonrivalry in consumption) as

(3.13) $$W^j = W^j\left(C_1^j, C_2^j, U\right).$$

Where variable C_i^j denotes the quantity of commodity *i* consumed by individual *j*. One could introduce other variables into the welfare function for Siberia; however, for simplicity, this model applies the Pareto criterion and attempts to maximize the utility of entity 1 without compromising that of 2 (see (3.12)). In addition, the transformation space (equations 3.1 through 3.6) imposes further constraints on utility maximization. Quantity demanded by entities 1 and 2 equals total demand

(3.14) $$C_i = \sum_j C_i^j .$$

And the total demand cannot exceed total output:

(3.15) $$C_i \le Q_i .$$

The problem then consists of maximizing the Lagrangean function

(3.16) $$\begin{aligned} L = {} & W^1\left(C_1^1, C_2^1, U\right) - \sum_i \lambda_{S_i^p}\left[H_i(Q_i) - S_i^p\right] - \sum_i \lambda_{Q_i}\left[Q_i - F_i(R_i)\right] \\ & - \sum_i \lambda_{S_i^r}\left[S_i^r - F_i^r\left(R_i^r\right)\right] - \lambda_S\left[\sum S_i^p - \sum S_i^r - S\right] - \lambda_U\left[U - G(S)\right] \\ & \lambda_R\left[\sum R_i + \sum R_i^r - \overline{R}\right] - \lambda^2\left[\overline{W^2} - W^2\left(C_1^2, C_2^2, U\right)\right] - \sum_i \lambda_i\left[\sum_j C_i^j - Q_i\right] \end{aligned} .$$

Several constraints define the transformation space in (3.16): the emission function, the production function, the abatement function, the diffusion function, the damage function, and the resource restraint. Additional assumptions required by these restraints include a constant utility for entity 1 and 2, the identity of total demand and the sum of individual demand, and the limitation of total demand to feasible output. The Kuhn-Tucker conditions for optimality for (3.16) are

(3.16a) $\frac{\partial L}{\partial C_i^1} = W_i^{1'} - \lambda_i \le 0 \qquad C_i^1 \ge 0 \qquad C_i^1 \frac{\partial L}{\partial C_i^1} = 0$

(3.16b) $\frac{\partial L}{\partial U} = W_U^{1'} - \lambda_U + \lambda^2 W_U^{2'} \le 0 \qquad U \ge 0 \qquad U \frac{\partial L}{\partial U} = 0$

(3.16c) $\frac{\partial L}{\partial R_i} = \lambda_{Q_i} F_i^{'} - \lambda_R \le 0 \qquad R_i \ge 0 \qquad R_i \frac{\partial L}{\partial R_i} = 0$

(3.16d) $\frac{\partial L}{\partial R_i^r} = \lambda_{S_i^r} F_i^{r'} - \lambda_R \le 0 \qquad R_i^r \ge 0 \qquad R_i^r \frac{\partial L}{\partial R_i^r} = 0$

(3.16e) $\frac{\partial L}{\partial S_i^p} = \lambda_{S_i^p} - \lambda_S \le 0 \qquad S_i^p \ge 0 \qquad S_i^p \frac{\partial L}{\partial S_i^p} = 0$

(3.16f) $\frac{\partial L}{\partial S_i^r} = -\lambda_{S_i^r} + \lambda_S \le 0 \qquad S_i^r \ge 0 \qquad S_i^r \frac{\partial L}{\partial S_i^r} = 0$

(3.16g) $\frac{\partial L}{\partial S} = \lambda_S + \lambda_U G^{'} \le 0 \qquad S \ge 0 \qquad S \frac{\partial L}{\partial S} = 0$

(3.16h) $\frac{\partial L}{\partial C_i^2} = \lambda^2 W_i^{2'} - \lambda_i \le 0 \qquad C_i^2 \ge 0 \qquad C_i \frac{\partial L}{\partial C_i^2} = 0$

(3.16i) $\frac{\partial L}{\partial Q_i} = \lambda_{S_i^p} H_i^{'} - \lambda_{Q_i} + \lambda_i \le 0 \qquad Q_i \ge 0 \qquad Q_i \frac{\partial L}{\partial Q_i} = 0$

(3.16j) $\frac{\partial L}{\partial \lambda} \ge 0 \qquad \lambda \ge 0 \qquad \lambda \frac{\partial L}{\partial \lambda} = 0$

3.4 Assigning an environmental price

One can now discuss the theoretical case for assigning shadow prices to pollutants, the basis for valuation of the environment as a public good. The evaluation of one unit of environmental quality results from the aggregation of individual utilities.

(3.17a) $\lambda_U = W_U^{1'} + \lambda^2 W_U^{2'}$.

Applying the Lindahl (Lindalh 1919) solution, which assumes the possibility of determining individual preferences for environmental value, from (3.13) we have the marginal evaluation of the environment by individual *j*, $W_U^{j'}\left(C_1^{j*}, C_2^{j*}, U^*\right)$. In the case in which a social welfare function is assumed in the maximization problem, we have $\lambda_U = W_U^{'}$; in other words social evaluation determines the shadow price of environmental quality:

(3.17b) $\lambda_S = \lambda_{S_i^p} = \lambda_{S_i^r} = -G^{'}\lambda_U$.

Using the simple diffusion function $\lambda_S \frac{\lambda_R}{F_i^{r'}}$, (3.17b) requires the same shadow price for pollutants ambient in the atmosphere, for emissions, and for abated emissions. The shadow price for emissions should be set equal to marginal abatement costs, $\frac{\lambda_R}{F_i^{r'}}$. The inverse function to the abatement function given in (3.3), $R_i^r = \phi_i\left(S_i^r\right)$, represents an input requirement function. The first derivative, $\frac{dR_i^r}{dS_i^r} = \frac{1}{\frac{dF_i^r}{dS_i^r}} = \frac{1}{F_i^{r'}}$, indicates the factor input necessary to reduce one unit of pollution. Multiplying this expression by the resource price, λ_R, gives us marginal abatement costs.

The shadow price of pollutants ambient in the environment, emissions, and abated emissions equals the physical marginal damage of one unit of the emission multiplied by the social evaluation of the environment. To meet the expectations of the model, Siberian policy makers must set the shadow price of emissions at a rate where, per unit, the tax equals the prevented marginal damage of that pollution. The actual setting of emissions tax levels only vaguely resembles this theoretic approach. As chapter four points out, an ad hoc approach to setting environmental prices is employed, based largely on industries' ability or willingness to pay fees in the transition period.

3.3.4 Establishing the shadow price

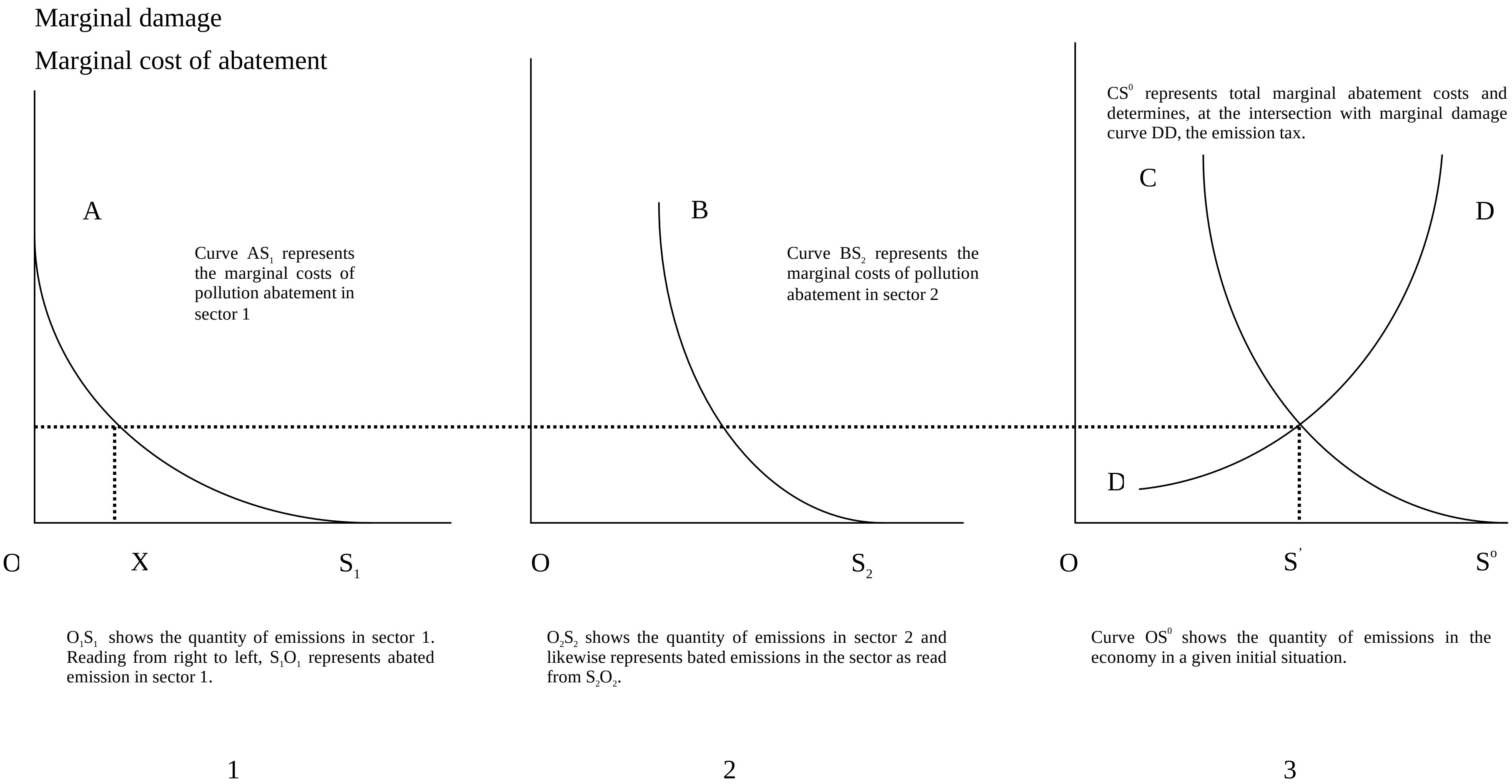
Two conditions for establishing the shadow price of one unit of emission now emerge, illustrated in figure 3.7. In panel 1, O_1S_1 denotes the quantity of emissions of sector 1, or the abated emissions after point S_1. Marginal costs of pollution abatement in sector 1 are represented by curve AS_1. With a concave abatement function, marginal costs of abatement rise progressively. One observes a similar pattern in panel 2 with the representation of emissions and abatement in sector 2, where BS_2 represent marginal abatement costs there. Aggregating both curves horizontally, CS^0 in panel 3 represents the curve of total marginal abatement costs with OS^0, denoting the quantity of emissions in the economy in the initial situation. Assuming λ_R is given, the emissions tax represented by curve CS^0 will shifts as resource prices change or as emissions output changes. In this case, λ_R represents the shadow price of the optimal solution.

Curve *DD* in panel 3 specifies the evaluated marginal environmental damage of emissions. Marginal damage increases progressively ((3.5) gives a damage function) at a constant λ_U with increasing emissions. Reading the curve from S_0 to O, the curve represents the prevented marginal damage. We assume that λ_U represents the optimal shadow price.

If the shadow price of emissions is appropriately set in Siberia, we expect prevented marginal damage and the marginal costs of abatement should equal each other. Now, OT is the optimal level of shadow price for emissions, $S^0S^'$ is the quantity of the desired abatement, and $OS^'$ is the quantity of emissions tolerated. Figure 3.7 shows the tradeoff between the improvement of the environmental quality and the costs connected with it. If one intends to improve environmental quality by increased pollution abatement, the abatement costs will rise. In this model resources have to be devoted to abatement and withdrawn from production activities. The opportunity costs of a better environment thus consist of the forgone resources in production. We earlier established that $\frac{\partial U}{\partial Q_i} < 0$.

This implies that there are opportunity costs of abatement in terms of production and, likewise, a tradeoff between industrial activity in terms of environmental quality. The economic presentation in panel 3 suggests that scarcity prices will address the environmental problems in an economy. The price for environmental use is determined by the intersection of marginal benefits and marginal costs associated with environmental quality.

Figure 3.7 Determination of an emission tax



The simplified diffusion function expresses costs of environmental policy in terms of the opportunity cost of resources in production. Environmental policy may negatively affect variables such as full employment, price-level stability, balance-of-payments equilibrium, or equity, which can play a role in individual functions. In such instances, curve *DD* shifts downward as prevented damage of abatement declines. If there are additional costs of environmental quality, more pollutants will be tolerated. This implies less restrictive abatement targets and lower scarcity prices for pollution.

3.3.2 Shadow prices and the regional economy

Setting a price for emissions will affect the economy's price system. Equation (3.17c) indicates the implications of a scarcity price for the environment on the price vector of an economy

(3.17c) $$\lambda_i = W_i^{1'} = \lambda^2 W_i^{2'} .$$

The Lagrangean multiplier λ_i denotes the shadow price of commodities from the consumers' point of view. Note that λ^2 is a multiplier that allows us to transform one unit of utility of individual 1 to one unit of utility of individual 2.

(3.17d) $$\frac{\lambda_1}{\lambda_2} = \frac{W_1^{1'}}{W_2^{1'}} = \frac{W_1^{2'}}{W_2^{2'}} .$$

The relative shadow price of the two commodities corresponds to the relation of their marginal utilities for each individual. The relative utilities among individuals, then, equal each other, a standard result from consumer theory. While the formal conditions for the household optimum do not change when a zero shadow price is assumed for the environment, the shadow price of the pollution intensive commodity may lower consumption there.

(3.17d) $$\lambda_{Qi} = W_i^{1'} - \lambda_{S_i^P} H_i^{'} = \lambda^2 W_i^{2'} - \lambda_{S_i^P} H_i^{'} .$$

λ_{Qi} indicates the shadow price for producers and is determined by consumer evaluation minus the social costs of production (expressed as pollution per unit of output $H_i^{'}$ and the pollution shadow price). Equation (3.17d) corrects incentives for producers, as the net price and hence production of the pollution-intensive commodity declines.

(3.17e) $$\frac{\lambda_{Q1}}{\lambda_{Q2}} = \frac{W_1^{1'} - H_1^{'}\lambda_S}{W_2^{1'} - H_2^{'}\lambda_S} = \frac{\lambda^2 W_1^{2'} - H_1^{'}\lambda_S}{\lambda^2 W_2^{2'} - H_2^{'}\lambda_S}.$$

If $\lambda_S = 0$ (no scarcity price for environment), according to the above analysis, not all social costs of production are attributed to individual producers, and relative prices are distorted for producers. A shadow price exists for emissions thus changes relative prices. Assuming commodity 1 to be pollution-intensive, or $H_1^{'}F_1^{'} > H_2^{'}F_2^{'}$, under a given environmental policy which establishes a shadow price, the relative price will change in favor of commodity 2, the non-pollution intensive good. Environmental policy such as Siberia's emissions charge will affect pollution-intensive producers.

(3.17f) $$\lambda_R = \lambda_{Qi} F_i^{'}.$$

The resource must be used in private production in such a way that the resource price equals marginal value product (the marginal productivity of the resource multiplied by the shadow price of the commodity). Rewriting (3.17f) as $\lambda_{Qi} = \frac{\lambda_R}{F_i^{'}}$ indicates that for proper incentives and environmental allocation, marginal production costs should equal the shadow price. Chapter five will point out that this is one of the central weaknesses of the current emissions charge system in Siberia. The inverse to the production function is the input requirement function $R_1 = F_i^{-1}(Q_i)$. The first derivative of this function, $\frac{dR_i}{dQ_i} = \frac{1}{F_i^{'}}$, gives the marginal production costs of the commodity, if the resource input for one additional unit of output is multiplied by the resource price. Conditions expressed in equations (3.17d) through (3.17f) require the net price to equal consumers' marginal evaluation minus the social costs of production.

3.5 Conclusions

This chapter has laid out the theoretical underpinnings for the discussion of Siberia's emissions tax policy. It first reviewed the assumptions of the air pollution policy, and noted that Siberia provides a context in which some of the most important institutional and economic aspects did not conform to theory. Imperfect market structures, weak environmental institutions, and an ability for firms to operate in informal markets where official taxes do not apply suggest that the following practical discussion of Siberia's pollution charge will not produce optimal results. The author sought, using a model following Siebert (1998) to establish the formal relationship between production possibilities of an economy, emissions levels, and impacts on industrial performance. Emissions produce negative externalities that both compromise environmental quality, and may impair the ability of enterprise to produce products efficiently. The author discussed the allocation of property rights and found that—while in theory a private allocation of property rights may achieve efficient results—in practice the government in Russia has still set standards and pollution charge levels to induce firms not to over-pollute. In spite of theories of shadow pricing and social welfare, the following chapters reveal an *ad hoc* approach to both setting tax levels and to achieving compliance. The difference between the important theoretical and practical variables for the success of market-based abatement policies becomes striking.

The presentation of this theory and model has provided a useful measure against which one can compare Siberia's regional air pollution policy. What becomes clear about the process is just how far from economic theory the implementation of the market based abatement instruments remains in the region. Siberia is characterized by high participation rates in barter and other forms of informal market activity, which severely limits the usefulness of a market based abatement tool. Nevertheless, the model presented here has pointed out some general rules by which even Siberia is likely to abide. As pollution levels, with associated negative externalities, persist or increase, industrial output will decline or become less efficient. This has already been observed empirically, as deteriorating worker health (due in significant part to pollution exposure) lowers output per worker in the most polluted Siberian industrial areas. As this chapter has attempted to point out, introducing a market-oriented institutional framework and a policy which assigns the costs of economic activities to individual units might appropriately solve the allocation problem (through abatement, investment incentives, and decreased pollution intensity). However, further scrutiny of Siberian markets and its institutions reveal significant obstacles for the pollution charge system to raise both revenue for other environmental programs and to provide incentives for enterprises to devote resources to pollution abatement. The following chapters add insight into the organization of the pollution charge system, and the two major issues involved in emissions tax implementation: evaluating the variables which most affect firm behavior and response to the emissions tax. Chapter five evaluates whether the major focus of the literature--the setting of tax levels to induce abatement—bears much weight in the Siberian framework, and evaluates noncompliance with the emissions tax.

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Chapter 4: Outline of Siberia's environmental tax program

4.0 Introduction

Compared with command and control methods, emissions taxes may in theory reduce the static costs of achieving abatement (Tietenberg 1992). An efficient pollution abatement policy reflects the individual differences in abatement costs and concentrates pollution reduction in least-cost sectors. In perfect markets, emissions taxes are more likely to achieve an efficient allocation of pollution abatement across polluters than a regulation-based policy (Atkinson 1974); (Seskin 1983). In addition to the static cost-minimization properties of the emissions tax, environmental market tools may also provide a dynamic incentive for the development of cost-effective methods of pollution control. In competitive markets, emission taxes provide an incentive to search for technological innovations that will reduce the optimal level of emissions (Wenders 1975); (Magat 1978); (Milliman 1989). *Ceteris paribus*, emissions taxes give a greater incentive for such innovations than command and control methods which only provide incentives for minimum compliance levels (Smith 1992). However, all things are not equal in Siberia's markets. For this reason, the functioning of the flawed emissions charge system may not achieve abatement levels better than regulatory approaches.

Moving from theory to practice reveals both the characteristics of Siberia's particular economic and institutional situation, as well as the limitations of implementing emissions charge systems to achieve improved environmental quality and revenue collection for negative externalities. The present chapter examines the development and implementation of the current system of pollution charges in Siberia. Section 4.1 sketches the current program, the context of its historical context of this development, and the development of environmental quality standards. Section 4.2 reviews the principle institutions for air pollution control in the region. This discussion helps fill a gap in understanding about the application of pollution charge policies in the Siberian context, and discusses some of the important impediments for an ecotax in a transitional region. As this chapter and the following two point out, institutional aspects appear to bear more weight in the outcome of the program in terms of revenue and collection and abatement than do tax levels or firm market or ownership structure, the standard foci of environmental economic theory. Section 4.3 outlines the emissions charge program goals, and describes the conflict between those goals. An evaluation of the outcome so far reveals that neither revenue nor abatement targets have been achieved in Siberia. The chapter concludes with a brief summary of the salient issues in Siberia's transitional economy as they differ from the economic theory presented in chapter three.

4.1 Emissions charge program

A description of Siberia's pollution charge system provides interesting information about the emergence of a market-based approach to air pollution abatement in what was a centrally controlled economy. While the general approach to environmental problems emerging in the decades after massive industrialization in Siberia followed a command-and-control format, market forces quickly came under serious discussion. Ambitious, even competitive ambient air quality standards were adopted (although the actual achievement of these is dubious, based on long-term human health indicators) and the Siberian region embraced plans towards air pollution abatement whose final result is the current pollution charge system.

4.1.1 Historical development of market-based environmental policy

Between 1964 and 1980 federal authorities enacted a series of legislative acts on environmental protection and the use of natural resources. Regulatory approaches dominated this period of environmental policy making. As early as the 1970s, environmental discussions began focusing on pollution charges. The system was favored for its theoretical ability to achieve multiple objectives such as raising federal and regional revenues, reducing pollution to target levels, and possibly lower administrative costs. Soviet researchers spent a large part of the 1980s studying the costs and benefits of alternative approaches; apparently as greater information about the nature and extent of air pollution damage became available, understanding alternate solutions for setting and reaching environmental goals also evolved. By the mid-1980s public protest of several environmental disasters combined with scientific research gave the necessary momentum to a radical implementation of the emissions tax system.

Under the duress of a collapsing macroeconomy and increasing international attention on the USSR's monumental environmental problems, experiments were introduced in 1989 and 1990 in pilot projects to test the feasibility of pollution charges. A general faith in the virtues of market orientation apparently led environmental authorities to place their trust in market-based instruments to achieve abatement and emissions stabilization. With the 1992 Environment Protection Act, the Russian Federation introduced economic tools into its environmental management plans. Pollution charges were chosen for their ability to raise revenue for environmental projects in a severely strained budget and also to compensate victims of environmental accidents. This step marked the beginning of an experiment of implementing a market-oriented tool into a regulatory framework of standards and permits.

The emissions charge system in Siberia evolved from Soviet-era predecessors and, as noted by Kozeltov and Markandya (Kozeltzev 1997) one of the key contributions to the scientific discussion might prove to be that both regulatory and market-oriented instruments have been simultaneously applied to reach abatement goals. While theoretical discussion often separate the two approaches, scholars increasingly realize the existence and possible necessity of complementary approaches. As Hahn (Hahn 1989) points out: "An examination of charge…schemes reveals that they are rarely, if ever, introduced in their textbook form. Virtually all environmental regulatory systems using charges…rely on the existing permitting systems. This result should not be terribly surprising. Most of these approaches were not implemented from scratch; rather, they were grafted onto regulatory systems in which permits and standards play a dominant role."

The current system evolved from an imperfect regulatory framework based on environmental performance standards. It continues to operate inefficiently and unlike theory would predict. Although the coexistence of standards and permits and emissions charges could complement one another to reach environmental and other goals, several key variables prevent the successful implementation of the program.

4.1.2 Development of environmental quality standards

The Public Health Act of 1969 obliged the Ministry of Health to work out and adopt environmental quality standards. Current ambient standards (Ministers 1980) played a central role in the system, based on maximum permissible concentrations (MPCs) of toxic emissions in the environment (defined for air, soils, and water). Through the years, various federal ministries bore the responsibility of setting environmental standards. The Ministry of the Environment, with regional branches in Siberia, is responsible for identifying and setting ambient air quality standards, called maximum allowable concentrations (MACs)[1].

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[1] The Ministry of the Environment assigns its lead branch institute of each polluting sector to coordinate with the regional environmental authority in its estimates of ambient air quality concentrations of an inventory of toxins. These calculations are made using mathematical models called "Zephyr 6" and

Table 4.1 Emission standard levels for Russian Pollution Charge System			
	Description	**Standard**	**Fine**
MAC	Ambient air quality standards which define allowable atmospheric concentrations for a given substance which cause no immediate harm or long term negative health effects in humans.	Human health-based limits,	No fine
MPL	Enterprise-unique legal standards outlined by the Law of the Russian Federation on Atmospheric Air Protection (1982) which guaranteed that emissions from all pollution sources would not exceed MACs for each substance.	Industry-specific pollution limits	Within MPL substance-dependent fee, above MPL 5 times that rate
TSP	Temporary (five to ten years) compliance levels of pollution, agreed upon by polluters and regional environmental authorities based more upon industry's ability to pay than environmental standards or criteria.	Negotiated pollution limits	25 times rate for MPL
Source: (Danilov-Danilyan 1990)			

This system involves different levels, but the maximum allowable concentrations (MACs), ambient air quality standards for toxic substances in the atmosphere, provide the standard of measurement.

Table 4.2 Russian maximum permissible concentration standards for urban areas (mg/m^3)		
Substance	**Annual maximum**	**Daily average**
SO_2	0.50	0.05
CI	0.10	0.03
Hydrogen sulfide	0.008	0.003
CO	6.01	2.01
NO_x	0.30	0.1
Phenol	0.30	0.01
Lead	--	0.0007
Mercury	--	0.0003
Arsenic	0.30	0.01
Nontoxic dust	0.50	0.15
Source: (Golub 1994a)		

"Warrant," developed by the former Soviet State Hydrometeorological Committee. In the event that these calculations show estimates of concentrations exceeding an MAC, then each enterprise involved prepares a list of activities to abate emissions and the procedure is repeated with new levels of emissions. Adjustments in planned activities (rather than executed actions) continue until estimated concentrations for each substance equal or are less than the MAC. The final product is an MPL for each enterprise and each chemical substance.

Introduced in 1969, MAC standards complied with medical requirements and were strict by all international standards. The MAC for SO_2, for example, according to Goskomstat is 0.05 mg/m^3, as compared to 0.26 in the US. Other Russian standards are summarized in table 4.2.

Although some Russian air quality standards exceeded even WHO ambient air quality standards, MAC compliance remains quite low. Real concentrations of harmful substances exceed MACs significantly in Siberia's delicate ecosystems. Table 4.3 shows the exceedance of these standards in Siberian cities. One of the outcomes of setting such strict limits for pollution is high noncompliance levels, particularly in Siberia's impossible-to-monitor environment and weak institutional framework. Enterprises in the pre-transition period regularly exceeded permissible levels and consistent and accurate reporting of emissions, or the payment of required emissions charges were not enforced as a rule.

The State Hydro-Meteorological Committee and the Ministry of Public Health also defined maximum permissible levels of emissions (MPLs) for stationary pollution sources. These form the foundation of the pollution charge system and set limits for industrial pollution. However, the calculation of MPLs does not account for background levels of pollution, emissions diffusion patterns, or the total amount of emissions from other industrial enterprises. These standards established maximum values for one-time concentrations and daily average concentrations. Air quality standards are divided into two categories, one set for residential areas and one for industrial areas. The settlement and industrialization patterns in Siberia nullify the importance of this division, however, since populations overwhelmingly live in industrial towns and because housing, schools, hospitals and other facilities are usually located in the near vicinity of polluters.

MPLs are difficult to enforce because according to legislation, maximum allowed emissions are established for each source of emissions (each stack in each industrial complex). Massive production facilities in towns such as Krasnoyarsk or Bratsk have literally hundreds of stacks, and the standards are theoretically set for each pipe. Monitoring becomes an administratively complex task, as does collection of taxes due from each of these stack emissions sources. Limited use of the bubble principle has improved the situation, but an unwieldy and complicated pollution charge system favors enterprises and they benefit under the claim that they cannot accurately report to the regional environmental authorities the emissions from each stack in a factory.

Many companies in Siberia are not able to achieve MPL emissions levels; therefore, following the introduction of MACs and MPLs, temporary emission standards (TSP) were introduced. These standards are based primarily on the ability of an industry to meet ambient air quality standards. They have significantly higher thresholds and constrain firms much less than the standards based on human exposure. Many industries continually receive short term TSPs, an aspect of the pollution charge system which in essence prevents market incentives from taking effect. Industry apparently abides by the very lenient TSP guidelines rather than MPLs, an aspect reflected in the following chart of air quality standards in Siberian towns. Due to the significant drop in production (and hence emissions) levels, almost all Siberian companies fall within the generous temporary emissions standards.

4.1.3 Setting pollution charge rates

In 1991 emissions charges were added to the system of setting ambient air quality standards. Charges became the main element of environmental management in Siberia. State authorities fixed the charge rates (Resolution of the Russian Federation Council of Ministers, January 9, 1991) per unit of emissions of toxic compounds. Although the standards part of the air pollution policy has three tiers—human exposure and air concentration limits, absolute limits for emissions based on human health, and a much higher "emergency" level for industries in economic distress—the charge system currently has only two tiers. The first level of charges are levied on all target pollutants within the appropriate MPL, the second for emissions exceeding MPL. Penalty fees for emissions above MPL for each substance exceed the base charge by five times. Emissions taxes are collected for the approximately 100 pollutants, listed in the Siberian Pollution Database. Table 4.4 exemplifies the emissions tax rates for a handful of chemicals and indicates a dramatic drop in charge rates from 1991 to 1996.

Table 4.3 Number of times MPLs are exceeded in Siberian cities in 1989, annual and single concentrations.

City	NO_2	NH_3	Benza-pirene	Formalde hyde	Dust	SO_2	CO	H_2S	HCI	Phenol	CS_2	Methythiol
West Siberia												
Barnaul	- / 9		3 / 8	2 / 4	1 / 14		- / 6	- / 10		- / 3	- / 4	
Kemerovo	- / 12	3 / 27	4 / 12	5 / 11	- / 8		- / 8		- / 12		- / 8	
Novokuznetsk	- / 15	- / 10	10 / 35	12 / -	2 / 7					- / 39		
Novosibirsk	- / 10	- / 6	4 / 10	4 / 4	- / 10		- / 4			- / 4		
Omsk	- / 21	5 / 30	2 / 6	5 / -	- / 17							
Prokopievsk	- / 8		6 / 24	2 / 8	2 / 8	- / 2		- / 8				
Tomsk	- / 10	2 / 6	3 / 9	2 / -	1.5 / 8		- / 4		- / 6			
East Siberia												
Abakan	- / 3		10 / 29		1 / 3							
Achinsk	- / 8		3 / 7		4 / 8							
Baikalsk	-										3 / 6	22 / 84
Bratsk*	1 / 28		17 / 124		- / 7		- / 14		- / 2(CI)	- / 4	4 / 7	12 / -
Chita	2 / 6		15 / 73	2 / -	2 / 6		- / 7			2 / 3		
Irkutsk	1.3 / 3		11 / 28	4 / 6	12 / -		12 / 8			- / 3		
Kansk			12 / 40		- / 3							
Krasnoyarsk*	- / 15		6 / 22	- / 4	3 / 10						- / 5	
Nazarovo	- / 23		3 / 8				- / 2			- / 4		
Norilsk	- / 15				- / 9	2 / 72	- / 9		- / 5 (CI)	4 / 49		
Selengingsk	- / 4		7 / 19	3 / -			- / 4				3 / -	8 / 30
Shelekhov	- / 4		12 / 36		- / 2		1 / 8					
Ulan-Ude	2 / 3		13 / 37	2 / -	2 / 11		- / 6			2 / -		
Usolie-Sibirskoye	2 / 9		4 / 17	4 / 4	2 / 4		- / 4					
Zima	- / 8		22 / 64		- / 4				- / 4 (CI)			

Table 4.3 continued.

City	NO_2	NH_3	Benza-pirene	Formaldehyde	Dust	SO_2	CO	H_2S	HCI	Phenol	CS_2	Methythiol
Far East												
Amursk	- / 4				- / 4			- / 4				12 / 69
Khabarovsk	- / 28	3 / 10	6 / 14	6 / 5	3 /17					3 / 19		
Komsomolsk	6 / 13	- / 10	6 / 30	6 / 5	6 / 22	6 / 13				- / 5		
Magadan	1 / 4		4 / -	4 / -	3 / 5		- / 4					
Vladivostok	2 / 9		3 / 20		2 / 5		- / 5					
Yuzhno-Sakhalinsk	1 / 8		9 / 20		1 / 14		- / 6					

Note: The figure preceding the slash represents reported annual average concentrations of the given pollutant while the figure proceeding the slash represent reported maximum single concentrations.

*Concentrations of flourides exceeding allowable levels reported for Bratsk and Krasnoyarsk.

Source: (Kiseleva 1996). Data obtained from (Mnatsakanian 1992).

Table 4.4 Pollution tax rates for Russian emissions in 1991 and 1996 (per ton)						
Pollutant	**Base rate (within MPL)**			**Penalty rate (exceeding MPL)**		
	Ruble(thousands) 1996	1991	US$ (PPP ex.rate)	Ruble(thousands) 1996	1991	US$ (PPP ex.rate)
SO_2	11.5	66	2.9	57.7	316	14.8
Dust and particulates	11.6	22	3.0	57.8	105.4	14.8
Lead	1925	11,000	494	9625	52,66.1	2468
NO_x	14.5	55.01	3.0	72.6	263.4	18.6
Source: (Ministers 1991).						

In the early part of 1993, irregular indexation to inflation levels of emissions taxes was implemented. Charges for emissions within MPLs were increased by five times, while those for emissions exceeding MPLs but within TSP limits were increased by 25 times.

The inclusion of lead in the above table illustrates that "shadow prices" for Siberian pollutants have to a certain degree been calculated according to toxicity of the compound in question. However, the setting of emissions taxes has taken on a generally *ad hoc* nature in Siberia, designed less to cover environmental and social costs and more to meet industrial constraints. For the Russian system, fees were first calculated according to (4.1) incorporating damage estimates, geographic considerations, and volume of emissions:

(4.1) $u = v * G * M$ where

u = damage estimate

v = monetary assessment of the damage caused by 1 ton of conventional aggregated emissions

M = total volume of aggregated emissions

G = environmental coefficient to account for particular features of the region

The total volume of aggregated emissions M depended upon a risk-weighting coefficient:

(4.2) $M = A_1 * m_1 + A_2 * m_2 + \ldots + A_i * m_i$, where

M_i, = total volume of emissions i

A_i = coefficient of the relative danger of substance i (using RfD values for the chemicals identified in the Siberian pollution database

Officials aggregated various harmful substances and discounted them to conventional types of emissions by using a risk weight (coefficient A). Federal environmental committees elaborated special rules to help regional authorities calculate rates of fees (Gofman 1986).

The collection of fees calculated on the basis of this method presented many problems. None of the cities in which this method of fee calculation was implemented actually correlated charge levels with the estimated *value* of environmental damage. Enterprises were unable or unwilling to pay the estimated sums. Thus, a second method for calculating fees was proposed. The regional Environmental Protection Committees defined the level of expenditures necessary to achieve the aims of the regional pollution control program (K). Then they used the formula to calculate payment for each polluting industry as a share of the total abatement costs.

(4.3)
$$P = \left(\frac{M_j}{M}\right)K ,$$
where

P = emission fee

M = total volume of emissions

M_j = emissions of polluter j;

$\frac{M_j}{M}$ = share of enterprise j in the total volume of emissions

The payments calculated using equation (4.3) were 10 to 15 times lower than the level of incurred damage, calculated using the first method. For example, the fuel industry paid approximately 81.3 billion rubles in emissions charges in 1995. However, human health costs associated with fuel industry emissions fall roughly in the range of 9.2 to 12.3 individuals per thousand in Siberia dying from cardiovascular and respiratory diseases, for which air pollution is one of the main causes of death ((Larson 1998) describe the methodology used to arrive at this figure). Although it is difficult to assign value to human life, an investment of this magnitude would cover only a small fraction of social costs associated with pollution damage. This implies a significant departure from the theory that polluters should pay for the damage incurred by their actions, and indicates in addition that even too-low emissions charges were underpaid.

4.2 Institutional aspects of Siberian air pollution policy

A discussion of key institutions in Siberia’s emissions charge system shows the interesting dynamics of pollution control in the region. A general understanding of Soviet environmental and industrial policy guides the discussion. However, specific

Siberian characteristics, particularly the view of the region as the resource "treasure chest" of the union, intensify these basic institutional codes. The central informal rule shaping the development and subsequent environmental degradation of areas of Siberia, what the World Bank termed the "legacy of overuse" (WorldBank 1996) was the perception of unlimited, inexhaustible natural resources there, for the sole purpose of the Soviet Union's industrial "leap forward". The Soviet goal to industrialize and mobilize the vast natural resources of Siberia shaped the actual institutionalization of industrial output and environmental performance (Jensen 1983). Important facets from the tax policy, central planning apparatus, and resource management to input prices (or lack thereof), employment structure, and pattern of industrial monopolies permeates the region's approach to environmental protection (Huzinec 1983).

Siberia shares the institutional heritage of the Soviet Union with its European Russian compatriots. However, as the resource for industrial development (particularly for energy, basic industrial inputs such as coal and minerals, forestry and agricultural products) Siberia bears special marks of Soviet institutions, which in turn have particular implications for the implementation of a nationwide abatement policy. In addition, Siberia stands out as an enormous, sparsely populated region—issues important later when we discuss the possibility of gaining a double dividend from an emissions tax. Perhaps slightly more than European Russia, Siberia's economy centers upon a handful of monolithic industrial towns where pollution is also most heavily concentrated, and where environmental policy may be more easily brushed aside than in Europe due to Siberia's resource-based economy and the lack of effective monitoring (Mote 1983). The level of damage incurred due to air pollution, in terms of human health, is also more severe in Siberia, which manifests some of the lowest average life expectancies in the Russian Federation (Bridges 1996). Kemerovo, which is by Siberian standards moderately polluted city, exceeded Russian ambient air quality standards by hundreds of times. Area coal miners, for example, have an average life expectancy of 48 years, reaching only three-fourths of an already dropping Russian life expectancy (*ibid*.). Also unique to Siberia is the economic and political strength on a nationwide basis of some of its most polluting enterprises, particularly fuel-related ones.

4.2.1 Institutional framework for emissions charges

Although Soviet environmental law provided the legal basis for strict monitoring, enforcement, and valuation of damages, the implementation of those laws through a conflicting institutional framework severely impeded effective regulation. Although market conditions have changed dramatically since this period, many of the institutional characteristics remain, with expected negative consequences for the emissions tax. A few of those qualities that persist include a division of policy implementation across ministries and administrative levels. Local jealousies and federal politics may interfere with the correct functioning of the program. The collection and analysis of data are separated from enforcement. Until the establishment of the State Committee for Environmental Protection (Goskompriroda 1992), much of the collected data remained confidential.

In 1988 Goskompriroda was created and “given broad powers over ministries in coordinating environmental management, issuing waste disposal permits, halting operations that violate norms, suing polluters” (*Pravda*, Jan. 17, 1988, p1). It established a network of regional offices, in part by absorbing regional offices from other state ministries (Forestry, Fisheries, Hydrometeorology, Gasogroprom, and Minvodkhoz), an organization which created conflicts of interest and mistrust. The newly established institution experienced an immediate conflict with the already-existing Gidromet, which long had the authority to monitor air pollution. This body was transformed in 1993 into the Ministry of Ecology and Natural Resources with an even wider range of functions it was often ill-equipped to handle. For example, in spite of the 1993 constitution’s guarantee of the people’s right to clean air, to accurate information regarding air pollution, and to compensation for damage incurred from polluted air, Ministry actions against major polluters remained infrequent. In 1995 Danilov-Danil’yan (Danilov-Danil'ian 1993) reported that only 22 cases had been brought against alleged polluters in the prior year. With such an extensive agenda, however, the body was not granted in terms of funding, authority, and personnel to successfully carry out the environmental plans earlier specified. Nevertheless, it is this body in Siberia which provides the official framework for environmental issues, particularly the implementation of emissions charges in Siberia.

The institution oversees the distribution of environmental tax revenues at various administrative levels. Authorities at the federal level make initial decisions about abatement goals and persecute violators. However, implementation and interpretation of these goals and programs goes increasingly to regional and local authorities. This has important implications for the outcome of Siberia’s emissions tax policy. The structure of incentives and motivations changes somewhat for regional authorities operating with Siberia’s imperfect markets. Inspectors are often ill-trained and too few in number to effectively monitor firms. Regional and local authorities often “look the other way” when Siberian enterprises flagrantly pollute. Sectors favored by local governments for their goods and services (such as public utilities, energy producers, major employers) may also use the opportunity to seek rents. In this way they may persuade local and regional officials to excuse tax nonpayment, prevent monitoring of a violating firm, or absolve the firms involved from investing in relatively expensive new technology or production techniques favoring the environment (Migue 1993).

In the transition period, greater responsibility has been given to regional and local authorities in abatement activities. In the current period, regional and local authorities are vested with the responsibility to inspect, monitor, and collect emissions charges from polluters under their jurisdiction. Regional authorities can adjust the fees with “correcting coefficients” according to local conditions, both economic and ecological. At least in theory, regional environmental authorities will have better information and overview about tax collection and expenditures. Some benefits are associated with this institutional set-up. With the emergence of a market economy and the disintegration of former funding systems, air pollution tax revenues can be used for public sector abatement expenditures. In addition, revenues fund abatement efforts for enterprises which could not finance such schemes alone. Regional authorities are assumed to also have the ability to better monitor and enforce standards and tax collection. In reality, however, the institutional strength of this ministry and its local branches is difficult to gauge, relative to industrial strength of polluters and historical institutional priorities (of which the environment was not one). Even regional environmental bodies are not likely to carry much real power in Siberia.

4.2.2 Institutional challenges for the emissions tax

While economic impediments clearly pose challenges for the successful implementation of the emissions charge program, institutional factors appear to play at least as large a role. The below discussion briefly characterizes five of the most important institutional challenges for the emissions tax: the outdated industrial structure in the region, conflicting regional and federal jurisdictions, asymmetric information regarding abatement alternatives and firm costs, the privatization program, and soft budget constraints. The importance of these variables becomes more clear in chapter six as indications of how near or far the economy has moved towards formal market restructuring.

Industrial structure. The concentration of Siberian industry provides advantages and disadvantages for an emissions charge. It is relatively easy to identify the major stationary polluters in any given area and theoretically easy to target these enterprises for emissions taxes. However, these industries may react to market forces more slowly and, due to historical economic importance, may not die after subsequent periods of negative profits. It may prove difficult to impose additional costs on these firms due to social concerns. An analysis of Siberian cities showed that a few industries tend to dominate, narrowing the economic bases, employment opportunities, and increasing economic vulnerability in these areas significantly (Maley 1995). The monopoly power of a few large firms reduces the ability of environmental authorities to impose additional burdens which might cause firms to layoff workers or cut back on goods and services such as housing so vital to the Siberian population.

These firms still bear many characteristics of state-owned enterprises in terms of slack managerial style and inefficiency of operation and resource use. Siberian firms in particular typically operate inefficiently. Another key feature of many industries in the Siberian region is their age. Since forced, rapid industrialization of the economy under Lenin and particularly Stalin, some industries (particularly textiles, food industries and agriculture) have continued using antiquated technologies and capital equipment. Aging machinery is not only inefficient but also tends to have much lower performance standards in terms of air pollution, in addition to posing dangers for accidents. In what one author called an "unstable technological regime," (Kozeltsev 1993) geriatric production methods and little investment in abatement technology are typical for Siberian industry.

Conflicting regional jurisdictions and levels of power. The emissions charge becomes further bogged down in a labyrinth of federal and regional administrative structures. In

1994 the Ministry of Environmental Protection and Natural Resources employed about 21,000 people. In addition, the official Russian environmental protection system included environmental agencies in each of the 89 administrative areas and several state committees responsible for the use of other natural resources. This web of organizations has impeded standard interpretation and implementation of the emissions charge system. Power struggles between local, regional, and federal institutions—set against a backdrop of declining legitimacy of government authorities from Moscow in almost all of Siberia—make enforcement, penalization, and tax collection extremely difficult for environmental authorities. Local authorities have manifested an ability and willingness to interpret environmental legislation to suit their budgets and local development plans. Bribery and other forms of rent seeking are manifest not too infrequently in the region, as local authorities disregard environmental concerns in order to strengthen their own positions or simply keep their industries alive.

Asymmetric information. Information about various technology options for abatement may not be fully disseminated among firms. If uncertainty about the marginal abatement cost function exists, the superiority of taxes over standards is no longer clear (Stavins 1991), (Parry 1997). The relationship then depends on the relative slopes of the marginal damage and the marginal cost functions. In Siberia's case, while a historic step in environmental policy, the current pollution charge system alone will not effect abatement or revenue raising. In such cases a mix of policy tools including the regulatory option for particular enterprises or sectors might lead to greater abatement than the current policy does, absent of economic recession.

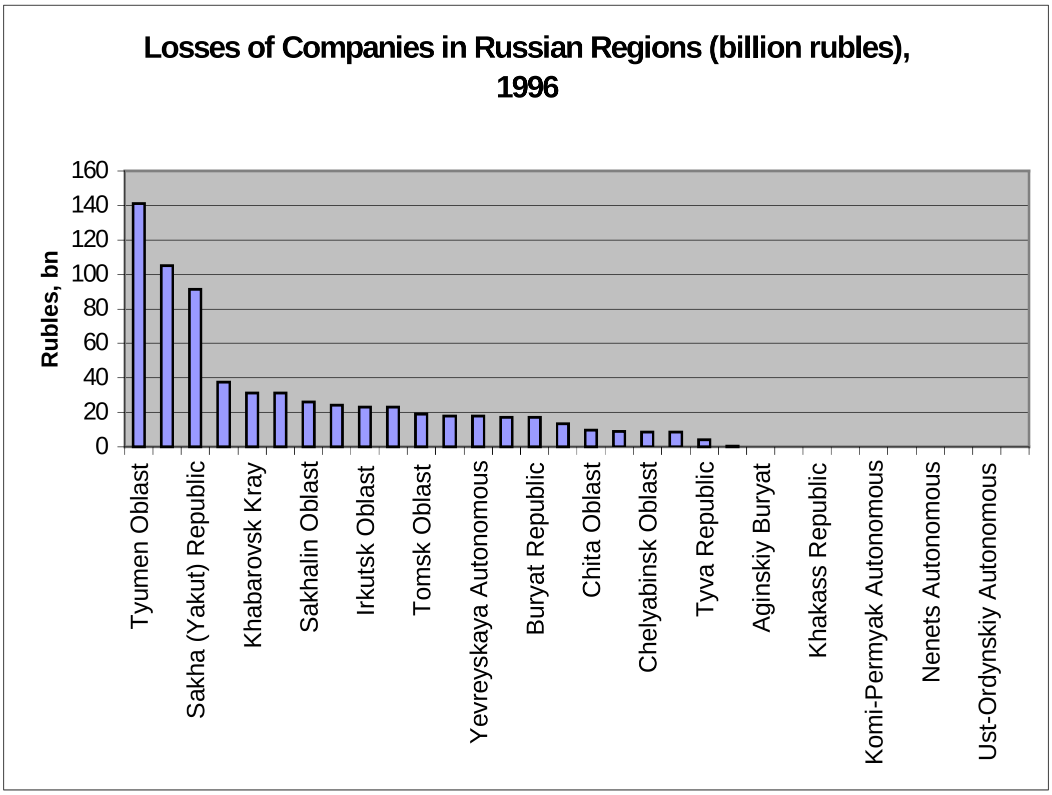
Environmental taxation requires that federal and regional governments are generally aware of enterprise costs. However, due to faulty accounting systems, Siberian enterprises misreport costs, for example by reporting income as production costs (Gofman 1993). Corruption in government-business relationships in the region is very common (Kotov 1993) and "under-the-table" deals are easily waged over Siberia's vast territory where monitoring becomes not only a political challenge but one of sheer geographic distance. Pollution is not reported, but is dumped or discarded in unobserved locations. Taxes are required on paper but are never paid. Related to a general paucity of reliable enterprise-level information is the problem of monitoring, discussed throughout this report. The successful implementation of Russia's ambitious emissions tax depends upon the environmental authority's ability to monitor emissions. Particularly evident in Siberia, environmental agencies are poorly funded, understaffed with often insufficiently trained personnel, and rely heavily on "expert opinion" and computer simulations of dubious quality rather than on direct measurement as monitoring tools. Although local regulators have an incentive to correctly gauge enterprise effluents (sixty percent of collected environmental taxes remain at the local level to finance environmental projects, (Bluffstone 1997)), proper monitoring and enforcement in Siberia still remains very much the exception, rather than the rule. Environmental authorities face powerful enterprise bosses without the general aid of legitimacy. Left over from the communist era, a disregard in Siberia for "all things Muscovite" and a casual regard for law seriously weakens the force of the emissions tax on enterprises in the region. A statement by Klarer supports this view (Klarer 1994): "Society was socialized in a system where behavioral rules, norms and possibilities were formed mostly in informal ways and had little to do with legal norms. Some polluters simply do not comply with the regulations because they believe they will be able to avoid suffering the consequences."

Privatization program. Experts have noted that most elements of the centrally planned economy continue to exist (Gaddy 1998); (Stoner-Weiss 1997). Market reforms in Russia—and particularly Siberia's monopolistic giants—have been privatizing former state property to shareholder associations in a way that the majority of shares essentially belong to the same ministries, committees, and managers. One of the fundamental assumptions of the emissions tax is that it will be implemented in a relatively integrated market economy, where private enterprise will respond to the economic incentives of fee levels. This assumption implies the presence of relatively strong market institutions and reliable information exchange between firms about profits, prices, and emissions levels. In contrast, Siberian enterprises appear less linked through integrated markets. Rather "they are linked to each other through networks of personal contracts and mutual services, as well as by a system of natural commodity exchanges between their enterprises" (Stoner-Weiss 1997). This implies that Siberia's powerful energy and steel complexes, among others, may with relative ease return to past connections both to claim public funds for enterprise finance and avoid paying taxes and tax evasion penalties. The privatization program has not created the type of private enterprise which Western advisors had hoped for. Instead, while private in formal discussion, the management continues to rely heavily on non-market relations to continue business operation. The fundamental distance between Siberia's newly "privatized" enterprises to competitive, integrated markets impedes the ability of the emissions charge system to raise revenue for the environmental fund or encourage abatement.

Soft budget constraints. The ability for Siberian enterprises to survive in spite of the lack of market profits and production cost efficiency also prevents emissions taxes from fulfilling program objectives. Emissions charges should raise the marginal cost of production for firms, and therewith provide economic incentives for investment in abatement technology, a switch to cleaner production, or some other shift away from the now-costly production of pollution. However, due to the economic and institutional structure currently operating in Siberia, firms appear not to calculate costs according to standard Western methods. Enterprises try to avoid taxation by obscuring profit levels and production costs, as well as output levels. Managers view input costs such as labor as fixed (typically viewed as variable in OECD countries), and overall accounting systems do not generally provide managers with the necessary information to make production decisions which account for the costs of pollution imposed by the emissions tax.

Many authors have noted that in spite of recent reforms, budget constraints for enterprise and government sectors are not actually hardening. In spite of significant losses, indicated in figure 4.1, the number of operating firms has increased from 48,857 units in 1987 to 69,960 units in 1993.

Figure 4.1



Source: (RUSLINE 1998).

Fragmenting once larger, state-owned enterprises likely accounts for the majority of this increase. Although reliable data about bankruptcies in Siberia is not available, it is likely that many firms operate on soft budget constraints and an average 25% of Siberian firms were unprofitable in 1997, compared with an average 16% for the Russian Federation (RUSLINE 1998). The degree of losses in Siberia is staggering: while 1996 losses for the Russian federation amounted to 1,288.30 billion rubles, Siberian losses amounted to 562.2 billion rubles, or almost half (*ibid.*).

It does not appear that economic duress causes Siberian firms to become more efficient in the use of production-related resources in the short and medium terms. Empirical evidence actually suggests the opposite. Resource utilization ratios for energy per unit of output have risen significantly since 1991, particularly in the energy sector. For example, data in chapter six illustrates the 1990-1996 change in industrial energy consumption and intensities for the region's most important enterprises (expectedly, also the greatest producers of emissions by volume and risk). Firms have adopted a survival strategy that involves using cheap resources more intensively rather than economizing on inputs or improving the quality of industrial output. Evidence of this sort of "economizing" in Siberia supports the thesis that general assumptions about emissions taxes need rethinking. Perverse firm behavior in situations of uncertainty dash the strength of Pigouvian-type taxes and their ability to efficiently improve social welfare.

4.3 Program Goals

The pollution tax system in Siberia has two primary, often inconsistent goals: emissions abatement and revenue accrual for an environmental fund. The goals conflict because the tax levels—even if noncompliance, monitoring and enforcement, and the institutional aspects mentioned previously were not as problematic—are too low to reach abatement targets. As a result, limited evidence indicates that the existing taxes have only a minor behavioral effect on firms in terms of their pollution reduction activities. The revenue raising function is left as the primary goal of the current program. The section below reviews the extent to which the environmental program reaches its goals, including a brief review of hypothecation of environmental tax credits and incentives for abatement investments. Although the emissions tax provides a little long-term hope of reaching some of the theoretical benefits of taxing the production of negative externalities, in its present form the system meets neither revenue nor abatement goals.

4.3.1 Environmental protection priorities

The economic crisis has significantly affected the position of ecological problems on the Siberian agenda. Pressing inflation, unemployment, crime, and insolvent industry dwarf air pollution in economic and political importance. Federal and regional budget deficits have squeezed out environmental protection as a beneficiary, in spite of feasible proposals for emissions abatement. An example of one such program, never implemented, which outlined the current priorities in environmental protection is the State Program for Environmental Protection and Natural Resource Use to 2005. This program was developed in 1988 and identified high-priority environmental areas at federal and regional levels, presented in table 4.5.

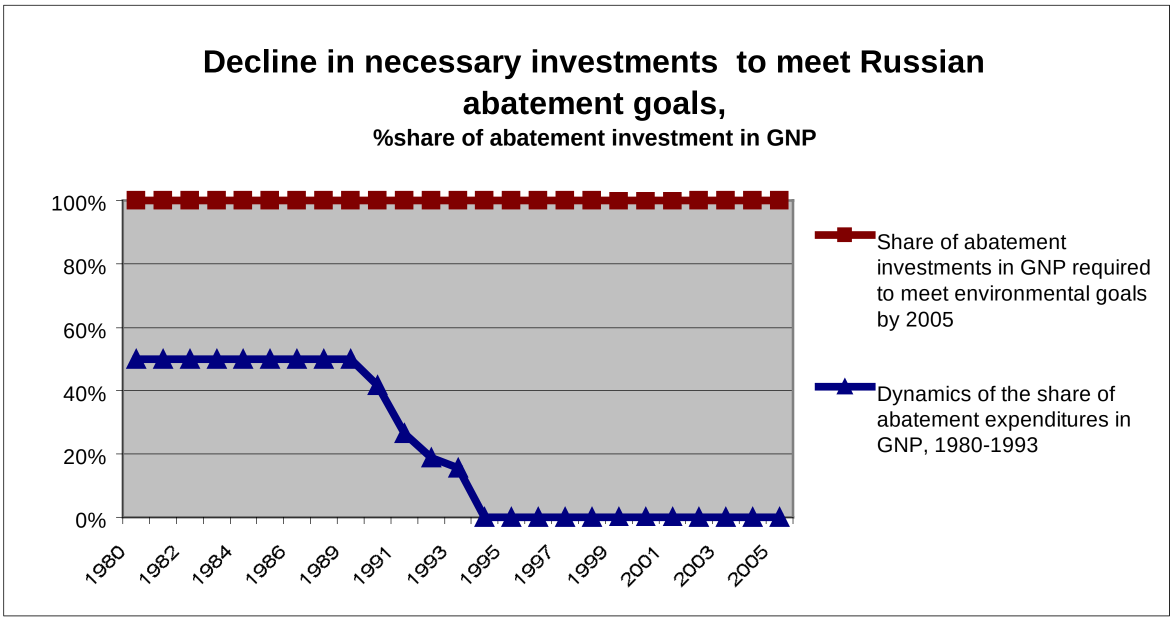
Table 4.5 Air-quality priorities of the State Program for Environmental Protection and Natural Resource Use to 2005

Task	By 1995	By 2000	By 2005
Ambient air quality protection	Decrease total emissions by 20%. Force large stationary pollution sources to meet emission standards.	Relocate inhabitants in contaminated zones. Use only unethylated petrol. End production and consumption of ODS.	Decrease total emissions from stationary sources by a factor of 1.9 and from mobile sources by 40%. Meet environmental standards

Source: (Klaassen 1995).

The program identified environmental standards for economic sectors, as well as specific locations in the region for specific protection policies. Although environmental investments have decreased since its inception, the main priorities remain the same on paper. Practical realities do significantly affect the implementation of these priorities, however. Figure 4.2 suggests that the introduction of market-based policy instruments has actually coincided with dramatic drops in abatement investment. As industrial production improves and available funds for such investments are easier for Siberian firms to come by, some firms may begin to invest more heavily in pollution-reducing measures. However, the extent to which the emissions charge will induce such activities remains unclear. Thus one of the most positive aspects of the charge on paper does not perform well in reality.

Figure 4.2

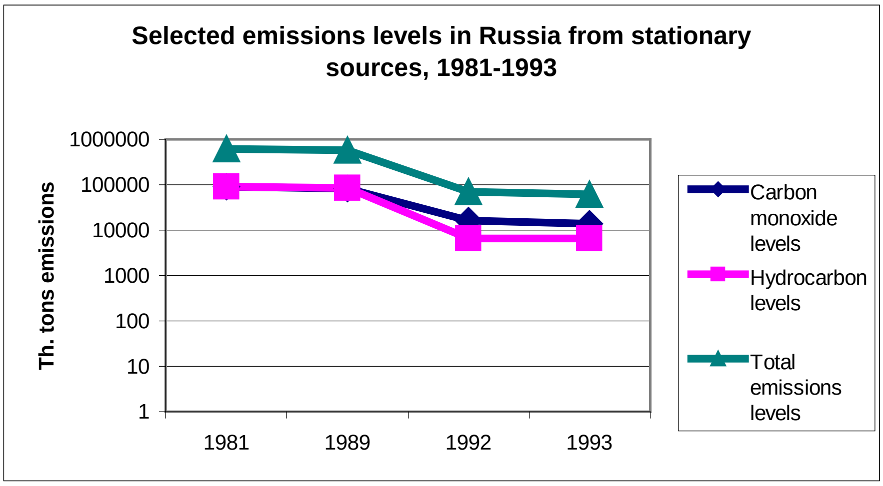


Source: (Golub 1995); (GKNT 1980); (Goskomstat 1985), (Goskomstat 1988), (Goskomstat 1989), (Goskomstat 1990).

While pollution impedes aspects of industrial production (in terms of labor quality and some other resource qualities such as forest products), the magnitude of available natural resources and gravity of the economic transition somewhat negate environmental efforts in Siberia. Due in part to crisis-associated production decreases, Russian (and Siberian) pollution levels have also declined, summarized in figure 4.3.

Although energy intensity per unit output has actually increased significantly, among other indicators of efficiency, the decrease in reported emissions and industrial output creates an impression of improvement of the environment and hence of a less-pressing nature than other issues (CENEf 1997).

Figure 4.3



Source: (IIASA 1996a).

4.3.2 Environmental fund and hypothecation

Pollution charges are paid in principle into regional and federal environmental investment funds. The introduction of the pollution charge makes it theoretically possible to collect fees for the environmental funds and enables polluting enterprises to use some part of the payments for environmental activities. As table 4.6 shows, emissions taxes provide the single most important source of revenue for Russia's cash-strapped environmental programs.

Emissions taxes serve as an important source of funds for other environmental projects. They also are a source of noncompliance as firms try to avoid taxation or as authorities grant tax forgiveness or credits for insolvent enterprises.

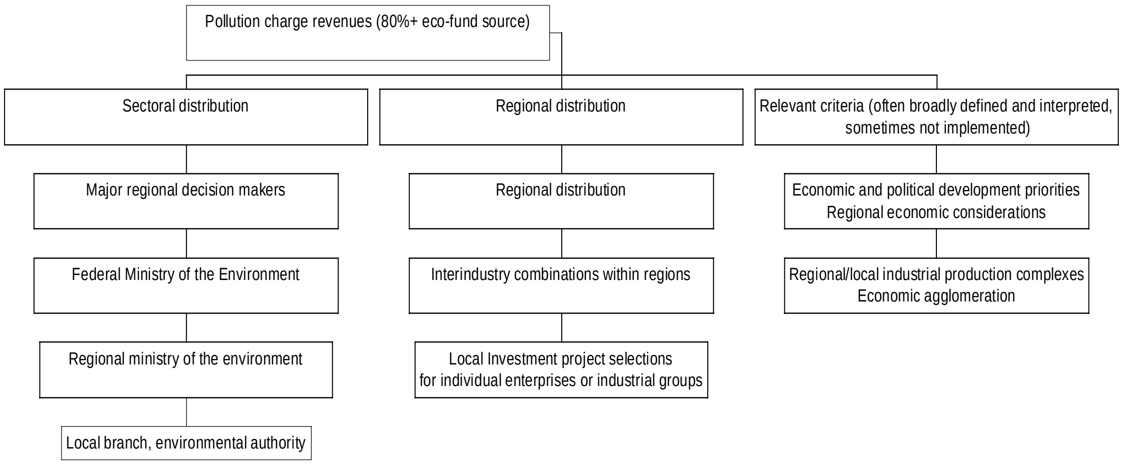
Table 4.6 Sources of environmental funds

Source of finance	**% of source**
Emissions charges	80.0
Charges for improper use or destruction of natural resources	3.7
Fines imposed for violating environmental legislation	2.6
Profit from usage of temporarily uncommitted money	2.0
Other revenues	11.0
Source: (Golub 1995)	

Emissions charges are designed to generate revenues, which are used for a variety of environmentally-related projects, including investment in pollution abatement, discussed below. Figure 4.4 describes the allocation of emissions tax revenues. While the federal Ministry of the Environment oversees the program and determines how funds will be reallocated after collection, regional and local authorities actually select fund recipients. The system is complex, proposals for access to the funds are not uniform and uniform criteria for judging the “soundness” of an environmental investment do not exist in the region. Award of these funds remains subjective. Funds are hypothecated, or earmarked, for use in environment-related purposes. However, this practice proves difficult because the use of funds created by emissions taxes are poorly defined and often misallocated.

Figure 4.4

Regional allocation of environmental investment funds



Source: (Klaassen 1995)

The environmental fund does provide a positive source of funding in otherwise poorly financed administrative regions in Siberia. However, loosely formulated guidelines and poor implementation prevent effective environmental projects in the region, with a few exceptions. Hypothecation (earmarking) of emissions taxes is questionable. Although different Siberian regions experience fund shortages in environmental protection implementation, it appears that hypothecated rubles are not fully utilized. For example, 44% of the money remains unused for the Saratov region; 45% for the Astrahkan region; 48% for the Krasnoyarsk Kray; 54% for the Murmansk region; 62% for the Tver region; and 67% for the Tyumen region. Local and regional environmental authorities lack experience in allocating grants or credits for financing abatement activities. They have few feasible tools for choosing priorities, and are not able to compare demand and supply of financial resources. In addition, in spite of general under-use of hypothecated funds for abatement, firms might not even use the funds for abatement activities. Golub and Strukova (Golub 1995) report that “many attempts to use resources from environmental funds for purposes other than environmental protection were often registered.”

Table 4.7 Allocation of environmental fund resources in 1993		
Trends in fund disbursement	**Ruble(millions)**	**Percentage of total fund**
Construction of environmental protection facilities	13,908.4	24.2
Credits and loans to cover current costs	6,152.8	10.7
Funds to develop and introduce ecologically friendly technology	1,161.1	2.02
Research and Development	4,208.9	7.33
Monitoring	1,856.6	3.23
Total for environmental protection and nature conservation	**27,287.7**	**47.48**
Development of forest and game preserves	1,208.4	2.10
Disaster repair and prevention	1,063.1	1.85
Compensatory payments	254.3	0.44
Training and retraining of district inspectors	176.6	0.34
International cooperation	299	0.52
Support for environmental protection staff (incl. salaries)	1,767.9	3.07
Meetings, workshops, etc.	554.5	0.96
Improving equipment and technical base of environmental protection system	12,473.1	21.71
Bank deposits	2,477.1	4.31
Other deposits	9,881.5	17.25
Total expenditure	57,443	100.0
Source: (Golub 1995)		

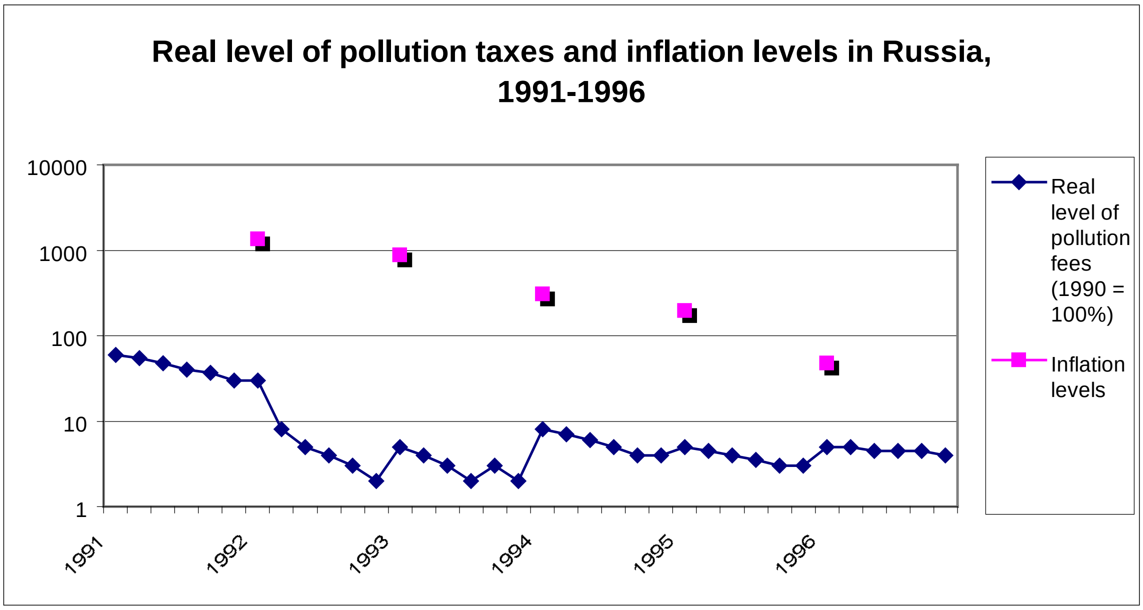
4.3.3 Revenue goal falls short

Pollution fees began falling in real terms almost before they were fully implemented in Siberia. When prices were liberalized in 1992 the depreciation of emissions taxes became continuous. By the middle of 1992 real fees had fallen almost to zero, and real periodic corrections allowed the maintenance of emissions charges at only a minimum level. In addition, Siberian enterprises manifest a pattern of withholding payments under inflationary circumstances to further decrease the value of their real tax payments.

Table 4.8 Russian Annual Inflation Rates 1992-1997 (%)						
	1992	1993	1994	1995	1996	1997
Annual avg. rate	1,354	875	307	197	48	15
Source: (Fischer 1998)						

Since their introduction in 1992, emissions taxes have undergone several alterations to correct for this. Special correcting coefficients for the basic rates, approved by the decision of the Russian Council of Ministers (Ministers 1991) are adopted biannually. The calculation of charges introduced in 1992 was based on 1990 prices, with the average charge for 1 ton of aggregate air emissions at only 3.3 rubles (Averchenkov 1994). Even corrected rates fell to below 5 percent of their original values.

Figure 4.5



Source: (Klaassen 1995); (IIASA 1996b); (Golub 1997).

Although charge levels were adjusted for inflation sporadically, real charge levels steadily declined. Comparing the inflation level (measured by an industrial production deflator) and dynamics of the basic rates of pollution charges, figure 4.5 illustrates the dynamic nature of real emissions tax levels from 1991 to 1996. Perhaps because of these significant reductions in charge levels, many authors have argued that real emissions charge levels must be increased to motivate polluters to abate. However, as chapter five points out, increasing tax rates alone will not provide a sufficient incentive for firms to either pay their charges and penalties or engage in abatement activities.

In the thick of transition, officials were concerned that an additional emissions tax burden on industry could drive firms to exit. Although the idea is not widely supported in theoretical or empirical research (see for example (Migue 1993) and (Bluffstone 1997)), Siberia caps charges to spare already overtaxed firms. The upper bounds for pollution tax liabilities are based on enterprise profits, which apply the regulations and calculate for themselves the maximum percentage of their profit that pollution charges can make up. These calculations are then checked by regional authorities and approved by local authorities. As an example of the degree of tax forgiveness which occurs, without such pollution tax caps, emissions charges would reportedly constitute 153 per cent of profits for the energy sector and 253 percent of chemical industry profits (Kozeltzev 1997). Those sectors emitting the greatest volume of chemicals, in addition to the highest-risk toxins, have access to this charge ceiling. The system provides clear incentives for under- or mis-reporting of profit levels, as figure 4.6 illustrates. It may also reflect the fact that many businesses in Siberia conduct their business in informal markets where tax-avoiding managers record profit levels imprecisely. In addition, a 1993 Russian survey of heavy polluters, several of which operate in Siberia, reported that directors did not believe they would be required to pay pollution charges if those charges reduced enterprise profits by between 5 and 20 percent (Kozeltsev 1993). Actual legislation contradicts fact in that firms may be required to pay all or all but five percent of total profits in emissions charges. Noncompliance and tax forgiveness prevents this from occurring in reality.

Table 4.9 Charge ceilings for emissions taxes, based on enterprise profits

	Profitability (in percent)		
	Up to 25%	26-50%	Greater than 51%
Pollution charge ceiling as a % of total profits	20	50	70

Source: (Kozeltzev 1997)

An additional loophole remains for those firms required to pay charges for air pollution. Officials do not collect the majority of pollution charges. They instead remain in company hands as tax credits. It is possible, as discussed in chapter six, that such “tax offsets” actually defy the purpose of the emissions tax system and grant enterprises more leverage than would be desired in order to abate pollution and make investments in environmentally less intensive production technology. Emissions tax credits are often granted to allow such firms to use their charge payments to finance environmental protection “investments.” For example, if the enterprise has to pay x rubles, it can obtain permission from environmental authorities to pay only y rubles to the environmental fund and use $z = x – y$ rubles for environmental protection. Tax offsets may subvert the basic purpose of the pollution charge system. Firms can count between 20% and 25% as payment of the charges. Environmental officials consider these financial resources the domestic source for environmental protection. However, the supervision of such investments lacks consistency and imposes few requirements or guidelines. No clear definition exists for what does and does not constitutes abatement or environmental protection investment. Scholars have not assessed the actual necessity of granting such offsets in Siberia's context and environmental officials do not apply a set of standardized criteria for granting them to firms.

As a result, collected emissions charge revenues have fallen dramatically short of those expected in the region, and in Russian Federation in general. Figure 4.5 shows that collections rose only slightly during the early 1990s. A positive aspect of the program is that revenue was generated; however, a detailed benefit cost benefit comparison of the emissions charge system and other air pollution policies might reveal that this market instrument has not performed according to theory in the initial period. The outcome will depend, upon firm response and the administrative efficiency of collecting this tax compared with that of imposing another policy instrument.

Figure 4.6

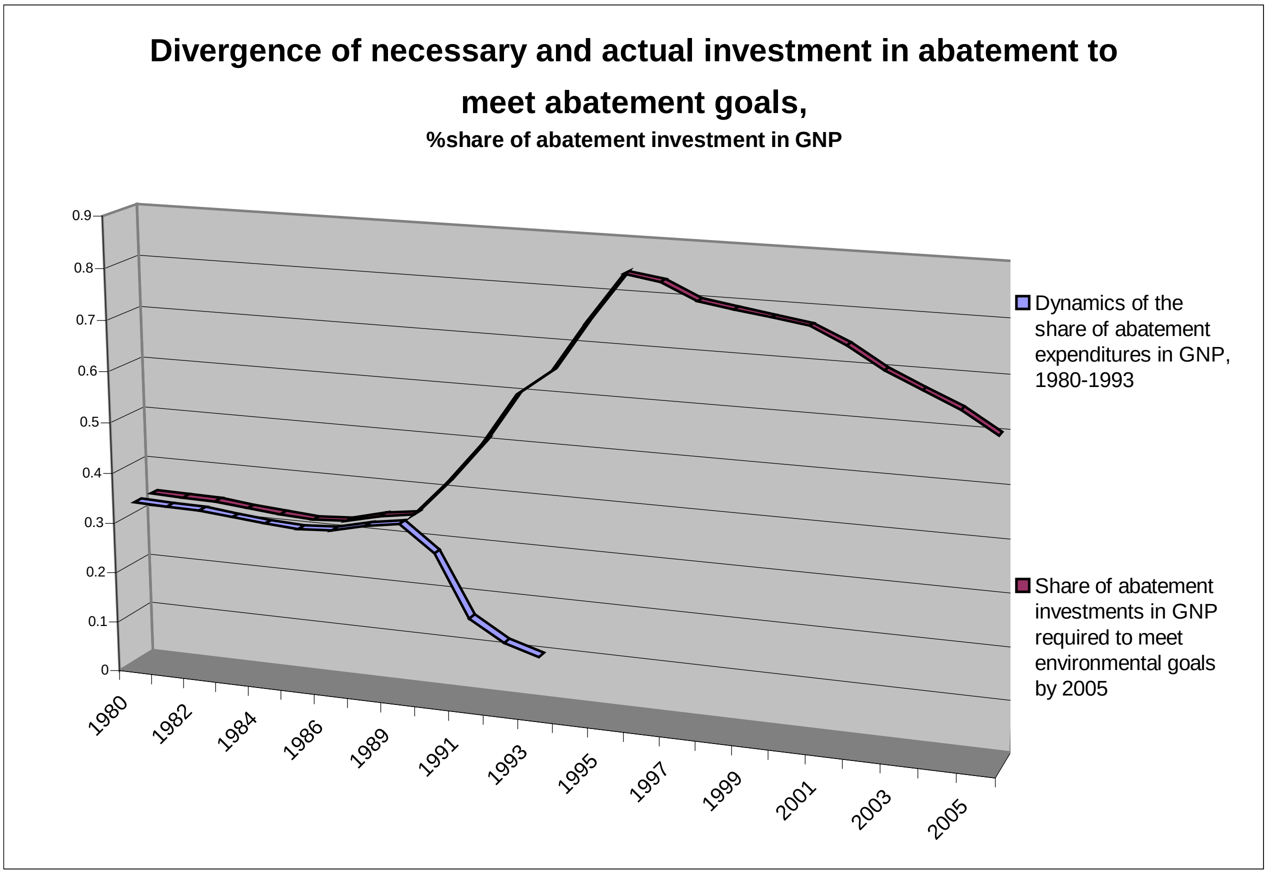
Source: (Golub 1994b)

4.3.4 Abatement and environmental quality

If the emissions charge system has not reached its practical primary goal of revenue generation, how does it fare in terms of providing polluters with incentives to change their behavior to less polluting activities? The data indicate that dropping pollution levels in the 1991-1995 period occurred mostly as a result of lower industrial output. Because input-intensity for resources such as fossil fuels has risen and general productivity has fallen, we assume that the pollution intensity for the general production process has risen. The degree of this pollution intensity will vary by industry, but research indicates that, should economic activity resume at current levels of pollution intensity, emissions levels would rise again even in the presence of the emissions charge as it stands now (DeBardeleben 1995).

What does become clear is that, in order to reach the program's abatement targets, investments are falling short. After 1990, fairly low but steady abatement investments declined rapidly. While the economic hardship experienced after 1990 caused declines in all investments in the Russian Federation (all investments fell by a factor of 2 to 2.5; (Shatalin 1994), environmental protection investments fell by twice that amount (a factor of 4 to 5). In 1993 Russia's total investment in environmental preservation was about US$2.3 billion, representing a 20 percent reduction from 1990, and less than 4 percent of the national budget category for "industrial construction," which includes environmental expenditures. Of this investment, 58 percent went to water resources, 24 percent to air pollution reduction measures, 7 percent for forest management, and 0.04 percent for nature preserves and species protection.

Figure 4.7



Source: (Golub 1994a). Calculated according to Goskomstat 1985, 1988, 1989, 1990, including forecasts.

Chapter three outlined a model in which assigning a price to pollution created incentives for enterprises to invest to reduce the short-run marginal benefits of pollution by using better processes, management and technologies. The mere existence of an incentive, however, does not ensure that expected benefits will be sufficient for enterprises to actually invest. Cause for concern is particularly justified given the thin credit markets in Siberia's economy, which increases investment costs. With imperfect credit markets, charges may not create incentives to invest and indeed could reduce enterprises' abilities to invest by siphoning off investable funds to pay charges. The presence of an emissions charge does impose a type of "peer pressure" on firms to invest in some type of cleaning mechanisms, however, actual dynamics of abatement investments by firms is not entirely clear. Firms appear to follow a rising trend to make some type of investment in very loosely defined environmental projects. However, the actual form and content of these programs suggests that many resemble profit diversions and tax shelters for many enterprises rather than representing genuine efforts to abate pollution. In an uncertain market where interest rates can become negative, lenders justify only very profitable investments.

Enterprises might use their resources for abatement investments if it proved more profitable than to pay pollution fees. However, case studies and analyses of branches of industries by Golub and Strukova (1994) indicate that in the current situation fees do not provide sufficient motivation for firms to use their own resources for environmental protection. Given the fact that, in 1990, the revenue increase resulting from the introduction of a new technique or technology amounted to an average of 0.38 rubles per 1.0 ruble of the investment costs, such investments did not attract many firms (Akopian 1992). Dumnov's study estimated that the average enterprise spent 0.2 percent of total annual receipts on pollution fees, with less than one percent of local enterprises by the pollution charge system to invest in abatement technology (Dumnov 1992).

Historical biases away from investment in the region might also place special constraints on Siberian industry: "Soviet investment policies have polarized rather than integrated the economies of Siberia and European Russia. Renovation of European Russian industry absorbs a growing percentage of capital investment, leaving an ever smaller portion to be allocated to Siberia. What is allocated to Siberia tends to be concentrated in developing the region's natural resources. By channeling available investment capital into resource extraction, Moscow has narrowed Siberia's industrial specialization and neglected the region's…infrastructures, particularly in East Siberia and the Far East (Shabad 1987)." To make matters worse, while Siberia serves as the natural resource provider for the Russian Federation, industrial development policies have focused on extraction rather than value-added activities. Resources are often shipped thousands of kilometers westward for improvement and sales, leaving few industrial linkages within the region (Huber 1996).

4.4 Conclusions

This chapter has outlined the features of the emissions charge system as implemented in a regional transition economy. Such economies have received praise for laying the groundwork for market-responsive abatement policies. Yet the emissions tax has drawbacks as applied in Siberia's context. An *ad hoc* process which sought to reconcile environmental standards with industrial needs resulted in an "expert opinion" approach which allowed policy makers to set prices for emissions in discord with the environmental shadow prices suggested in chapter three. In spite of periodic indexation to inflation, emissions tax levels have plummeted and have remained too low to achieve effective abatement or revenue goals[2]. Institutional features such as geographically scattered monolithic industries, weak environmental authorities, and a generally weak framework necessary for market based environmental programs mean that the current policy rarely meets ambitious or even moderate abatement goals. Revenue is difficult to collect and, when paid into the fund, may be equally difficult to allocate in ways that efficiently minimize environmental damage and related social costs. Actual taxes collected fall significantly short of the estimated necessary revenues for abatement, and the inflation-ridden charge appears to provide very little real incentive for firms to undertake abatement investments. Pollution intensities have increased per unit of output in the region, in spite of the emissions charge. Assuming more stable future economic conditions, the current pollution charge system will not prove effective in pollution abatement. Table 4.10 summarizes some of the weaknesses of the current emissions charge system as it is implemented in the region.

Table 4.10 Summary of program weaknesses and flaws

Institutional	Tax level	Industry response
Poor institutional framework for implementation, collection, and monitoring of polluting industry	Taxes only sporadically adjusted for inflation	Largely ignore pollution taxes
Weak tax collection structure with tax offsets that allow industry not to pay emissions taxes	Studies show that tax levels the less important issue. Instead, high probability of monitoring and enforcement seem to bring greater compliance than higher taxes on emissions.	Industry itself does not know its own production costs, making a charge on pollution less effective in raising known marginal production costs and inducing abatement
Dual market structure. Taxes on emissions may encourage less participation in formal markets	Tax levels unclear and changing	Little accountability for pollution, culture of environmental disregard
Asymmetric information	Tax levels too low to provide abatement incentives	Largest polluters often excused from emissions tax payments

This review paints a pessimistic picture of the emissions tax. The exercise does point out many issues vital to the larger discussions about instrument choice and implementation. For example, although charges promise the boon of revenues for reallocation and possible correction of pre-existing tax distortions, in economies ill equipped with market institutions they will prove difficult to administer. They may be subject to inflation, as well as rent-seeking activity. Increasing levels of emissions taxes may have the perverse effect of increasing cheating rather than increasing tax payments by firms, as discussed in the following chapter. Finally, as Siberia’s case illustrates, the granting of tax credits and other forms of incentives for investment in abatement may not forward environmental program goals if they cannot be well-defined and properly monitored. In situations of economic hardship, environmental investments may have lower rates of return for individual firms, in spite of an effective rate of taxation.

[2] However, as chapter five and six will discuss, raising tax levels may not aid the program in some optimal allocation with a competitive equilibrium.

Institutional factors and the policy framework play a more significant role in the implementation of the emissions charge program than do charge rates.

Chapter four has served as a practical reminder that the theory behind emissions charges deviates in important ways from practice. The author intends not to discount the possible benefits of a market-oriented solution to emissions problems in economies such as Siberia's. Rather, the investigation focuses on the variables which play key roles in determining the success or failure of a market-based instrument in imperfect economic systems. Understanding these variables may help researchers in the future design environmental policy that can overcome some of the obstacles which practical experience raise. In order to understand why market tool alone doesn't accomplish the program goals, we look at the response of different types of firms in Siberian context. We see that market incentives such as raising tax levels do not alone tend to increase compliance. Chapter five explores enterprise response to the current air pollution policy and points out some of the important aspects of policy design for the region.

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Chapter 5: Enterprise response to Siberia's emissions tax

5.0 Introduction

The model presented in chapter three suggested that an environmental policy for air pollution abatement should have impacts on economic activities in the region. The model included some weak assumptions about the relationship between pollution and Siberia's economy, which necessitated a comparison of actual implementation of the pollution charge system in chapter four. The current chapter questions how the emissions charge system affects polluter behavior. This chapter compares a theoretical presentation of enterprise response with empirical evidence from Siberian enterprises. It reveals that, contrary to the emphasis of a majority of writing about environmental taxes, tax levels in an economic context such as Siberia's may not be the most important factor determining the success of the program. Discussions of raising taxes in order to provide greater incentives for abatement miss some of the most important issues surrounding the charge system for the region. To illustrate these issues, the author discusses three major types of enterprise. Each case illustrates an important facet of the emissions charge system and impacts on firm behavior in Siberia.

Section 5.1 reviews some of the important thoughts about environmental taxation in transitional economies. The following sections (5.2, 5.3 and 5.4) examine the theoretical and practical impacts of charges on three major categories of Siberian enterprise: price-taking competitive firms, monopolistic firms, and non-profit maximizing firms. Section 5.2 begins with a simple case of a profit-maximizing polluter, using a model specifically for a charge system in a transition economy in which some noncompliance exists. First, private firms are assumed to maximize profits under the tax with some tax evasion, then we relax the perfect competition assumption to examine how firms with different market structures operate with an emissions charge. Siberian firm behavior deviates from standard profit maximization. Section 5.3 and 5.4 examine the impacts of the emissions charge on monopolists and upon firms which maximize some other objective function. This discussion reveals that the actual levels of environmental taxes imposed do not affect a firm’s actual emissions to the degree that it does the firm’s reported wastes.

5.1 Firm response to tax levels

Enterprise response to environmental taxation is a key area of interest. As chapter three implied, the imposition of taxes on pollution, considered a joint product of production, will cause firms to reduce pollution in order to avoid the costly fines. In reality, we are interested to know whether a charge induces such pollution reduction, and if it does to what degree.

A substantial literature has emerged which shows that under perfect competition a tax per unit of pollution equal to marginal damages with no compensation of victims is the Pareto optimal policy (and that no other solution can attain Pareto optimality) (Baumol 1988). In such cases the most important issues involve the level of effective taxes, and the structure of firms reacting to those taxes. While much of the theoretical literature deals with the setting of prices for environmental goods and services, because of Siberia’s imperfect market and institutional setting, many theoretical assumptions about the things which taxes can achieve no longer hold. Practical research has found that the actual tax levels play a relatively minor role in the implementation of an emission charge system. Optimums concern policy makers less than simply collecting taxes at levels sufficient to meet environmental program goals. Given the complex and incomplete institutional framework in the region setting individual optimal fees is not practical. This requires extensive information about price elasticities of demand and the abatement costs of each polluter—information often unclear even to enterprises. In addition, even if environmental authorities could meet the information requirement, implementing such a set of discriminatory fees would prove difficult given the current political and legal setting. Anecdotal information illustrates the point. On December 5, 1998, an article in the *Economist* reported that the mayor of a Siberian town kidnapped the board of directors of a subsidiary of a major Siberian oil producer. The motivation was to persuade the firm to pay local taxes. Although the business leaders gained their freedom next day, the mayor was not so lucky and was discovered dead from a gunshot a few weeks later.

Ironically, those who most enthusiastically promoted the use of emissions taxes in transitional economies also cited institutional and market structures as the central key to success or failure of an emissions tax. The OECD ((OECD 1994)) reported that “charges, even if the rates are high, will be passed on through product prices without any impact on the polluter’s environmental performance. Also, hyperinflation may erode the incentive impact of real, unindexed, charge rates.” Empirical evidence, in chapter four, indicates that countries have only raised nominal tax levels. Rapid inflation reduced the importance of emissions taxes for firm behavior very quickly. On the other hand, raising real tax rates encourages tax evasion, not greater compliance. In spite of these findings, however, some authors continue to suggest that raising tax levels is the best way to improve program performance. A recent study performed by the HIID (Golub 1997) recommend raising pollution fees in Russia to increase revenue and abatement. The study's simulation model showed significant increases in forecasted revenue, but did not account for institutional weaknesses apparent in the region which would probably prevent collection. What most research has not discussed to date are possibly differing reactions to an emissions tax depending upon the type of firm. This analysis adds insight into the types of issues that become important for various enterprises reacting to a pollution charge.

This chapter discusses three types of enterprise, identified by the maximization of either profit or some other objective function, in the context of the emissions tax. The chapter attempts to roughly categorize the groups of polluting sectors from chapter two (results presented in the conclusions). It outlines expected behavior for firms which manifest a given characteristic and infers the effect of the emission tax on enterprises of each kind. The approach allows greater clarity in evaluating the important variables for the emissions charge system in a transitional regional economy, and sheds some light on weaknesses of the current policy. Briefly, chapter five draws the following conclusions about the response of different types of firms to an emissions tax:

- Under the case of a "normal" profit maximizing firm, higher taxes and penalties may increase noncompliance rather than decreasing actual emissions in profit maximizing firms. Siberian firms can violate regulatory standards, required emissions reporting, and tax payments.
- The imposition of an emissions tax may exacerbate monopolistic (or oligopolistic) distortions in output and allocative efficiency. Nevertheless, gains in social welfare from abatement outweigh such losses by a magnitude. In an effort to prevent firm exit, emissions taxes are recycled back into the firm, destroying incentives to abate pollution. This system of internal hypothecation may cause declines in both social welfare and allocative efficiency.
- Under optimal conditions, non-profit-maximizing firms attempt to reduce the costs of pollution abatement rather than pollution output itself. Because rent seeking is possible in the region, this type of behavior may induce a firm to invest more in political relations than in pollution abatement as tax levels rise.

This chapter tries to evaluate the important variables which affect firm behavior and which variables are relatively more important to the success or failure of the emissions tax. Not only the level of the tax but the institutional framework and firms involved play a key role in abatement and tax collection. Focusing on tax levels and nominal privatization efforts overlooks the more important variables of compliance and response to formal market price signals, explored further in chapter six.

5.2 Profit-maximizing firms and the emissions charge

We first consider the behavior of a polluting firm when tax levels change. Standard theory indicates that increases in taxes decrease polluting activities. However, in this model designed by Harford (Harford 1978), taxes are only imperfectly enforced. In such a scenario, the actual level of the tax may not be the key question. Although the probability of detection and tax levels affect *reported* levels of pollution in Siberia, based on empirical data in chapter six, *actual* levels of emissions appear less sensitive to changes in tax or penalty levels.

The model considers a profit-maximizing firm which produces a good *x* from which it receives a revenue *K(x)*. The firm may be either a perfect competitor or, in this region's case, some form of imperfect competitor. The costs *P* of producing a good *x* depend both upon the quantity of *x* produced and also on the amount of wastes, S_i^p, emitted. By definition, the cost function $P \equiv P(x, S_i^p)$ reflects all abatement processes. Marginal output costs for this firm are P'_x and marginal revenue are K'_x. We assume that $|K''_x - P''_x| < 0$, which exist for all relevant functions unless otherwise noted. In order for pollution to be profitable for the firm, the cost of waste creation and emission, $P_{S_i^p}$, must be negative over a range from zero pollution up to some level S_i^{p0}. This is the point where the costs of emissions equal zero and would reflect the preferred level of emissions in the absence of any environmental policy. We assume that P becomes positive at all points following S_i^{p0}, meaning it would increase firm costs to release any more pollution. We assume that $P_{S_i^p}'' > 0$.

Enterprises can evade the pollution charge in Siberia. This implies that actual emissions S_i^p vary from reported emissions S_i^{pr}, and that taxes are charged for reported waste only. The unit tax *t* is applied to S_i^{pr}, so that total pollution tax paid equals *t* times S_i^{pr}. To prevent the firm from evading all taxes by reporting zero released wastes, the regional environmental authority imposes penalties for evasion of pollution taxes, five times the level of the normal rate (Golub 1993). The size of evasion *v* is $v = (S_i^p - S_i^{pr})$, the difference between actual and reported emissions. The shape of the expected fine, $G(v) = pf$, is a function of the violation size where the probability *p* of detection and fine *f* are positive functions of the magnitude of *v*. Firm *i* is risk neutral. The firm's only concern is the expected fine. The expected penalty function has two parts, both equal to one: $O_{expected}$, the shift parameter of the probability of detection, and the fine shift parameter *F*, multiplied by $O_{expected}G(v)$ to reflect the expected size of the fine. The second component is a tax collected on unreported but detected emissions of $O_{expected}\, pvt$. To simplify, $B = pv$ and we note that

(5.1) $B' = p + p'v \qquad B'' = 2p' + p''v.$

Expected profits for the firm are:

(5.2) $$\prod_t = K(x) - P(x, S_i^p) - tS_i^{pr} - FO_{\exp ected} G(v) - O_{\exp ected} B(v)t \; .$$

The firm tries to maximize expected profits with three control variables. The necessary first order conditions for a maximum are

(5.3a) $$K(x)' - P(x,)' = 0$$

(5.3b) $$-S_i^p - FO_{\exp ected} G' - O_{\exp ected} B' t = -S_i^p - G' - B' t = 0$$

(5.3c) $$-t + FO_{\exp ected} G' + O_{\exp ected} B' t = -t + G' + B' t = 0$$

where (5.3a) states that marginal revenue should equal marginal cost, the same result in the absence of a pollution tax (although the level of marginal costs will be affected by the actual level of pollution control). Condition (5.3b) indicates that the marginal cost of reducing actual waste should equal the marginal increase in the expected penalty (expected fine plus additional tax) with a unit increase in violation size. Condition (5.3c) says that the increase in expected penalty from a unit decrease in reported wastes should equal the unit tax on reported wastes. If these conditions hold, then the marginal cost of actual pollution abatement by the firm will equal the unit tax on reported pollution, $-S_i^p = t$. Actual emissions aren't directly dependent upon the size of the shift parameters for the fine or the probability of discovery of the violation.

Two extreme outcomes are possible for the pollution charge with some noncompliance. In the first case the regional environmental authority executes thorough monitoring and sets significantly higher penalties than currently imposed (refer to table 4.4 for a sample of emissions charge rates). In this case, if the expected punishment levels are generally high enough for the firm maximizes expected profits by accurately reporting actual emissions S_i^p = S_i^{pr}, then the unit tax on reported wastes continues to equal marginal costs of waste reduction (at $t < (G' + B't)$ all positive *v* would cause this situation).

In the second case, lax monitoring and lower penalties leads to large variances in reported and actual emissions. Expected punishment costs are sufficiently low and increase slowly enough that the unit tax on reported wastes exceeds the increase in expected penalty in relation to violation size at all points. In this instance it is likely that reported wastes stay closer to permissible levels and the marginal costs of actual waste reduction would be equal to a smaller magnitude of the increase in expected penalty costs.

The second case resembles Siberia, although such extremes aren't likely. The revenue-raising function temper the outcome, because regional environmental authorities need to set penalty rates high enough to ensure at least some tax collection. In addition, given the assumption that all production processes generate some level of emissions, reporting permissible MPLs when other indicators show exceedance of these standards signals violation and catches the attention of officials. Many firms in Siberia, particularly those relatively smaller sources of pollution, appear to report just under or above maximum permissible emissions. Marginal costs of abatement for individual firms neither equal emissions taxes as they should in theory, nor do they too significantly fall below tax and penalty rates. In many cases, given the firm's ability to "escape" into informal market production (discussed in chapter six), managers perceive the marginal costs of abatement as much higher than taxes and penalties. The results vary from firm to firm, as the following discussion indicates.

The actual level of waste emission appears independent of the level of fines or probability of detection and punishment—disheartening news at first for the current charge system. Small changes in $O_{expected}$ and F have no effect on actual emissions. In addition, small changes in $O_{expected}$ and F have no effect on the firm's level of output because, if the optimal level of actual waste doesn't change, then costs as a function of output also would not change. Marginal revenue equals marginal costs at the same output level both before and after any shift in fines or the probability of punishment for tax evasion.

Under imperfectly enforceable emissions taxes an enterprise's marginal costs of abatement equal the constant rate of the pollution tax as long as the slope of the expected penalty function is rising. Harford (Harford 1978) finds that actual waste declines slightly as the tax on reported waste increases. This occurs because of the connection of both actual and reported wastes to the rate of change in the expected penalty with respect to violation size. In Siberia, environmental authorities may monitor firms; however, officials rely on enterprises themselves to measure and report emissions. This provides ample opportunity for cheating, and given the size of Siberia it may be relatively easy in some locations to avoid detection when emissions significantly exceed those officially reported.

Industrial structures provide a key to understanding firm behavior when noncompliance exists. If costs of production and abatement are not separable in output and emissions, as in the case of some fuel taxes, output is a negative function of the charge. If costs are separable, then the tax on reported emissions will not directly affect the firm's output, as may be the case for metallurgy. This implies that on the firm level the amount of pollution tax evasion is independent of the actual wastes. Harford's study (*ibid*) concluded that the general level of fines and the probability of punishment affect reported wastes but not actual wastes, which likely applies to Siberia's case with pervasive evasion opportunities. Close examination of the Siberian pollution database indicates this occurrence for several industries. In addition, the data suggests that although increasing tax rates on reported wastes may reduce actual firm wastes, it will reduce reported wastes even more, implying an increase in pollution tax evasion. The academic discussion about setting shadow prices, and the applied discussion of policy options for Russian environmental authorities seems misguided. Focusing on increasing price levels—the recommendations of some of the major studies for transitional economies (see (OECD 1994); (Farrow 1997); (Larson 1997))—addresses a less-vital issue for Siberia's economic framework and pollution profile.

Section 5.2 has pointed out one of the main important variables that affect polluter behavior in Siberia: the ability to cheat. Harford's model offered practical insight into understanding the behavior of a profit-maximizing firm operating in a competitive way. Siberia has noncompetitive firms, which are some of the largest polluters. Sections 5.3 and 5.4 discuss these. Related issues are important for firms that dominate large shares of the relevant market or behave as monopolists. Emissions charges impact such firms, but the abatement incentive of any given tax level varies with the degree to which institutions can enforce how tax revenue is used. In the case of monopolist-type firms, scholars have focused attention on the impacts of a tax on social welfare and technical efficiency.

5.3 Noncompetitive firm behavior and the emissions charge

The above analysis indicated the impact of a Pigouvian tax on polluting activities for competitive, profit maximizing firms.[1] The Siberian industrial structure deviates from this model. State institutions still dominate many sectors of industrial production, while privatized Goliaths such as Gazprom act as monopolies in others. Many of the large factories that emit enormous amounts of pollution are owned and operated by huge firms in highly concentrated industries in Siberia, such as steel, petro- and polymetallics, and energy production. The application of a competitive model with infinite small, price-taking firms may not suitably fit the most significant polluters in the region.

Non-competitive, non-profit maximizing firms vary across sets of objectives and in their responses to the abatement incentives presented by an emissions charge in Siberia. Section 5.3 presents interesting insights about monopoly reaction to market incentives for pollution abatement and section 5.4 reviews relevant issues for firms which maximize some non-profit objective function. A model of organizational behavior developed by Oates and Strassmann (Oates 1984) provides insight about how decision makers in different institutional structures respond to the introduction of a pollution. It suggests the important variables in firm response, and how such responses will affect resource allocation while accounting for distortions caused by market imperfections, bureaucratic behavior, and a constantly shifting institutional framework.

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[1] The optimality conditions of this type of environmental tax require the assumption of perfect competition.

5.3.1 Evidence of imperfect competition: Dominant industrial polluters in Siberia

Chapter two showed that the major sources of pollution do not necessarily come from competitive firms. Monopolistic producers of steel, oil, coal, manufactured goods, and industrial chemicals in each region also often dominate particular pollution patterns. Table 5.1 identifies some of the largest producers of emissions by volume, including the energy production, fuel, polymetallic, and steel sectors as the largest polluters.

Table 5.1 Total emissions by industrial sector in Siberia, 1992/93

Industry Name	Total Emissions (th.tons/year	Industry Name	Total Emissions (th.tons/year
Energy production	24,809.21	Coal	1,476.49
Coal burning power and energy stations (big)	22,549.56	Steel	13,945.03
Fuel	18,574.09	Polymetallic	16,269.78
Oil dwelling	8,177.8	Chemical	7,440.54
Oil refining	4,918.62	Machinery and tool	5,772.49
Gas	3,769.97	Machine building	4,841.3
		Tractor and agricult. machinery	501.88

Source: (IIASA 1996)

The effects on market competitiveness are still unclear, but privatization has begun to dismantle some of the largest or clumsiest of such enterprises. However the mammoth energy sector, for example, promises to remain centralized and relatively noncompetitive for years to come (OECD 1994). It counts as one of the major polluters in the region, in terms of volume and risk. Publicly owned power plants, for example, are heavy contributors to air pollution, as is the energy extraction and generation sector in general. Energy extraction and production-related sectors generated approximately 55 percent of 1992-93 air pollution across Siberia. The figure reaches 92 percent in East Siberia, where the oil dwelling industry—dominated by one or two monopoly-like firms—alone accounts for 78 percent of emissions. In addition, private but publicly regulated firms such as utilities, gas, oil, and heat and energy-generating municipal utilities, are also among the largest polluters in Siberia. Finally, many of the large factories that emit massive quantities of waste are owned and operated by huge firms in highly concentrated industries like steel and chemicals, in industrial towns such as Novosibirsk and Krasnoyarsk.

Industrial patterns in Russia indicate that many of Siberia's largest firms operate as regional monopolies. Industries that are highly dependent on the availability of natural resources are heavily concentrated in the region—oil extraction, metal production, and forestry. Production concentration in Siberia largely occurs as one oblast or one cluster of industries in an oblast takes an excessively large share in production (Huber 1996). Chelyabinsk dominates the ferrous metal industry accounts for over 20 percent of the share of total output in the 1990s, and Krasnoyarsk accounts for 20 percent of non-ferrous metal production. Tyumen holds an even more dominant position in the fuel industry, producing over 30 percent of total output (*ibid*.). There are some indications that the transition period, with its emphasis on industrial restructuring and privatization, may actually have fostered greater concentration rather than diversity among the largest industries (and largest producers) in Siberia. Table 5.2 illustrates the total share of output enjoyed by the 10 largest firms in the region by industrial sector (in some cases, 10 firms do not exist).

Table 5.2 Output Share of 10 Largest firms, 1987-1993

	1987	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
Electric power	44.19	44.26	44.56	44.19	32.59	35.07	36.55
Fuel	73.47	73.44	73.55	72.94	74.12	73.20	73.59
Ferrous metallurgy	78.83	78.81	78.53	78.33	77.84	81.34	82.94
Nonferrous metallurgy	76.00	75.99	77.68	79.13	74.83	77.26	78.15
Machinery	44.02	44.51	45.04	44.10	43.62	48.46	50.66
Chemical	48.91	48.66	48.79	49.49	47.86	52.41	54.90
Forestry	44.93	44.68	44.35	44.08	45.95	52.22	47.93

Source: (Huber 1996)

The response of these types of firms is crucial to understand, and they represent some of the most interesting cases of polluters in Siberia. The analysis offers insight about how decision makers in different institutional setups respond to the incentives of a pollution charge system, particularly when we relax a key assumption that pollution charges are not credited back to the firm (not to be confused with the revenue recycling discussed by (Goulder 1995)). To simplify the analysis we treat a sample enterprise as the sole provider of a good or service in a given region.

5.3.2 Model of monopoly response to a pollution tax

A standard monopoly model sets the stage for the analysis of firm behavior. The monopoly maximizes profit and exercises discretion over prices charged for a given output. As before, the firm's production function assumes that output is a function of a given resource R_i, which represents a vector of all inputs other than the firm's level of emissions, S_i^p. This is another way of restating relationships (3.1) through (3.6) in chapter three.

(5.4) $$Q_i = Q_i\left(R_i, S_i^p\right)$$

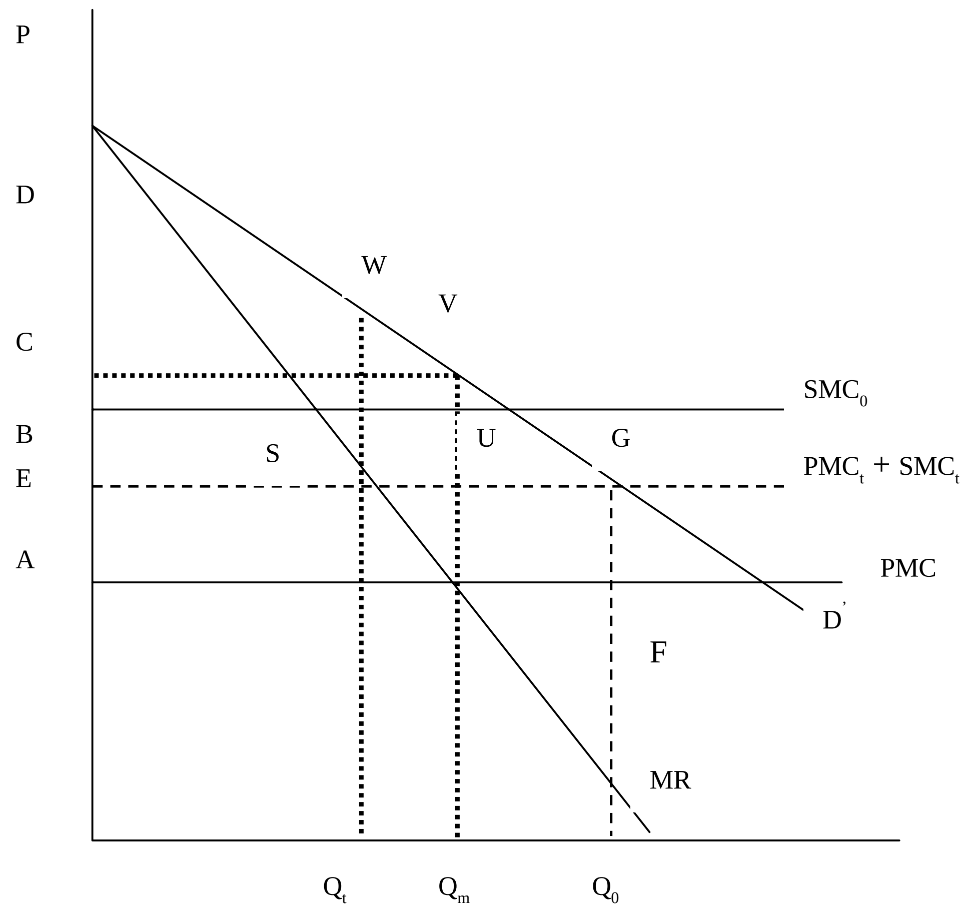
The firm sees waste emissions as a productive input. If factor markets are perfectly competitive and if environmental authority confronts the firm with an emissions tax equal to marginal social damage (*MSD*) represented as curve *DD* in figure 3.8 in chapter three then the firm will select the cost-minimizing combination of factor inputs for whatever level of output chosen. This process of cost minimization leads to technical efficiency in the use of all inputs including environmental goods and services. If units of emissions from all sources are equally damaging, a uniform effluent fee will motivate cost-minimizing polluters to seek the desired level of environmental quality (marginal abatement costs) at the minimum aggregate abatement cost (least-cost). Although pollutants impose widely varying impacts, the risk-ranking analysis suggests that a classification of pollution groups could facilitate this type of policy and lead to least-cost outcomes in Siberian industry.

While a pollution charge achieves environmental goals in theory, Buchanan (Buchanan 1969) points out that, as a result of increased marginal costs imposed by the charge, the monopolistic firm faces an incentive to reduce output. This creates an allocative distortion. The tradeoff between pollution abatement and monopolistic output restriction raises the question of what the effects are for Siberia's net social welfare.

Baumol and Oates (Baumol 1988) depicted the problem in the following way. Let DD' represent the industry demand curve confronting a monopolist, with *DMR* representing the marginal revenue curve. The monopoly produces at constant costs but its production activities imply externalities (*PMC* = private marginal cost). In the absence of any pollution tax, the firm generates pollution costs equal to *AB* so that the social marginal cost (SMC_0) curve indicates the true cost to society of each unit of output. To maximize profits in this scenario, the firm produces OQ_m.

A pollution charge per unit of S_i^p is set at a level that provides the enterprise with an incentive to alter production processes, which reduce the ratio $\frac{S_i^p}{Q_i}$. The *PMC* curve rises and the *SMC* curve declines over some range, implying both a reduction in output (and an increase in price for output) and improved social welfare (fewer pollutants in the environment). This second effect results from a social standpoint of what is a lower-cost method of production (accounting for pollution costs). The minimum social cost of production will be reached when the firm entirely internalizes pollution costs (where $PMC_t = SMC_t$, where *t* equals the emissions tax). After tax imposition, the firm will select of a production process based on a set of input prices that reflects social opportunity costs. Due to the two sources of allocative distortions, both a tax and a subsidy would be required to fully resolve the problem.[2] This is particular to Siberian firms, and has important consequences, discussed at the end of this section.

Figure 5.1 Monopoly output before and after shift to functional emissions tax



Source: (Baumol 1988)

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[2] In this constrained setting, it becomes even more relevant for the environmental authority to determine an effluent fee that balances marginal social costs and gains of improved environmental quality and possible reduction in monopoly output. It is possible to determine an optimal set of effluent fees on all polluters, regardless of their structure. Lee (1975) and Barnett (1980) formalized the first-order conditions for a second-best optimal fee

$$t_i = t^* - \frac{\dfrac{\lambda_R}{F_i^{r'}}}{|\eta_i|}$$

where t_i represents the optimal tax per unit of waste emissions for firm *i*, and η_i represents the price elasticity of demand for that firm. Marginal welfare loss per unit of reduced output times the marginal reduction in output associated with an additional unit of abatement equals the second term of the right hand side in the equality above. A perfectly competitive firm's marginal welfare loss per additional unit of tax will equal zero, thus $t_i = t^*$. However, since the firm in this scenario exercises some control over market prices, the optimal tax on emissions will vary inversely with marginal abatement cost and directly with the price elasticity of demand for the firm's output.

Instead of finding optimum taxes for each firm, the relevant policy question for Siberian environmental authorities involves striking the balance between tax compliance and revenue collection, and emissions abatement and general societal welfare. If charged with some effective tax, will monopolistic firms reduce output? The following discussion attempts to assess the extent of the welfare loss associated with monopolistic distortions under an environmental tax. Human health statistics indicate, on the other hand, that emissions abatement for high-risk chemicals such as heavy metals would bring about a very large welfare gain for Siberian populations. Empirical evidence indicates that the magnitude of the allocative losses in the economy due to monopolistic distortions is relatively small (Harberger 1954); (Schwartzman 1960). The applied general equilibrium model GREEN has been used to estimate costs with respect to abatement activities (Burniaux 1992). The study found that countries with high energy prices have already used energy saving devices. It implies that they will have captured as much efficiency as possible and that their marginal costs of emission reduction are relatively high. Countries with low energy prices and relatively high degrees of technical inefficiency such as the Russian Federation could gain with lower levels of abatement investment.

Table 5.3 summarizes the structure of machinery stock installed in the factories of three principle industrial complexes in the Russian economy. Aging is the prime characteristic. A large substitution potential exists not only for the type of input, but also for the level of technology used in Siberian firms. Basic investments in capital equipment could secure gains in output and, assuming that recent technology is also less pollution intensive, lead to abatement. If environmental authorities could ensure that monopolies pay the correct level of emissions taxes, some decrease in output should occur. However, the social benefits associated with decreases in pollution (especially high-risk) outweigh the costs of decreased output.

Table 5.3 Aging structure of Russian machinery, 1990					
	Total units of installed equipment (1,000. Units)	**Of which equipment age is**			
		Up to 5 years	5-10 years	10-20 years	20 + years
Fuel-Energy complex	1859	31	27.8	26.4	14.8
Chemical-forestry complex	2221	31.2	29.7	26.5	12.6
Machine-building complex	1423	26.1	25.7	30.6	17.6
Source: (Akopian 1992)					

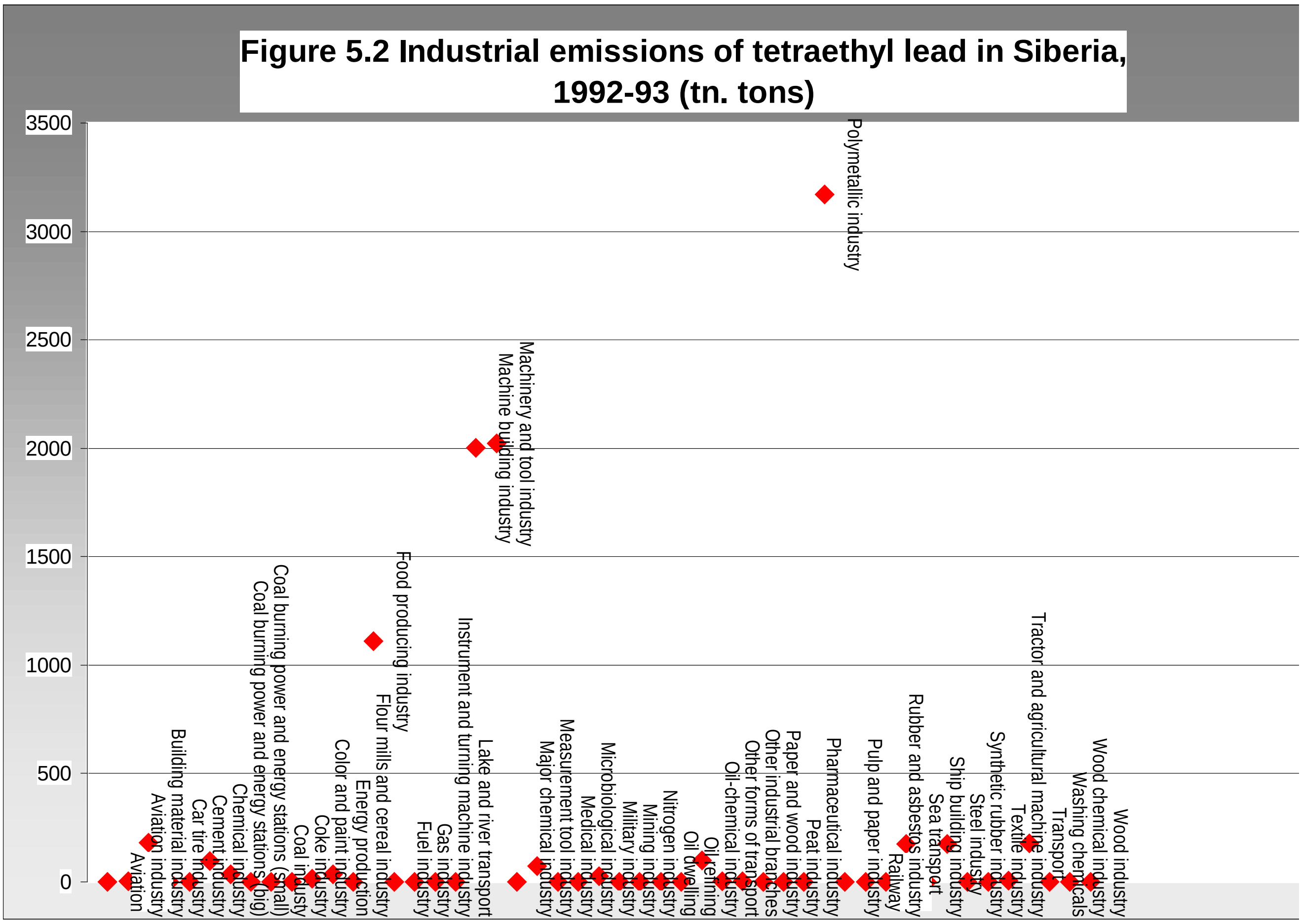
The following section evaluates the potential efficiency losses and gains in social welfare if monopoly output declines as a result of the current air pollution policy. The analysis looks at the polymetallic industry in Siberia, which bears the characteristics of a regional monopoly (Sagers 1990), and which dominates the high-risk pollution profile for Siberia.

5.3.3 The polymetallic industry, a regional monopoly

The following discussion estimates how damaging monopolistic elements might be for a non-optimal, uniform emissions charge. Following the methodology outlined by Oates and Strassman (Oates 1984), the author chooses a representative industry and compares two different equilibrium positions. In the first case, there is no pollution control and virtually no abatement under the current emissions policy. We have already observed widespread noncompliance and numerous existing distortions in current production structures, and we assume that current tax levels remain too low to encourage abatement. The second case evaluates the outcome under a system of pollution charges where the fee is set at a level that may induce firms to abate. In moving from the first to the second case, we compare the welfare gains from reduced pollution net of abatement costs to the increment of new allocative losses associated with increased taxes and monopoly elements in the existing market structure. Some limited abatement information from the region aids the discussion.

To illustrate possible costs and benefits of a pollution tax under imperfect market conditions, the polymetallic industry serves as the representative polluter. This industry manifests monopoly-like characteristics in Krasnoyarsk and other Siberian subregions, and is one of the greatest emitters of pollution both by volume and by risk. A high-risk compound, tetraethyl lead, illustrates the possible gains from a pollution tax in terms of increased social welfare when abatement occurs. Figure 5.2 illustrates the distribution of industrial emissions of tetraethyl lead (thousand tons *per annum*). Polymetallic production produces the greatest magnitude of lead pollution in Siberia.

Figure 5.2



Source: Siberian air pollution database, IIASA

Lead imposes particularly high costs to social welfare. Previous risk-grouping of the chemicals in the Siberian database allows policy makers to pursue policies generally appropriate for pollutants with different social costs and abatement characteristics. In general, gains to social welfare from pollution reduction will be greater for high-risk chemical groups than lower risk ones. Using a different grouping of chemicals, for example a lower risk compound such as CO_2, would bias the model towards a larger welfare loss associated with monopolistic distortions. The marginal social cost of production associated with each level of abatement activity is approximately constant over the relevant range. The welfare gain from reduced pollution net of abatement costs is estimated as

(5.6) $$W_{gain} = Q\left[SMC_0 - SMC_t\right]$$

where SMC_0 and SMC_t represent social marginal cost before and after the imposition of an emissions tax. Assuming that emissions fall because of the tax, the welfare gain is the reduced cost (private plus external) per unit of output times the level of output.

At the same time, an emissions tax may encourage the polymetallic industry to reduce its output in official markets. If this happened the associated welfare loss would be

(5.7) $$W_{relative} = \frac{\Delta Q[P - SMC_0]/P}{Q[SMC_0 - SMC_t]/P}$$

and

(5.8) $$W_{loss} = \Delta Q_i[p_i - SMC_0].$$

Welfare loss is the loss per unit (the difference between price p_i and social marginal cost) times the change in output (area *TWVU* in figure5.3). Dividing (5.6) by (5.7) allows an estimation of the two effects. Its also possible to perform a rough assessment of the dimension of losses in social welfare.[3]

The Russian Federation does not publish reliable sector-specific data about abatement investments per unit of output. However, older studies in OECD countries indicate that a properly-functioning fee system may reduce abatement costs significantly through more cost-efficient patterns of abatement and technology (Robinson 1983). Possible savings must be balanced against the effluent charges that sources have to pay. Inflation, rapid decreases in production output due to economic crisis, and general economic instability interferes with an accurate analysis. Consider a (conservative for Siberia) 5 percent increase in production costs due to an emissions tax for the polymetallic industry. Control costs and effluent fees both make up 2.5 percent.[4] Price elasticity of demand for Siberia's polymetallic sector is uncertain, but it is fairly elastic for other major industries (including power generation, chemicals, etc.). Using an elasticity of two, an estimated value of $\frac{\Delta Q_i}{Q_i}$ for the polymetallic sector is

(5.9) $$\frac{\Delta Q}{Q} = |\eta|\frac{\Delta p_i}{p_i} = 2(0.05) = 0.1$$

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[3] The first term in (5.8) is expressed in terms of a production index where 1990 serves as the base year.

[4] Oates and Strassman (1987) note that this division is important because control costs represent actual social costs, while tax payment represent a transfer from the social perspective.

An effective emissions tax (i.e. firms pay it) which is high enough to induce abatement might be associated with a 10 percent reduction in output for the polymetallic polluter. Returning to (5.8), the difference between price and private marginal cost not offset by the marginal social damage of pollution, $[p_i - SMC_0]$, is

(5.10) $$\frac{[p_i - SMC_0]}{p_i} = \frac{[p_i - (PMC + MSD)]}{p_i}$$

where *MSD* represents the marginal external cost associated with emissions. Finding exact magnitudes for these variables is difficult. However, given the health effects of lead and the associated social costs (Bridges and Bridges, 1996; Mnatsakanian, 1992), the benefits from air pollution reduction—at least for the high-risk groups of chemicals—probably outweigh the costs of abatement by a good deal. Lave and Seskin (Lave 1977), for example, estimated the health *benefits* from meeting environmental standards for ambient air quality in the United States at about $16 billion as compared to the EPA's estimate of $9.5 billion for abatement *costs* in the mid-1980s.

Given many obstacles to making investments, abatement costs may be more expensive for managers in Siberia, so, like Oates and Strassman (*ibid.*) abatement costs are doubled and another 3 percent are added to account for residual damages. When taxes are too low to induce abatement investments or where enforcement is poor, marginal social damage equals about 10 percent of marginal costs of abatement. The estimate implies that an effective emissions charge tax could reduce the marginal damages for the polymetallic industry by up to two-thirds. In comparison with studies by the EPA that report emissions reductions of 50 to even 90 percent in some cases for abatement efforts, this assessment appears generous.

Following this methodology we look for a figure for monopolistic markup over marginal cost for our representative industry. Lacking this information for Siberian sectors in the current period, we rely on a study performed by Shepard (Shepard 1972) which finds that the margin of price over cost rises at an approximate ratio of 1:10 in the four-firm industry concentration ratio (C_4). Assuming that freely competitive markets involve a C_4 of 20 and that "monopolistic" industries have a typical C_4 of 70, we would have a level of monopolistic prices exceeding competitive prices by about 5 percent. Under current economic transition, it remains unclear whether such predictions about price differences based upon market structure apply to Siberian firms. However, to make a generous estimate, we arbitrarily choose a ten percent markup price for monopolistic firms over private marginal cost. This leaves an estimate of 3 for the difference between price and social marginal cost as a percentage of price. If the markup were only 5 percent, then the social marginal cost would actually exceed the monopoly price for the polymetallic industry so that a contraction in output due to an effective emissions tax would raise social welfare, rather than lower it. This may hold true in some Siberian cases, but lack of empirical data make the evaluation cursory.

Returning to (5.7) we see that the denominator of the second term follows from the profile of the polymetallic industry. The representative reduction in marginal social damages from the emissions charge program is 5 percent of the price (assuming that benefits are two times the level of abatement costs). Subtracting 2.5 percent of the price for abatement costs we have a net reduction in social marginal cost of 2.5 percent of the price. Equation (5.11) estimates the monopolistic welfare loss from an effective emissions tax as

(5.11) $$W_{relative} = (0.1)\frac{0.025}{0.025} = 0.1,$$

or about an order of a magnitude smaller than the welfare gain from reduced pollution (net of abatement costs). Given the lack of reliable data for Siberian industry, this estimate depends upon previous studies performed in OECD countries. The choice of parameter values is also arbitrary; however the calculation here for a representative industry and compound under two scenarios of an emissions tax is conservative relative to the magnitude of the potential welfare loss from reduced monopoly outputs. Given the degree of environmental degradation in Siberia due to industrial emissions, marginal costs and losses from other parameter values would likely not rival the size of gains from improved ambient air quality. The incremental output distortions that a monopoly may experience due to a system of emissions charges is, therefore, likely to prove relatively insignificant for Siberia compared to feasible environmental improvements under current policy. This evaluation indicates that allocative losses associated with monopolistic distortions are much smaller in magnitude than gains in social welfare associated with pollution abatement. If the emissions charge system were effective, social welfare could increase in spite of decreases in output. However, empirical evidence indicates falling social welfare in terms of human health, increasing pollution intensity in monopoly-like firms such as the energy and metallurgy complexes, and decreasing emissions tax revenues. Policy shortfalls prevent the capture of gains in social welfare from pollution abatement in the current period.

A final note on monopoly response to an emissions charge system deserves mention. The model implicitly assumes that the monopoly pays its taxes (i.e. that the tax is both enforced and is high enough to induce abatement), and that once collected these taxes are not recycled back to the firm. The political and economic realities in Siberia violate these assumptions. Enterprises argue that, combined with dramatic declines in official industrial output, a high emissions tax levels could economically impair Siberian firms. Due to the weak financial condition of many firms, a tradition of soft budget constraints and widespread tax evasion, environmental authorities often grant pollution charge "credits" rather than actually collecting tax dues. These credits are intended to allow firms to use their charge payments to finance environmental protection activities such as abatement technologies. But the rules are so loosely defined and monitoring of Siberian firms so sporadic, that charge credits also appear not to provide abatement incentives. In addition, enterprises (particularly monopolistic ones which also carry political clout) can negotiate away tax obligations because payment is not required if enterprise profitability falls below a certain level.

The actual channels through which taxes passed remain opaque in the region, dampening the incentive effect of the tax. In principle, enterprises pay pollution charges into a system of regional and local (to a lesser degree federal) environmental investment funds. The funds are hypothecated (earmarked) specifically for environmental purposes, but environmental authorities have no systematic way of ensuring that funds are properly used. In an effort to provide firms with an incentive to engage in abatement activities, Siberian environmental officials have been observed to assess charges to enterprises and then provide a similar sum to the enterprise for poorly-defined environmental investments (Golub 1995). The Slavic Research Center at Hokkaido University, provides the following information about abatement investment and costs in Siberia. In 1997, Siberia had 7,407 “polluting companies,” of which an estimated 6,363 of those firms had loosely-defined environmental projects. Overall Russian investments in environmental protection projects of this sort (million rubles) amounted to 592,806.8, and equaled approximately 18,511.3 million rubles in Siberia. In some cases, tax credits may become part of the personal profits of managers (Golub 1994). The allowance for tax credits in the current charge system attempts to address allocative distortions but fails, due to weak monitoring and enforcement of the application of the credits for abatement purposes.

Misallocation and mismanagement occur, with the result that investments in abatement technology likely do not. However, a study by Dumnov (Dumnov 1992) indicates that 80% of managers of enterprises surveyed reported that they had increased the prices of their products or reduced production to compensate for the emissions fees charged. The same study reported that the average firm spent 0.2% of total annual receipts on charges for reported emissions. Rather than creating incentives for monopolistic producers to invest in abatement, when pollution taxes are recycled and inappropriately used, allocative efficiency declines as well as social welfare.

5.4 Non-profit maximizing firms and the emissions tax

In addition to monopoly-type firms, Siberia also has a portion of firms which appear not to operate strictly following profit-maximizing objectives. Many researchers find evidence that Siberian firms in the transition phase may not actually operate as profit maximizers (Ahlander 1993). These models show two additional types of polluters: firms which maximize a more complex objective function that incorporates values other than profit levels, and public enterprises. To analyze the possible responses of such firms to an emissions tax, the author uses models of bureaucratic behavior. Organizational models of firm behavior such as Williamson-type models treat managerial decisions in the context of the firm’s internal structure and environment. To explore the impact of effluent charges on public decision-makers, who may neither maximize profit nor minimize costs, we look at a variation of Niskanen’s model of bureaucratic behavior (see (Niskanen 1977); (Oates 1978)), which bears some resemblance to Williamson's model of private managerial maximization (Williamson 1963).

Following a history of central planning rather than market interactions, this method suits the present analysis. Models of organizational behavior permit a degree of managerial slack, in terms of budget decisions, timelines, etc. The existence of such slack bears implications for the behavior of a public enterprise under an emissions charge system. The case for such a system assumes that increasing the cost of polluting will induce firms to use less of those compounds in the production process relative to other inputs. In the longer term, emissions taxes should provide an incentive for firms to engage in greater research and development activities that facilitate less expensive, more efficient production and abatement technologies. However, the incentives to change production policies quickly in response to relative price changes appear extremely weak in the context of Siberian management. Already squeezed by the economic recession, cutbacks in production levels, poor internal finances, and a managerial staff relatively new to market signals, Siberian public enterprises may respond less to the emissions tax than to other, higher priority, demands. Changes in production methods, especially to less polluting ones, may involve major changes in equipment. Considering the aging structure of Siberian equipment in general (table 5.3), these firms must make major technical improvements to compete.

However, studies indicate that regional enterprises are "putting off the inevitable" task of investing in better equipment. Fischer *et al.* (Fischer 1998) note that instead of witnessing greater rates of external trade, Siberian enterprise has increased inter-oblast trade and decreased exchange with external areas, indicating substandard products unacceptable in wider markets. Such enterprises may employ some of the "fat" in firm budgets (or may operate under soft budget constraints) to avoid the effort and possible complications associated with the adoption and adaptation or development of new production and abatement techniques. In addition, the concentration of industry in Siberia may induce firms to respond more slowly to changes in externality prices and innovate than would competitive firms (Kamien 1975). In the model below, emission charges may not work well in terms of cost-minimization.

The Williamson (Williamson 1963) model illustrates a firm with a more complex objective function.[5] Williamson formulates a managerial utility function that incorporates "expense preferences" for expenditures on staff (L), managerial emoluments (M) (extra salary and perquisites), and "discretionary profits" consisting of the difference between actual profits and the minimum profits demanded. The firm maximizes

(5.12) $$U = U[L, M, \pi_R - \pi_0 - T] \quad \text{subject to} \quad \pi_R > \pi_0 + T$$

or

[5] The author employs Williamson's notation, except where it conflicts below with formerly used notation.

(5.13) $U = U\{L, M, (1-t)[K(X) - C(X) - L - M] - \pi_0\}$

where

K	= revenue =	$PX; \frac{\partial^2 K}{\partial X \partial L} \gtreqless 0$
P	= price =	$P(X, L; \varepsilon); \frac{\partial P}{\partial X} < 0; \frac{\partial P}{\partial L} \gtreqless 0; \frac{\partial P}{\partial \varepsilon} > 0$
Q_i	= output	$PX; \frac{\partial^2 K}{\partial X \partial L} \gtreqless 0$
ε	= demand shift parameter	
C	= costs of production =	$C(X)$
π	= actual profits =	$K - C - L$
π_R	= reported profits =	$\pi - M$
π_0	= minimum (after tax) profits demanded	
T	= taxes, where t = tax rate and $\pi_R - \pi_0 - T$	
$\pi_R - \pi_0 - T$	= Discretionary profits	

To treat waste emissions and the effluent fee explicitly, we alter the Williamson model slightly to distinguish between emissions (S_i^p) and all other inputs (R), so (5.13 becomes

(5.14) $U = U\{L, M, (1-t)[K(g(R, S_i^p)) - P_R R - zS_i^p - L - M] - \pi_0\}$

where P_R is the price of other inputs and z denotes the effluent fee. Maximization of this utility function yields the cost-minimizing combination of factor inputs as one of the first-order conditions

(5.15)
$$\frac{P_R}{z} = \frac{\frac{\partial Q_i}{\partial R_i}}{\frac{\partial Q_i}{\partial S_i^p}}$$

Firms that may technically operate inefficiently can still effectively minimize pollution abatement costs. Because abatement activities contribute nothing to staff or emoluments and reduce discretionary profits, the firm's managers have an incentive to minimize the expenditure on abatement (equaling emissions taxes plus pollution control or reduction costs). The firm does this by engaging in abatement activity to the point where marginal abatement costs equal the emissions tax for *reported* emissions. If a firm sees some sort of "good will" benefits accruing to it from pollution abatement, it may incorporate abatement into its managerial utility function and extend abatement activity past this point. However, it is more likely in the Siberian context that firms undertake only token abatement activities, enough to avoid more stringent monitoring and enforcement of penalties. In spite of rising awareness and emphasis on environmental compliance by the Siberian public (DeBardeleben 1995) the "good will benefits" will likely come more through governmental relations and other types of economic power than through investment in environmental protection. Non-profit maximizing firms may view such taxation as a cost which it can minimize through rent seeking, evasion, or other inefficient use of resources which do not forward an environmental cause (Migue 1993).

In a time of radical transformation of economic and institutional rules, enterprises may show some preference for the perquisite "ease of management" which could introduce some inefficiency in the allocation of abatement quotas among polluters. Officials are likely to have some incentive to economize on abatement costs. However, the degree of managerial slack may prevent rapid diffusion of technology and information.

Decision-makers in public enterprise's seek to maximize an objective function that maximizes the utility gained from the enterprise's output (Q_{pub}) and its level of earnings (p_{pub}).

(5.16) $$U_{pub} = U_{pub}\left(Q_{pub}, p_{pub}\right)$$

Officials seek an increased output, which enhances the enterprise's power and prestige vis-à-vis Moscow and its capacity to influence the course of events. Some authors argue that officials also place a high value on the agency's "discretionary budget," the excess of the agency's funding above its necessary costs. This "extra" in the budget can be employed for a variety of purposes ranging from higher salaries, reduced effort, increased staff and additional facilities (Migue 1974). Given past evidence about managerial behavior under a centrally planned economy, it is reasonable to assume that such behavior still persists to a degree in Siberian public enterprise.

The production function depends upon emissions and some other output. In addition, some budget constraint applies to the enterprise,

(5.17 $$B_{pub} = \lambda_R R + zS_i^p + cp_{pub}$$

where c is the constant marginal cost of perquisites. Variable R includes only the minimally necessary quantity of other inputs such as labor to provide a given output; likewise, resource price λ_R represents the reservation wage. The enterprise views extra salary and labor as perquisites. Officials in Moscow determine the budget for Siberian public enterprise.

Within this framework, the official must maximize the utility function (5.16) subject to its budget constraint

(5.18) $$M_{pub} = U_{pub}\left[Q_{pub}\left(R_{pub}, S^{p}_{pub}\right)p_{pub}\right] + \left[\lambda_R R_{pub} + zS^{p}_{pub} + cp_{pub} - B_{pub}\right]$$

Solving (5.18) the bureau minimizes pollution abatement in ways that resemble the Williamson model. It minimizes costs which do not generate perquisites. Emissions taxes, assuming no recycling of fees or pollution credits, don't provide any utility for the manager of a public bureau and are effectively lost money. By minimizing pollution abatement costs, the public enterprise maximizes the remaining budget for the procurement of perquisites. Like cost-minimizing firms, a public agency behaving in this way has an incentive to pursue abatement activities up to the point where marginal abatement costs equal the emissions tax.

Because the survival of public enterprise generally doesn't rely on aggressively tight management, they need not respond as quickly to policy or price changes and to new technologies as competitive firms must. Although an emissions tax does present public managers (and private) with an incentive for abatement, due either to lax enforcement, too low of charges, or a combination of both, little abatement activity can occur. Similarly, if public enterprises falsely report or receive subsidies used for activities other than abatement, pollution levels may not decline. Siberian firms appear driven by motives not entirely clear to western market analysts. As Wilson *et al.* (Wilson 1980) observed, "We view these agencies as coalitions of diverse participants who have somewhat different motives…[Public agencies] prefer security to rapid growth, autonomy to competition, stability to change…Government agencies are more risk averse than imperialistic." The observation suggests that Siberian public enterprises will respond only slowly to economic incentives for environmental improvement. The actual structure of Siberian markets may play an important role in firm behavior. The model presented in chapter six explains how decision makers might choose to invest in legitimate market activities such as pollution abatement investment or to invest in utility-maximizing activities such as investments in "power relationships." This builds upon the present understanding of public bureau behavior. It appears that in this economic framework, Siberian firms experience greater incentives to alter reported emissions rather than actual emissions. Tax payments do not appear effective, almost regardless of the level, because of policy loopholes and individual firm's abilities to avoid or evade taxation.

5.5. Conclusions

Chapter five has investigated firm response to the emissions tax in Siberia. Chapter four noted drastically falling real charge rates, leading some authors to conclude that raising taxes will provide an effective remedy for the ailing program. Yet recent literature emphasizes that the actual level of taxes, regardless of the theoretical emphasis on "getting the prices right," affects firm response to the emissions program less than other factors. Most of the empirical research has focused on estimating the impact of environmental taxes on the use of the taxed commodity, and occasionally on closely related sectors. The studies which seek to estimate elasticities of demand and substitution include time-series estimates and estimates using micro data on individual firms, industries, or households. Although the data requirements for such estimates are small, it remains difficult to distinguish price effects from other variables such as income and output price levels, especially in a transitional economy. What such studies generally show, however (Hunt 1989); (Brannlund 1991), are that an emission tax which increases a product price significantly reduces the consumption of that product only slightly. In addition, the tax has only negligible impacts upon the concerned industries. A key study for the purposes of understanding Siberia's pollution problem, Ingham and Ulph (Ingham 1990) found that the scope for changing resource efficiency is much less with existing, vintage plants and machinery than when new machinery is installed. The authors find that to achieve speedy results, a much higher level of taxation (set in a system where noncompliance is not an option) would be required than if resource consumption changes were sought over a long time. This implies for Siberia that the price elasticities of pollution-related products are quite low. Emissions taxes alone may not prompt aging firms to invest in abatement equipment or more efficient production technology, and only as compliance rises and real tax levels begin to be felt and paid in cash by firms will the existing program achieve its joint goals of revenue and abatement.

Chapter five presented three major types of market structure and found that firm response to the emissions charge depends less upon tax rates than upon likelihood of getting caught cheating, general economic conditions, and the institutional framework of the environmental program. While the findings imply that Siberian firms will negatively to the emissions charge, the analysis does provide insights about the kinds of issues which become important to differently structured enterprises. Table 5.4 clusters the major polluting industries from chapter three into the firm structures discussed here. It summarizes the most important issues for these three types of firms in Siberia.

First, for the standard profit-maximizing firm, the effects of various policies on the expected average costs of firms are important and may not always work in the same direction as the effect on the individual firm's marginal decision. While increases in costs associated with pollution control measures will limit profit maximization, making the emissions charge stricter at the margin might actually increase the amount of waste released by the firm. The size of violation increases at about the same degree as the increase in emissions taxes or the decrease in allowable waste levels. The recommendations of a majority of the scholars writing about emissions tax levels in transitional economies would produce a perverse outcome of more rather than less pollution.

In addition, because of evasion, it may be wise to rethink policy goals which equate efficiency with the equality of marginal damages of pollution with marginal abatement costs. With estimates that up to half of anticipated state revenue goes uncollected, it is unlikely that—in the generally faulty Russian taxation framework—a higher emissions charge will produce the desired results. A 1998 survey revealed that, among employed persons, only 41 percent said that taxes are deducted when their employer pays wages. Of these respondents, 56 percent responded that there is no need to pay taxes because the government will be unable to detect evasion, and 77 percent believed that a cash payment to official tax collecting bodies would facilitate evasion (New Russia Barometer Survey VII 1998). Instead it may be more prudent when marginal damages are set equal to the marginal costs of physically eliminating the waste plus the additional costs of enforcing any pollution control instrument to the extra degree required to induce the unit reduction in pollution. This implies that enforcement costs will rise as officials attempts to reduce actual pollution through, for example, stricter monitoring. Marginal costs of abatement increase, including additional costs of enforcing pollution taxes. This would argue for a reinterpretation of the rule that pollution should be eliminated to the point where marginal damages equal marginal costs of abatement. Rather, officials might wish to minimize the damage caused by pollution plus the cost of treating or preventing pollution plus the cost of enforcing the taxes by which pollution control is encouraged (Harford 1978).

Second, for profit-maximizing firms including those which exercise some control over market prices of a good or service, the discussion indicates that an effective emissions tax would lead to reductions in firm output. However, if high-risk chemicals are also reduced, social welfare may improve. In Siberia, though, firms often receive tax credits which they are officially obligated to use for abatement activities. Due to a lack of enforcement and strict definition of appropriate investments, the tax may lead to decreased output and little or no abatement activity as tax credits are used for non-environmental purposes. Social welfare and efficiency decrease, particularly as tax levels increase.

Finally, firms that do not necessarily maximize profits do react to the emissions tax, but not necessarily in expected ways. The Williamson model and the Niskanen models both predict that managers of bureaucratic agencies do have a real incentive to minimize costs when investing in abatement. However, as the model in chapter six shows, such firms may minimize abatement investment completely. That is, by investing in relationships with officials, such bureaus may find ways to completely avoid their emissions charge obligations.

Table 5.4 Firm response to an emissions tax by structure cluster				
Firm type	Probable response	Important variables	Less important variables	Policy implications
Profit-maximizing price-takers • Machinery and tool • Construction materials • Forestry • Food production • Textiles • Light industry	Underreport actual pollution levels, will invest in abatement equipment if monitoring increases, increase production in informal markets to survive transition period	Probability of getting caught and violation size important, relative size of informal markets and costs of producing in formal and informal markets (taxes raise formal costs) influence whether such firms react to market signals	Penalty rates not so important when separable from monitoring	Improved monitoring of actual and reported levels, increased probability of detection; closer monitoring of machinery and construction may reduce high-risk emissions
Profit-maximizing firms with some influence over market price • Polymetallic • Chemical • Fuel • Oil refining	Availability of tax credits discourages abatement, firms restrict output and use tax credits for other purposes, less likely to invest in abatement equipment	Whether taxes are recycled to the polluter, monitoring, ability of firm to receive tax forgiveness or avoid taxes by underreporting or producing in informal markets	Tax levels less important when tax credits available. Some firms may increase pollution to have access to larger tax credits, which may not be invested in abatement activities.	Restrict tax credits for oil refining in East Siberia, in general require monopolistic firms to pay taxes and increase effective monitoring of current tax levels. Monitor use of environmental credits.
Non-profit maximizing firms • Energy production	Invest in relations rather than abatement, some efficient use of abatement equipment when effective monitoring present, otherwise underreporting.	Ability of firm to invest in relations rather than market investments in abatement, importance of bureau's good or service (probability of forgiveness)	Tax levels less important than effective monitoring and reduced ability to cheat	Strengthen market institutions, reduce rent-seeking opportunities, increase effective monitoring

The discussion of firm response to an imperfectly enforced pollution tax revealed interesting results that illuminate the particular complex of issues in Siberian environmental policy. Our modeling exercises revealed how differently structured firms respond to an emissions charge. Although varying in their degree of response, we see that monitoring, possible evasion, reported pollution levels, and institutional factors seem to play a larger role in the implementation and execution of an emissions charge system than does the actual structure of the firm. This implies that greater emphasis on the institutional framework of the emissions charge system might induce greater abatement and compliance. We explore these issues further in chapter six.

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Chapter 6: Environmental tax compliance

6.0 Introduction

The literature on tax compliance[1] has burgeoned since Allingham and Sandmo (Allingham 1972) extended the influential work of Becker (Becker 1968) on law enforcement to taxation using modern risk theory. At the same time, the equally copious literature on environmental taxes has largely overlooked the vital importance of compliance in the effectiveness of this policy tool to achieve abatement, revenue, or other goals (Siebert 1998). Harford (Harford 1978) and Harrington (Harrington 1988) do touch upon the importance of imperfectly enforceable pollution taxes and institutional leverage and Franzoni (Franzoni 1998) writes, “institutional and procedural features matter. They impose costs on taxpayers and affect the outcome of the…process.” Yet the majority of the environmental taxation literature bases its findings upon the underlying assumption that market forces induce high environmental compliance rates among risk neutral firms. Even one of the most comprehensive works on the issue of pollution charges in transitional economies touched compliance issues only peripherally (Bluffstone 1997). A good deal of the literature on environmental taxation in transitional economies assumes that polluting firms operate within competitive, formal markets. This assumption is feeble, particularly for a remote and economically segmented region such as Siberia. The ability of enterprises to diversify risk between formal (and taxable) and informal (and non-observed, non-taxable) economic spheres leads us to expect that only in limited cases will the current pollution charge system actually provide market incentives for abatement and greater investment in pollution-reducing technologies.

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[1] The author discusses corporate taxation rather than individual. This study discusses noncompliance with environmental taxes and penalties by polluting enterprises rather than income tax evasion by individuals.

Enthusiasm surrounds the implementation of environmental taxes, extending from internalizing costs to the possibility of a double dividend. Yet if a modest degree of compliance is not attained, taxes perform no better and possibly worse than other policy tools designed to control abatement. Evasion and other forms of noncompliance constrain the set of possible policies that can be implemented to address environmental degradation. Franzoni (Franzoni 1998) notes "When taxes can be evaded, taxation will prove to be an imperfect tool for pursuing government aims…which will be only partly achieved." One of the strongest arguments against a pollution charge system, it cannot be ignored in Siberia's imperfect institutional and market framework. Compliance and evasion play key roles in the ability of a pollution charge system to achieve its theoretic aims of inducing abatement or greater investment in abatement technologies. Compliance, and particularly the institutional aspects characteristic of Siberia, shape the impact of an emissions charge.

Chapter five evaluated the importance of finding the appropriate levels for pollution taxes. Many recent studies conclude that a key to greater program success lies in raising tax levels to induce abatement (Larson 1997); (Golub 1997); (Air Pollution Working Group 1998). Unlike these standard program recommendations, the compliance literature suggests that changing tax rates account for only a part of enterprise tax payment or abatement. One study of the tax reform programs in transitional economies reported that a general pattern emerged in which such economies copied taxation programs of OECD countries without first having built up the necessary institutional framework, which often lead to conflicting taxation and expenditure policy targets. One report (Vaskova 1996) noted "The high taxation levels…can be viewed as counterproductive both for the desired level of economic growth, and when taking into account the international experience, for the improvement of tax compliance and the capacity to collect tax revenue."

A complex interplay between institutional leverage, social perception of extra-legal activity, probability of monitoring and probability of that monitoring leading to enforcement of penalties, and an array of institutional rules influence compliance behavior. The literature indicates that the level of taxes is not necessarily the prime tool for inducing compliance (Allingham 1972); (Srinivasan 1973); (Yitzhaki 1974); (Baldry 1987); (Dubin 1988); (Feinstein 1991). Evasion constrains the ability of the tax to achieve revenue and abatement. Analysis of the situation in a dual economy scenario reveals the incentives and constraints which Siberian enterprises face. This chapter provides an alternative framework to better understand how and why Siberian firms react to emissions charges. This case may provide a suitable example of how firms react to market-based policies during the transition.

6.1 Historical background of tax compliance

Corporate taxes, as understood in OECD countries, did not play an important role in the former Soviet economic system. The Soviet state owned and controlled a majority of the economy. It derived the greatest share of its income directly from the state-owned assets. The state employed almost all workers, and served as the principle source of income for them. Income tax was deducted only for a handful of better-paid employees. One author observed "By virtue of the nature of the Soviet system of collecting state income, income tax, and similar taxes paid by individual citizens [was] unimportant, and consequently tax evasion by individuals [was] of almost negligible significance" (Feldbrugge 1989). He instead focuses on how the state gains control over resources. The Soviet central plan imposed a scarcity economy, which withheld resources at the outset. In this system, control was paradoxically based on the infringement of rules. The formulation of Soviet law in practice meant that the conduct of normal activity typically involved the violation of the state's legal system. A "history of noncompliance" for Siberia is based less on the appearances of tax payment and more upon the underlying institutional structures that shaped formal and informal market activity.

Were enterprises more compliant with environmental policy under the former command-and-control framework? Measurement is difficult, but the likely answer is no. The central goal in the former system—with a historical bias towards unrestrained industrial development—gave higher priority to meeting ever-higher output plans than compliance with environmental protection legislation. As early at 1917, Lenin began passing legislation to prevent environmental abuses (Belichenko 1968). In spite of this superlative beginning, the weak and young Leninist government could hardly implement laws related to production, let alone environmental disruption in remote Siberia. Hence, these laws met little compliance and set the tone for future legislation without enforcement (Mote 1983). At the institutional level environmental legislation and enforcement took on increasing importance with the implementation of the 10th Five Year Plan (1976-1980), which introduced the "polluter pays" principle (Articles 18 and 67 of the new constitution) and increased state investment in abatement. Although becoming an integral part of Soviet decision making, target implementation and firm compliance appears to have been low.

Figure 6.1 Ease of tax evasion in the Russian Federation

Source: (New Russia Barometer Survey VII 1998)

Institutional rules encourage noncompliance today. Written in 1972, Pryde gives the following report about compliance with environmental regulation in the former Soviet Union:

> A large gap appears to exist between the theoretical controls over industrial pollutants and the amount of control which actually takes place. The State Sanitary Inspectorate is authorized to order the closure, either permanently or temporarily, of any enterprise which is violating emission standards, and to forbid the opening of any new plant lacking the proper emission control devices. In practice, many plants have been shut down, but they have generally been either very small or ones having an out-moded technology. A serious polluter whose importance to the economy is beyond question…will certainly not be shut down out of pollution considerations…The managers of plants which are persistent air pollution violators are rarely brought to trial on criminal charges, but even when they are, the fines are tool small to be effective…The net result to date has been that Article 12 of the Russian Republic Conservation Law (Appendix 26) is simply not complied with."

Environmental attitudes and aspects of the former system persist almost three decades later in Siberia. Issues such as non- or underreporting, regarding environmental policy as illegitimate, viewing corporate taxes as immoral, and risk diversification through production in both formal and informal markets surround Siberia's environmental compliance problem. A hidden economy of pollution emerges in which sectors appear to underreport pollution and evade paying taxes for emissions. Similar to the situation in the planned economy where managers underreported production output to keep future output targets low, underreporting production volumes, sales, and related emissions became a common practice in the 1990s to avoid local taxes (Stoner-Weiss 1997). The legitimacy of a "polluter pays principle" is not yet an integrated part of industrial culture in Siberia. Instead, managers appear to diversify their production between formal and informal markets, the latter characterized by noncompliance and the use of pollution-intensive production methods. For formal production, the ability to trade ecotax arrears for industrial favors often ensures the enterprise that environmental authorities will not seriously pursue punishment nor question self-reporting as long as reports are not audaciously skewed (refer to chapter five; (Harford 1978)). The nature of the problem indicates that few reliable data sets exist to measure the problem. However, using engineering and tax compliance estimation methodology, it may be possible to at least estimate the magnitude of environmental noncompliance in Siberia.

6.1.1 Methodological issues

This section defines and outlines the author's procedure for estimating environmental noncompliance in Siberia using a set of indicators. Feige (Feige 1979) defines this "hidden economy," as activities which "go unreported or unmeasured by the society's current techniques for monitoring economic activity." Tanzi (Tanzi 1980) and Macafee (Macafee 1980) take a narrower view and define hidden economic activity as those acts which generate factor incomes (in this case utility from environmental free riding) which are not measured by official statistics.[2] For our purposes, we define environmental noncompliance as the deliberate or unintentional misreporting of emissions and the non- or underpayment of emissions taxes that result in the unauthorized use and overuse of air resources.

Discrepancy methods are widely used to estimate components of unobserved activities, particularly individual income. The author is concerned with estimating noncompliance with environmental standards and pollution fees due to underreporting and nonpayment. This approach offers a reasonable estimate of the magnitude of the phenomena, given the possibility of measuring underreporting and evasion by independent means such as concentration/emission ratios, comparison with human health statistics, pollution and energy intensities, and emissions tax revenue shortfalls. Only very rough approximations may be derived from such an approach for Siberia; however, because data is not directly related to the environmental policy in question, we may assume a relatively unbiased report of data with respect to pollution taxes. Unfortunately, the nature of data from the region suggests that other important biases may exist, and the author takes these into account.

[2] Cowell further draws a distinction between tax evasion and tax avoidance based on the *agent's perceived budget constraint.* "Avoidance" in its strict sense implies certainty on the part of the taxpayer at the time when he makes his decisions about the deployment of his assets and his report to the tax authority. "Evasion" activities involve a decision or series of decisions made under uncertainty with respect to the taxpayer's eventual tax liability (Cowell 1990).

The author first presents some modest indicators of noncompliance. Given the lack of data, we compare reported emissions with indicators of actual air quality (particularly human health statistics). The author accesses the following data: officially reported emissions per annum by industry and location, emissions standards (MPLs) and exceedances in designated Siberian locations, area, and the physical properties of given chemicals. Using a mass balance model, which assumes that factors accounting for the destruction or transformation of the given emission equal zero, the author calculates the divergence between reported and evident emissions. A set of health data shows a mild negative correlation between officially reported sinking pollution levels and rising respiratory illness, an ailment responsive to short-term changes in air quality. The inability to control other variables does severely limit the use of this statistic, although respiratory rates increase at an average rate of over 20 percent between 1990 and 1993 in selected Siberian regions. Next, the author compares the tax gap between expected and collected ecotax revenues, and identifies patterns of the firms most likely not to comply with emissions fees. The estimate here, while raising methodological questions and requiring further investigation, make a moderate case for noncompliance with the region's current air pollution policy.

6.2 Indicators of environmental noncompliance

Some disagreement arises over the degree of environmental noncompliance in different regions in the Russian Federation. This section to assesses non-enforcement and non-compliance based on a selection of abatement policy variables. Little concrete and Siberia-specific data are available on the level of emissions tax compliance of various industrial sectors at the local and regional level. No systematic survey has been performed about enterprise performance under the pollution charge system, and no official reports on the findings of environmental inspections have been published. However, an examination of sparse empirical and anecdotal evidence reveals the following pattern for Siberian compliance and enforcement of the emissions tax:

1. Surveillance of most pollution sources in the region is low, with average monitoring frequency every 2 to 3 years.
2. Violation of MPLs is expected and when discovered, the approximately fines and penalties are rarely assessed.
3. Polluters comply to emissions abatement programs only partially, depending upon the level of the charge, the size of the violation, and the probability of detection.

Because direct information about cheating is not available, discrepancies between officially reported pollution levels and collected fees suggests if environmental criteria are met and proper payment of emissions taxes occurs. This evidence shows an enterprise-specific, weak correlation between officially reported pollution levels and taxes due and possible unreported emissions and taxes. Underreporting or other noncompliance appears to vary across firms and across pollutants. The outcome may be a function of the environmental tax structure and the particular costs associated for each firm in reducing or emitting particular chemicals. A recent case study of Tula oblast (compare (Larson 1997)) reports that, at least for SO_2 emissions, "Tula enterprises are not only complying with their limits, but are emitting SO_2 far below [permitted] levels." One explanation could be relative ease in changing fuel inputs to reduce sulfur content. Another explanation could be that limits may be set too high or that the reports are incorrect. In contrast, several other reports (Kiseleva 1996); (Bridges 1996); (Mnatsakanian 1992) indicate that Siberian industries chronically violate maximum permissible concentrations (MACs) for human health in several locations. The author acknowledges the high degree of uncertainty involved in working with data from this region, as exact explanations of the calculus and definitions involved are usually unclear. The following presentation is an estimation of general trends in air pollution rather than a measurement of reliable data.

A careful perusal of the Siberian pollution database indicates that the self-reported *per annum* emissions levels of enterprises in Siberia contains discrepancies. A large number of sources appear to understate their emission levels and some appear to report the maximum permitted levels of given pollutants (MPLs) as actual emissions levels.

Table 6.1 Reported enterprise emissions and dosage discrepancies for selected Siberian enterprises

Location and industry	Chemical	Sector's reported emissions (1,000 tons) per annum	Recommended dosage: annual max/daily avg	Estimated reported dosage	Estimated actual dosage	Exceedance of MPL p.a. and in max. single concentration
Kemerovo Paper and wood	Formaldehyde	650	1.2mg/m³/2.5 mg/m³	1.4mg/m³	7mg/m³/27.5mg/m³	5/11
Omsk, Oil chemical	Ammonia NH_3	404,825	17mg/m³/24 mg/m³	8mg/m³	85mg/720m³/mg/m³	5/30
Tomsk Paper and wood industry	Hydrogen chloride HCl	456,378	.03mg/m³/10 mg/m³	0.03mg/m³	0.2mg/m³	-/6
Norilsk Building material	Phenol C_6H_5OH	3,280	0.01mg/m³/.30mg/m³*	0.009mg/m³	.04mg/m³/14.7mg/m³	4/49
Baikalsk Paper and wood	Methylmercaptan	650	10mg/m³	3mg/m³	220mg/m³/840mg/m³	22/84

Sources: (Mnatsakanian 1992); (Forestry 1994); author's calculations

Note the strictness of official standards: The USEPA standard for phenol is 5mg/m³

One example of what appears to be underreporting involves the oil refining industry in Irkutsk oblast. The sector reported an annual emission of 2,438 thousand tons of the hazardous chemical benzo(a)pyrene. The pollutant, produced as a gaseous by-product when certain carbon substances burn, is a carcinogen. Using the EPA sampling standards for this substance, the author estimates that this sector would *not* have exceeded the recommended airborne exposure limit of 0.1 mg/m^3 (an 8-hour time-weighted average, TWA), but that concentrations would have been approximately 0.0067 mg/m^3. In 1992, however, the State Committee on Hydrometeorology recorded the annual average concentration for this area as exceeding the MPL by 17 times. Maximum single concentrations in Bratsk alone exceeded the MPL by up to 124 times (Sostoyaniya 1994). Underreporting becomes evident. Other reporting discrepancies are reported for selected areas in the table 6.1.

The very rough deposition accounting performed here illustrates discrepancies between reported emissions p.a. and actual measured emissions. A key assumption made here is that the system is "closed," that emissions are not transported to other areas and that they are not destroyed or transformed before deposition

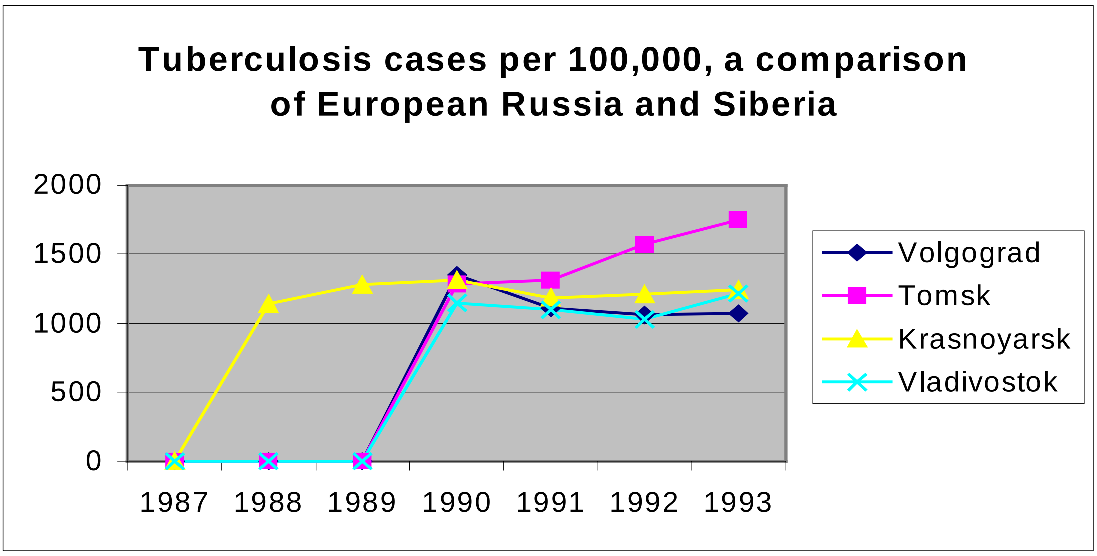
$C_i = \Gamma Q_i$ where C_i is measured concentrations of chemical *i*, Γ is the transformation function, and Q_i are reported emissions

What becomes interesting is to examine $\frac{C_i}{Q_i}$ and investigate how physical characteristics of the compound vary with reporting levels. For example, certain classes of chemicals may have roughly similar physical characteristics, regardless of factors which may become important for impact or economic reasons (such as risk to human health or damage to forest growing stock). Attributes such as deposition velocity and phytolisis across similar groupings should show a positive correlation with $\frac{C_i}{Q_i}$, while factors such as risk should not (Howard 1991). Concentration data were not available for samples of lead, mercury, or other heavy metals with high risk. Future studies may compare compounds within similar physical groupings and with varying risk groupings to examine the possibility of under or misreporting in Siberia. Relying on health data for diseases sensitive to heavy metal exposure such as cancer require a time period longer than that which could capture policy-related changes in emissions levels. However, given five to twenty-five fold penalties for the emission of high-risk compounds, Siberian enterprises would certainly face an incentive to underreport particularly toxic pollutants in order to avoid the higher charges.

Some industries report emissions which are very close to their permitted levels (this may be due to an effective ecotax, but it also indicates falsified reports). Spot checks often show exceedances of hundreds of times the maximum permissible levels, yet the application of penalties even in such dramatic (and probably relatively common) instances remains unlikely.

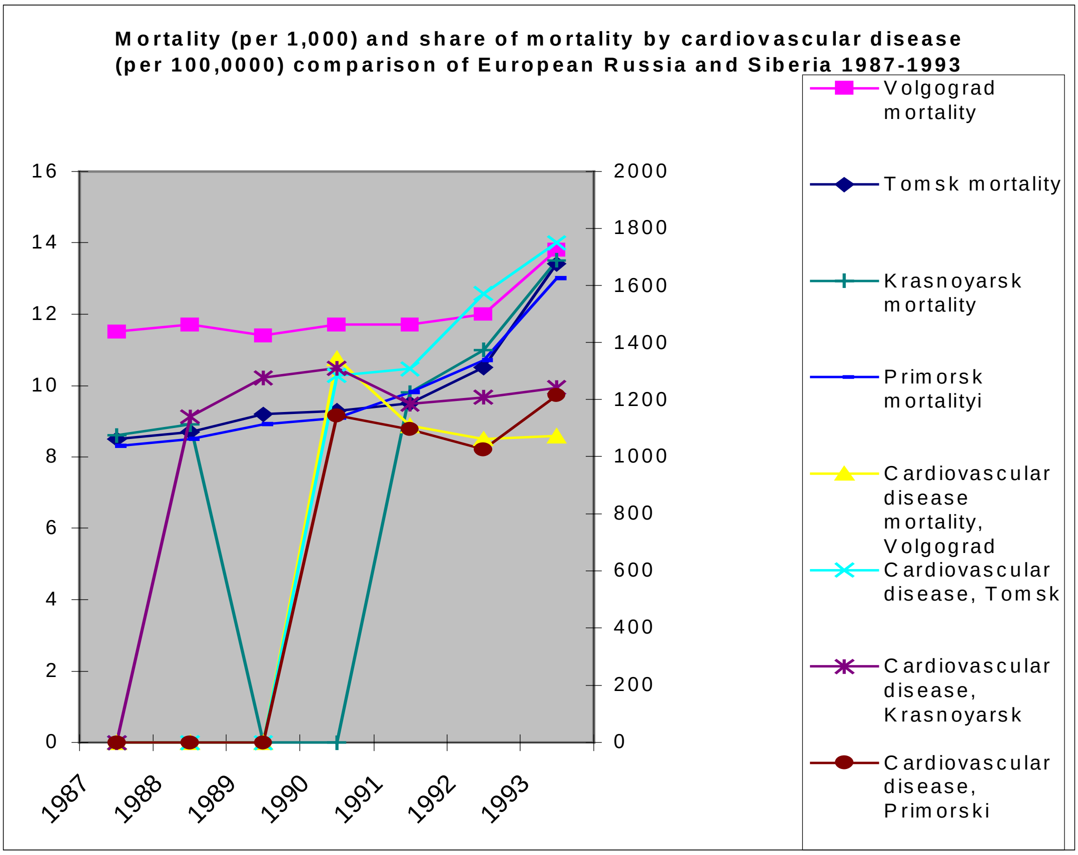
Weak empirical correlation between respiratory diseases among adults and children (a short term indicator of air quality) show an association between pollution intensity. Some of those indicators are presented below. It is difficult to link higher pollution intensities to increasing mortality in Siberian areas, due to corresponding deterioration of economic and social conditions. Nevertheless, general increases in cardiovascular and respiratory diseases do indicate that air quality may not be increasing proportionally to decreases in production.

Figure 6.2 (IIASA 1996b)



As a comparison of air quality conditions in European Russia and Siberia, the chart below compares general mortality rates with cardiovascular mortality rates. While in Volgograd, a notoriously polluted region in southwestern Russia, shows a rise in mortality rates and a decline in mortality due to cardiovascular disease, the trends covary in Siberian samples. Krasnoyarsk manifests a modest decrease in cardiovascular mortality and rise in mortality; however, we can infer that death from air-pollution related causes such as respiratory and cardiovascular illnesses has increased in Siberia during the early part of the 1990s. While declining health may be a factor of economic duress and other variables, it is also reasonable to assume that improved air quality could have significantly decreased mortality. This leads us to conjecture that Siberian ambient air quality has probably not improved, and may have deteriorated in spite of officially reported declines in all categories of emissions.

Figure 6.3 (IIASA 1996b)

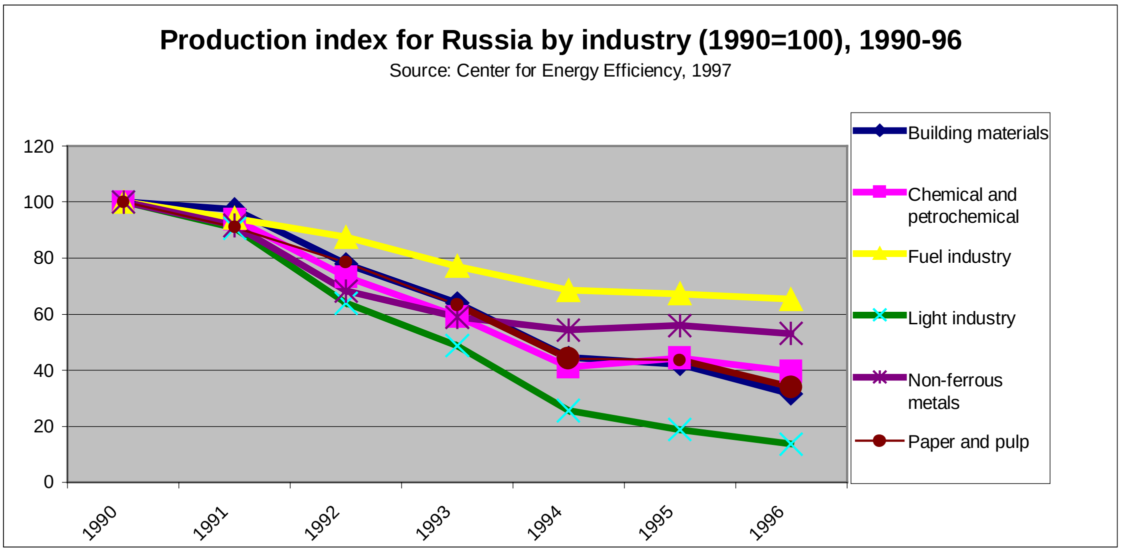


The Russian State of the Environment report for 1993 notes that "the current unsatisfactory state of the environment is a powerful factor influencing the health of the population" (Sokolovsky 1994). The existence of deteriorating, often pollution-related, health in Siberia can be used as a very rough indicator of firm noncompliance because, as previously explained, the federal environmental authority set environmental standards according to human health exposures to various pollutants. Were firms in compliance, human health should show lower morbidity in pollution-related diseases. Institutional factors and tax-related issues may account for varying levels of compliance, however, based only on human health statistics, not only does pollution continue to plague Siberia, but enterprises continue to disregard official standards and charges for pollution levels. Noncompliance in tax payments may serve as an indicator of the effectiveness of the current pollution charge policy to improve environmental quality directly and indirectly.

While not a direct indicator of pollution intensity, given increasing energy intensity per unit of output, pollution intensities might also be increasing in the region. Golub and Strukova (Golub 1994) noted that the decline in reported emissions between 1991 and 1993 could "be evidence for the efficiency of the pollution fee system, but we must also take into account the overall economic situation in Russia in this period. There were sharp reductions in all production indices…Although there has been a reduction in total emissions, the amount per unit of GNP has actually increased. Thus production processes appear to have become more environmentally intensive, and the pollution fee system is now less effective than the CAC [command and control] policy."

Production processes have become less efficient, due in part to the use of lower-quality, cheaper goods. This transformation could imply an increase in the pollutants associated with such production. Figure 6.4 shows a significant drop in all industrial sectors, but particularly light industry and chemical and petrochemical production. Other industries such as fuel and polymetallic (nonferrous metals) carry significant political weight (referred to later as an endowment of "relational capital") and, even in the absence of increasing local or international demand, continue to produce in spite of economic difficulties. What might occur given the increased energy intensities per unit of production and the low utilization of cleaning devices is a stable or slightly increasing, rather than falling rate of total emissions, especially for fuel particulates.

Figure 6.4 (CENEf 1997)

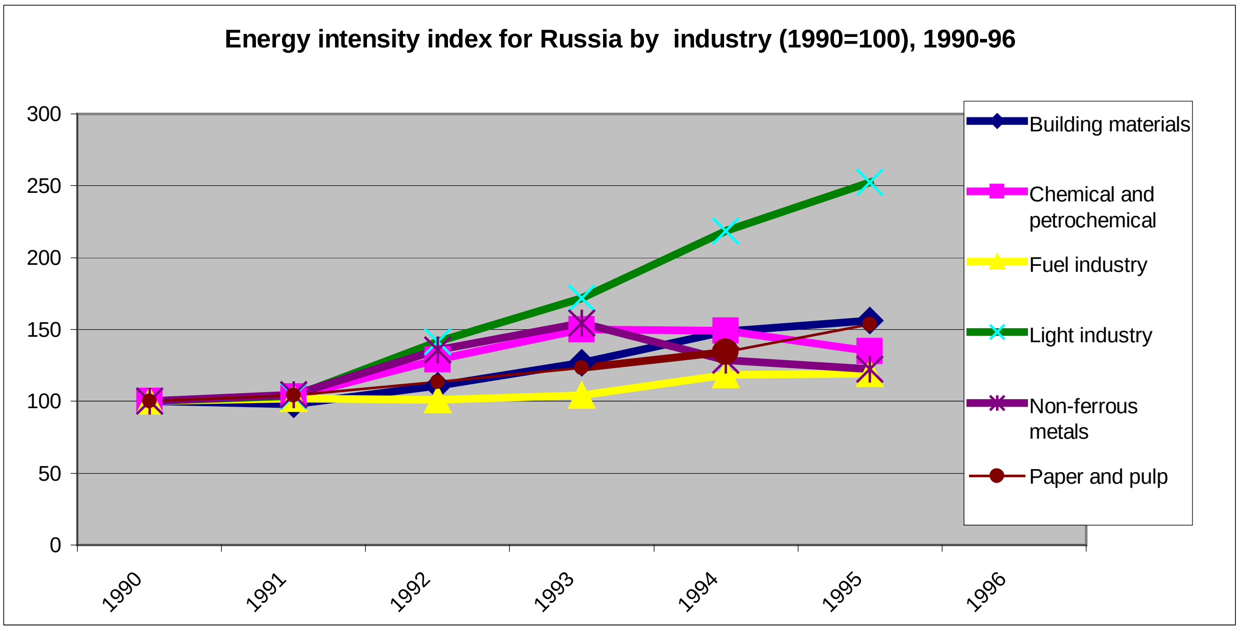


Though production has dropped off dramatically since the beginning of the transition period, indicated in figure 6.4, the necessary energy per unit of production has actually increased. This indicates decreasing production efficiency and, given the low utilization of abatement technology in many factory stacks,[3] may imply some underreporting in emissions. Officially reported declines in pollution and production may actually vary significantly from true emissions levels.

[3] In 1988, 33.7% of all Russian stationary sources of air pollution had air purification facilities. Of that, 21% of such facilities did not purify air to existing norms and 52.9% had been in place for at least 10 years. In 1989, the figure of factories operating with abatement technologies rose to 38%; however, the estimates for Siberia hovered as low as 6-18% of enterprises having any form of treatment for harmful emissions (Doklad 1990).

In 1995 the Ministry of Environment collected only half of the 600 billion rubles (US$130) it anticipated. Official reasons for this shortfall include enterprise insolvency or bankruptcy (Golub and Strukova, 1994). Another author estimates that about two-thirds of this gap can be explained by the lack of profits reported by enterprises (activity in informal markets, underreporting, evasion) and poor enforcement and monitoring. In the first quarter of 1993, polluting enterprises paid only 30% of the fees due. Firms managed to cancel their debts only after obtaining large-scale credit from the Russian Central Bank. Figure 6.4 charts the real shortfall in collected emissions taxes, in inflation-adjusted US dollars (Golub and Strukova, 1994)

Figure 6.5 Energy intensity index for Russia by industry 1990-96 (CENEf 1997)



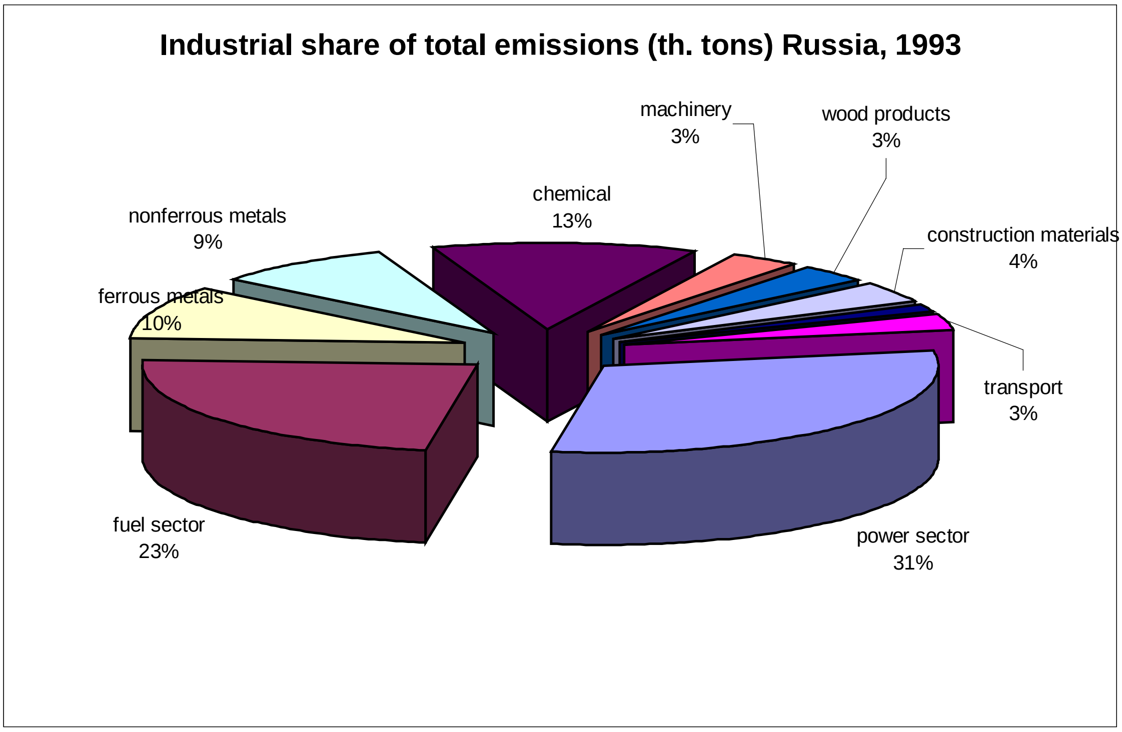
Goskomstat reported that the collection of emissions fees for pollution within and above MPLs varied among industrial sectors. The pattern which emerges indicates either forgiveness of emissions taxes, payment in-kind, or noncompliance to both emissions standards and the payment of pollution taxes. Table 6.2 presents sector-specific payments for 1995.

Table 6.2 Payments for Emissions into Ambient Air in 1995 (bn rubles)

Sector (Russia)	Below MPL	Above MPL	Total
Power sector	51.4	4.9	56.3
Fuel sector	45.2	36.1	81.3
Ferrous metals	21.3	22.1	43.4
Non-ferrous metals	59.1	17.9	77
Chemicals	7.6	5.3	12.9
Machinery	18.7	8	26.7
Construction material	24.5	3.4	27.9
Food production	22.9	7.6	30.5
Source: (Goskomstat 1996)			

Figure 6.6 indicates that the power-generating sector accounted for 32 percent of total industrial emissions in Russia in 1993. Given health statistics and official records of MPL exceedances for fuel-burning chemicals within Siberian cities, we assume that the power-generating sector should be responsible for paying a relatively large portion of emissions taxes. Given moderately rising energy intensity in the power sector, the power sector continued to account for a high percentage of total emissions. Yet the sector paid only 3 percent of taxes for charges on pollution levels exceeding MPLs in 1995, and 13% for charges on pollutants within the MPLs. Given the reported emissions—particularly of high-risk chemicals by the ferrous metals and chemical production industries—it appears that the fees collected do not represent actual emissions, either reported or unreported. This again suggests tax forgiveness, some type of tax offset, tax evasion, or tax default for these industries.

Figure 6.6 Industrial share of total emissions (th.tons) Russia, 1993 (IIASA 1996a)



In theory, an emissions tax bases charges on units of pollution, either by volume or risk. We would assume then that the payment ratios for the above industries would roughly reflect their share in total emissions. However, figures 6.7 and 6.8 show that proportionally, the most polluting enterprises appear to pay proportionally less emissions charges than others. This provides mild support for the thesis that the current policy does not meet with full compliance, either due to built-in rules such as a charge cap for public utilities or due to extra legal factors. .

Figure 6.7 (IIASA 1996a)

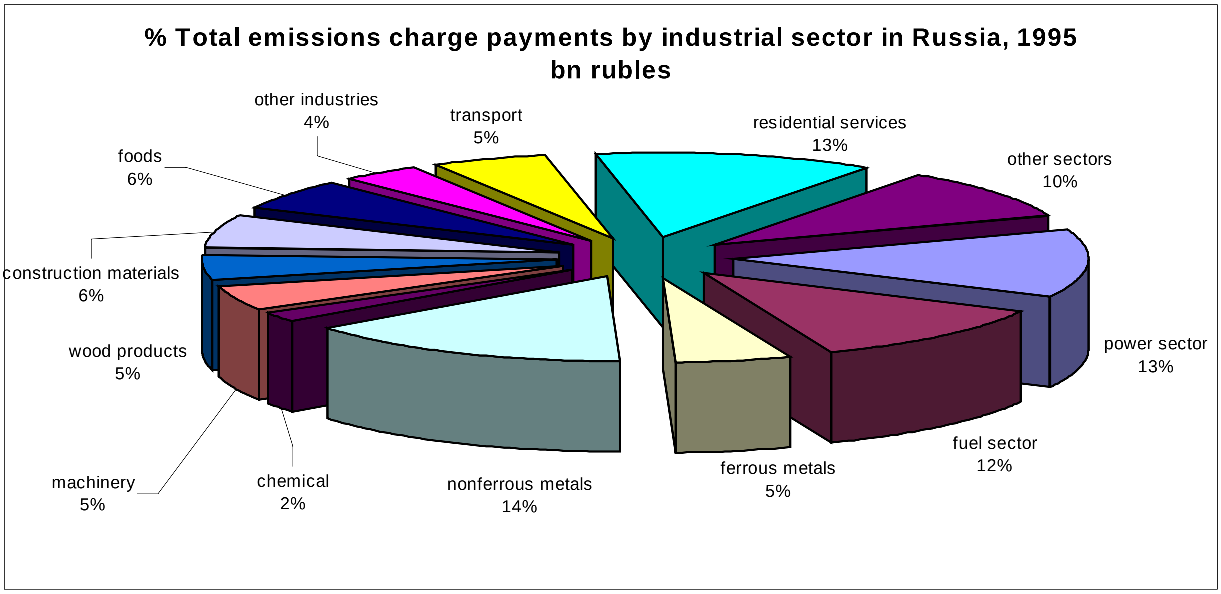
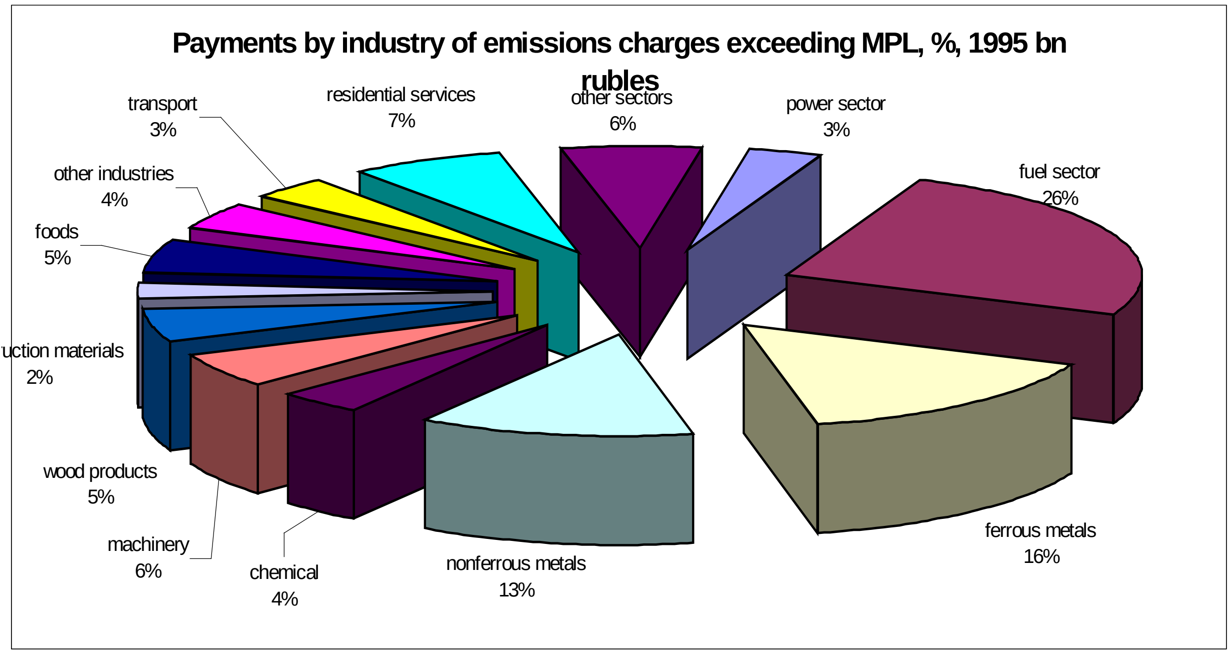


Figure 6.8 (IIASA 1996a)



Based upon the given charge rates discussed in chapter four, Siberian industry should have contributed the following taxes (based on MPL charges only) for emissions in 1993.

Table 6.3 Expected collected fee levels for selected air pollutants (rubles/ton) in Siberia		
Chemical	Total industrial emissions in Siberia, 1993 (th. tons)	Expected fee collection for emissions within MPL, (bn) rubles
NO_x	909.69	50
SO_2	3,169.48	209.2
Lead	195,143.00	2,146,.6
Dust	6018953.4	132,477.2
CO	25,60.33	2.9
Benzo(a)pyrene	84,849	280,001.7
Source: Russian Council of Ministers (Ministers 1991)		

This limited probe of payments and expected payments before deductions further supports the hypothesis that the emissions tax is either not paid, not fully paid, or that firms alter emissions reports to avoid payment of the tax.

6.3 Compliance calculus and Siberian firms: A model for analysis

It remains difficult to assess the magnitude of noncompliance. Anecdotal and institutional information suggest that underpayment and underreporting are rampant, and some of the reasons for this are discussed below. Enterprise management holds the widespread opinion that even if penalized for environmental noncompliance, the execution of these penalties will not occur. Legal exemptions exist within the program which excuse emissions offenders from their pollution charge liabilities if the expected fee accounts for “too much” of a firm’s profit.

With indications that Siberian enterprises do not comply with the current emissions tax system of reporting and paying fees, the next question to ask is *where* noncompliance occurs and why. The following section uses a managerial decision-making model to intuit which industries do not comply with the taxes and incentives imposed by the current charge-based air pollution policy and possible factors in those decisions. Using this analysis, a model predicts which industries will continue to operate emissions-intensively and which will reduce emissions.

The search for causes in policy noncompliance has occupied the literatures of economics and other social sciences. Finding the motivations to all types of evasion—taxes, underreporting, engaging in illicit markets, illegitimate trade, etc.—should lead policy makers to the point where they can create smarter and more effective policies. Examining Siberian pollution and reporting patterns above indicates a degree of possible noncompliance. In this section, the author examines the economic landscape in which polluters operate, and which stumbling blocks impede a less faulty performance of the environmental charge system. In general, some of the most common sources of noncompliance for transitional economies include the following:

- A need for environmental authority capacity building
- An inability to meet abatement goals and maintain production/employment levels
- Misinformation about permitted emissions levels, taxes due, abatement alternatives, monitoring procedures, etc.
- Lack of resources to either pay taxes or invest in abatement technologies

While these points guide a general discussion of Siberia's particular problem, some institutional evidence and recent research provide even more specific insight about the decisions faced by firms with regard to the ecotax. This research provides a springboard for our understanding of environmental noncompliance in Siberia. Particularly important, it indicates economic tools alone may not independently achieve pollution reduction. Examining the sources of noncompliance with environmental taxes points to economic and institutional conditions in Siberia which must be taken into account before assuming that a market-based instrument such as the pollution charge can simultaneously reach revenue and abatement goals.

Because of market, environmental authority, and institutional structure weaknesses, the ecotax does not provide meaningful incentives to abate, restructure production processes, or pay for the environmental services consumed. Environmental authorities and enterprises face a wide variety of incentives and constraints in undertaking any abatement-related action. Acts that Russian environmental law defines as compliance (or noncompliance) may occur for various reasons having little to do with the policy tool itself. Clarifying the ecotax-independent, first-order sources of compliance and non-compliance provides an insightful way of avoiding falsely characterizing compliance as tax-induced. This section examines some of the primary sources of environmental noncompliance, employing a model (Gaddy 1998) to make inferences about the environmental compliance behavior of an array of Siberian industrial sectors.

Environmental tax evasion and other forms of noncompliance take place within a larger framework of formal and informal economic activity in Siberia. The central aspect of the current economic situation is the ability of enterprises and state owned firms to escape the formal marketplace and operate in informal markets. The widespread use of informal markets provides the most important stumbling bock for the use of economic tools to address environmental externality problems. The following discussion explains the trade-offs involved in enterprise operations in formal and informal markets, and draws connections to the air pollution charge system in Siberia.

Siberia manifests the characteristics of a regional dual economy. This dual economy is comprised of a modernizing private sector and a "paternalistic, unrestructured" industrial sector (*ibid.*) which chooses to mitigate rather than reform. Some of the worst aspects of the economy are manifest here. Ironically, in the face of an official privatization program and financial stabilization efforts, the entire economic system appears to be diverging away from formal activities towards the shadow economy. Investment levels have dropped to less than 24% of 1990 levels (OECD 1997), only half of Russian enterprises showed profits in 1998, and estimates of barter trade are estimated at 70%. In Siberian regions, an average of 25% of operating firms are "unprofitable" and in some regions up to 55% of enterprises show no profits. Although investment levels in nominal rubles have risen, real investment levels for the years in our data set have actually declined (IIASA 1996b). In addition, the data do not specify a definition of "investment" and practical understanding of the term in Siberia may range from production costs to the purchase of equipment. No accurate estimates exist of the magnitude of barter trade (used here interchangeably with informal markets) in the region. The geographic and economic remoteness and economic concentration around a cluster of heavy industry might imply that barter trade plays an important role in the region's isolated economy. One author writes, "The immediate response of most regions to the collapse of central command administration system was to enact independently their own inter-oblast barter agreements," presumably as a way to mitigate the severe bottlenecks experienced in the period following 1990 (Stoner-Weiss 1997). As Gaddy and Ickes (1998) note "Rather than recording success in adapting to the marketplace, Russia's enterprise sector shows every sign of moving away from it." Boris Yeltsin gave an even more colorful representation of the situation in his 1998 State of the Nation address:

> The Russian market is still crammed with barter deals and is suffocating on mutual arrears. Enterprises live on borrowed resources, yet are unwilling to pay debts. Reasons are many. One key reason is that the budget is unrealistic. This country is an economy of irresponsible debtors. This practice is fallacious. Continuing is unacceptable. It is senseless and pernicious to try and dupe the economy."

Why has Russia not yet achieved at least partially functioning markets? What causes such exotic economic behavior? The typical analysis points to management incompetence, information distortions—even blatant and ill-willed dishonesty—as the main culprits. However, by viewing managers as rational actors responding to a unique incentive landscape within a dual economy, we gain insight into general enterprise behavior and environment-specific noncompliance. This framework allows us to understand why firms may choose to disregard the pollution charge system, and why real pollution may actually increase in the face of officially reported declines in production. It also adds insight into the possible distribution of continuing offenders and future abatement leaders.

6.3.1 Relational capital and market distance

The following model[4] shows that Siberian firms may choose to engage in formal and informal activities depending upon their need for cash and their need for tax leverage. The key variables in enterprise behavior include relational capital and the distance (in terms of effort required to achieve) from the market. Relational capital is goodwill that can be translated into informal economic activity. It determines the types of transactions and the degree to which noncompliance may be tolerated, and carries over from earlier periods. Feldbrugge (Feldbrugge 1989) comments,

> In a society of the Soviet type, where state control, state ownership, and state interference are extremely pervasive, permission and cooperation of state officials is required at almost every step…The use of administrative power or an official position in order to further the interests of a section of the state economy is …more widespread than the same use for the purpose of private gain.

Endowments of relational capital may ensure firm survival, even if formal market activities prove unprofitable. The enterprise's history and its particular costs of restructuring determine market distance. As firms alter their production portfolios to become more involved in formal markets and less in informal markets, they will have a greater likelihood to begin to respond to the constraints and incentives imposed by a pollution charge system such as that currently in place. Institutional frameworks with strict and accurate accounting methods and the imposition of accountability exist, whereas in informal markets they do not in the form which would encourage lower emissions. Formal market production is more likely to be associated with better environmental performance than informal market production (Andreoni 1998). Market activities are more likely to reap the benefits of "clean production" and investment in abatement than informal exchange. An emissions abatement policy based upon the internalization of externalities should function more effectively among firms that operate in formal markets. This framework predicts which industries will stay dirty longer, and the ability of the pollution tax tool to achieve its goals.

The model considers Siberian firms in terms of their initial endowment of r_i and d_i , which differs from the distribution observed in an established market economy. Unlike competitive firms that enter or exit a market depending upon productivity (meaning all firms cluster around a low value of d_i), enterprises in a transitional economy begin with endowments of d_i unobserved in the market economy. The central task is to restructure, increase competitiveness, meet international environmental and other production standards—in short, reduce the distance to the market.

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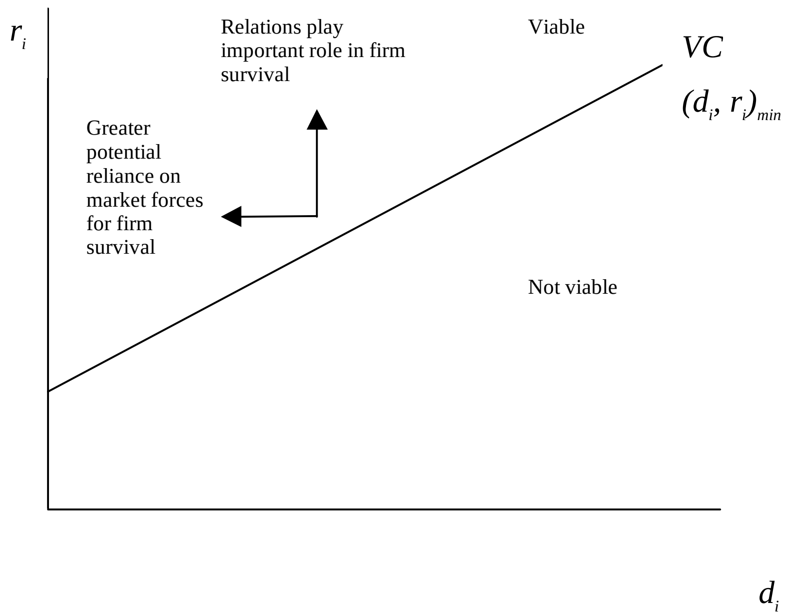
[4] The author has adapted the basic model introduced by Gaddy and Ickes (1998) to help explain when firms will respond to market-oriented policy in a transitional economy. The author added the idea of a compliance response boundary, and adapted the ideas of relational and market capital, and the viability constraint introduced previously (*ibid*.).

Years after official privatization programs were introduced, Siberian firms continue to manifest large d_i. Failure to achieve market nearness is attributed to soft budget constraints, incompetent management, and an array of institutional barriers. Enterprises have survived due to endowments of relational capital. Gaddy and Ickes (1998) point out, "A viable, even flourishing enterprise does not have to be one that has adapted to the market. It may have adapted to the informal regime of paternalism, tax offsets and barter, via the strategic use of relational capital." This model bears significant implications for the emissions charge policy.

Figure 6.9 R-D Space



Firms will vary in their r_i and d_i. Even though a firm may survive on a measure of relational capital, the endowment of r_i plays a critical role. Firms with neither r_i nor d_i face a viability constraint, the line *VC* in figure 6.9. The positive slope of this line marks the boundary between viable and nonviable firms. The larger the d_i, the greater r_i must be to ensure enterprise survival. In this model, firms which neither have the relational capital nor potential to enter formal market production within some reasonable period cease existence. Firms which lie below the viability constraint in the grid between r_i and d_i should eventually cease production in either informal or formal markets. Firms above the viability constraint will balance production in formal and informal markets.

The author divides firms into two categories: those in which d_i and r_i are small (such as oil with high international market exposure and high participation in the formal sector), and those in which both r_i and d_i are high (such as internationally noncompetitive firms such as, perhaps, steel. These firms may remain in the informal sector). The feature which aids our understanding of compliance with the environmental tax policy is the insight into initial endowments. Enterprises can use relational capital to survive or they can invest to reduce d_i. With the possibility of noncompliance, however, and participation in informal markets, enterprises have another alternative. Retreating to informal markets, where underreporting and evasion of taxes facilitate economic activity, the current emissions tax policy might inadvertently *discourage* environmental investment and compliance and even *encourage* greater emissions. The effort required to move in either the direction of cash or non-cash production appears to influence whether Siberian firms will respond to the ecotax through payment and investment in abatement.

The viability constraint aids in understanding how firms survive by diversifying risk between informal and formal markets through investment in r_i and d_i. What boundary divides potential environmental tax compliers with noncompliers? It is reasonable that a type of investment boundary exists, beyond which firms are less likely to respond to the constraints and incentives of a market-oriented environmental tool. What follows illustrates that as enterprises move below the restructuring boundary but remain above the viability constraint, they will begin to respond to pollution charge incentives for abatement and air quality per unit of output should improve. Therefore, the location of a firm with relation to its endowments matters for the outcome of an emissions charge.

Investment in r_i and d_i. imposes opportunity costs for enterprise managers. Investment in tangible capital (such as abatement technology) which moves a firm into environmental compliance increases commitment to observable activities. As the firm's visibility increases and information about the firm's pollution profile becomes known to environmental authorities, it is more difficult in subsequent periods to revert to noncompliance. By entering into formal markets and the pollution charge scheme, such enterprises enter the game with environmental authorities. Prior to this point, authorities may have assumed the firm incapable of meeting standards or making investments. Afterwards, tax evasion or other forms of noncompliance are more difficult. The decision to invest in tangible capital such as abatement technologies involves an increase in formal production and a decrease in non-cash production. The enterprise trades off a lower d_i. with a higher cost of informal market participation.

Investment decisions depend upon current r_i and d_i, and how changes in these endowments could affect future profitability. Assuming that a manager knows the benefits of investment in r_i and d_i., respectively, for future profitability, the only source of uncertainty is relative prices in the future. Current profits constrain the manager's investment decisions. Observable profits plus borrowing (*B*) constrain investment in abatement enhancing activities and investment in relations by current real profits.

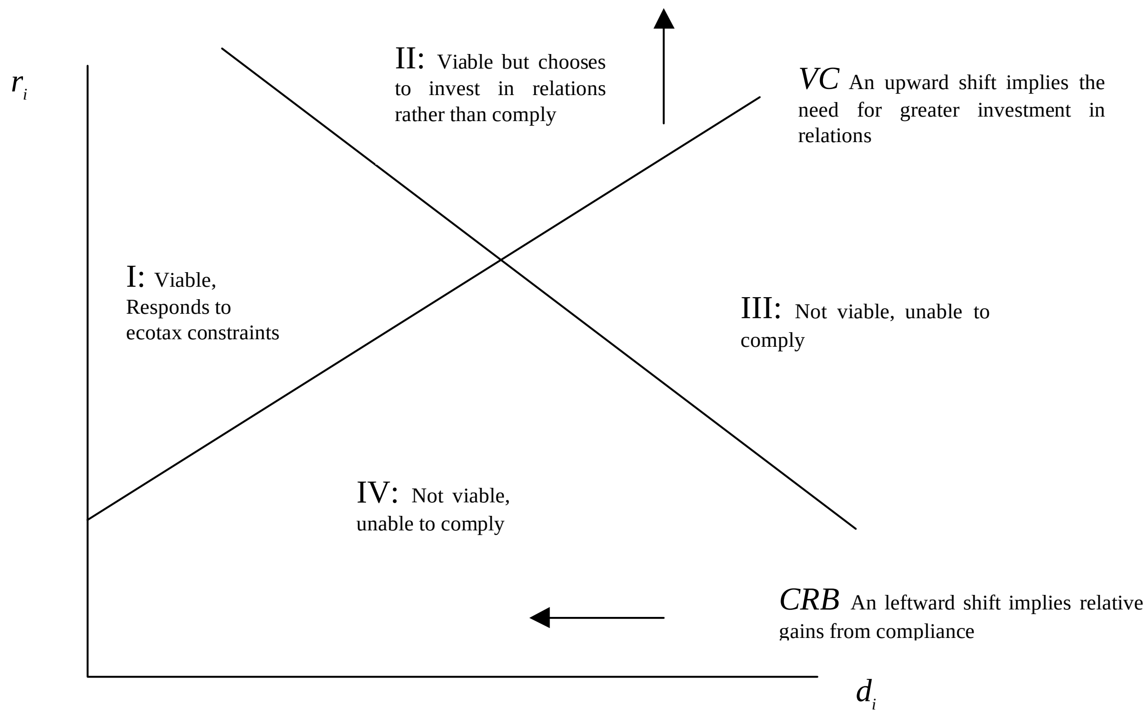
(6.1) $$I_r \leq \pi_i \quad \text{and} \quad I_d \leq p(1-\tau)f(e_c, d_i) - \phi(m_i + x_i) + B$$

where p represents formal profits, τ the tax rate, e_c the effort required for cash production, ϕ the cash constraint, and m and x the payments in cash or in-kind goods and services. The enterprise manager maximizes the present value of profits subject to expected returns in each kind of investment. The decision to abide by the ecotax depends upon the enterprise manager's evaluation of the effect on profits from investing in abatement or paying taxes or continuing in informal activities and not complying with environmental taxes.

Assuming that the enterprise manager can simultaneously engage in informal and formal market activity (investments I_r and I_d not mutually exclusive), then the manager will choose I_r and I_d in a way that equates marginal returns. Combinations of r_i and d_i will emerge in which the firm is indifferent between environmental compliance or informal activities and noncompliance. If a firm has a very high distance to the market the reward to distance reduction may be quite low in comparison to greater investment in relations. A downward-sloping production function implies that firms will move along this boundary, labeled *CRB*, investing in both distance reduction and relations

with diminishing marginal returns.

Figure 6.10 Firm behavior with compliance boundary



This compliance response boundary separates the regions where enterprises engage in reducing market distance and respond to the constraints and incentives of the pollution tax, and the region where firms do not respond to the market incentives of the ecotax and continue in informal activities antithetical to abatement investment and environmental responsibility.

Enterprises in quadrant I have the likelihood of responding to ecotax policy as they move closer to formal markets and increase overall commitment to formal production. Enterprises in quadrant II manifest a greater tendency to pursue survival strategies (by investing in r_i) which involve informal production, environmental noncompliance, and continued use of pollution-intensive techniques. If the *CRB* line shifts outward (reducing the real value of r_i in maintaining or achieving viability), enterprises will be more likely to reduce noncompliance and respond to ecotaxes. Upward movements of *VC* harden the budget constraint and pressures enterprises in quadrant II to increase cash production. and lower compliance activity. Although budget constraints may be harder, the ability of firms to escape to informal markets through investment in relations implies lower compliance. However, without an inward movement of *CRB*, investment and compliance with pollution charges will not increase.

6.3.2 Tax offsets and non-cash production to pay taxes

The model suggests that Russian enterprises engage in informal market activities as a survival tactic, as a response to the structure of taxation, and because of the weak system of governance. The key aspect of the Siberian informal economy is the peculiar phenomenon of producing and exchanging goods and services in a parallel, non-cash economy. Formal, market-type activities require greater investments in human and physical capital to produce competitive goods (including technological and abatement investments). Informal activities require greater investment in relational capital. Enterprises lacking funds are expected therefore to invest more in informal activities, in-kind services (barter) and forms of noncompliance rather than investing in productivity- and efficiency-boosting technologies. The emphasis of pollution charges upon formal tax payment implies that the tool is not optimal for the actual, not fully monetized economic situation.

Participation in informal markets (barter and other non-monetary forms of exchange) plays a direct role in emission tax evasion. The use of barter allows enterprises to record the value of transactions in ways that reduce overall tax incidence. While official output may fall, as well as official profits, informal output may rise. Because production and pollution output are directly linked, underreported output and emissions imply possible increases in pollution intensities. Ineffective monitoring exacerbates the situation.

One of the key institutional issues surrounding environmental payments and proper reporting is the widespread use of tax offsets and non-cash production to pay taxes. The mechanism of tax offsets lies at the heart of the specific form of informal market activity observed in the region. Federal, regional and local governments show great willingness to offset enterprises' tax obligations against goods or services delivered to the government. Local governments frequently use the offsets to obtain vital services from enterprises, including employment, value-added products, etc. This aspect of the Siberian tax system reduces payment transparency as "tax-in-kind" exchanges severely weaken the link between pollution output and industry payment for use of this natural resource.

Due to the lack of economic diversity in many Siberian industrial centers, enterprises are often the sole providers of many goods and social services, in addition to employment opportunities. In 1992-93, firms paid for over one-third of their labor costs by in-kind services rather than cash, very high in comparison with firms in most OECD settings (Commander 1993); (Commander 1997). Siberian firms provide vital social services such as education and health care, housing, public utilities, and other forms of infrastructure. Such firms provided in-kind payments and are linked to their host communities "through networks of personal contracts and mutual services, as well as by a system of natural commodity exchanges between their enterprises" (Stoner-Weiss 1997). Such firms have ready currency to trade when taxes come due. In an area characterized by low labor mobility and deteriorating standards of living, enterprises gain considerable leverage using tax offsets. In this case, the use of a pollution tax might *not* provide incentives for abatement at all. Perversely, the pollution charge system may reward a firm with greater leverage (greater relational capital) in various levels of government as the firm essentially has more to offer desperate local and regional authorities in terms of its goods and services. Since government orders have a notorious reputation for nonpayment, taxes such as the pollution tax (although it plays a relatively small role in the overall corporate tax burden) provide Siberian enterprises with a form of currency to peddle.

Tax offsets for pollution charges significantly weaken abatement incentives, indicating the particular frailty of the tool for revenue raising and abatement of pollution. Gaddy and Ickes estimate that such activities may account for between 80 and 90 percent of tax payments by major industrial enterprises included in our set of heaviest polluters in the region (Gaddy 1999). With hard currency in short supply, air quality improvement tends to take a lower priority in relation to other pressing economic issues. Institutional weaknesses plague environmental authorities.

Siberia has developed into a type of industrial subsistence economy, where the bare necessities for enterprise survival are often exchanged in kind. The following discussion helps us discern which enterprises may have the tendency to operate more in the formal market (with its associated incentives towards reform, investment, and productivity) and informal markets (with its associated aversion towards innovation and detection). While of general interest, this emerging pattern implies that those firms choosing greater involvement in formal markets may also make pollution-reducing decisions. The central feature is the degree of effort required to abate pollution. Shown below, the firm weighs the benefits and costs of reducing emissions with the probability of being effectively monitored and penalized for noncompliance. The author roughly groups those industries which may respond to the pollution charge system, and those which may choose to blatantly disregard it, depending upon the degree of effort required for compliance in formal markets.

6.3.3 Pattern of enterprise compliance

Peculiarities of the Russian taxation system, particularly the claim of authorities on bank deposits for the payment of taxes, encourage enterprises to find ways to carry out their activities outside of the formal system. Formal profits attract attention from tax collection authorities and are costly to managers. They make it more difficult to delay paying wages and in short may decrease leverage for the enterprise. One reason why Gazprom, for example, may pay its taxes and its environmental fees and penalties is that its large cash-flow and heavy involvement in international, formal markets puts it in a poor position to evade (low d_i and low r_i). Successful market-oriented firms play critical cash-raising roles in the Siberian economy. Gazprom and firms like it provide the inlet of currency and face pressure to pay wages and transactions in cash, not in kind. Counter-intuitively, their r_i tends to be low because of the very economic role played by them. Firms with real value, high profit levels, and involvement in formal markets have a limited maximum acceptable rate of nonpayment. Gazprom plays a key role in redistributing this value throughout the region. Those enterprises which can better disguise their outputs and profits, and any associated pollution levels through underreporting or claiming insolvency, can achieve greater noncompliance. Such firms may also lead the way in abatement investments, as these firms begin meeting international production standards, both competitive and environmental (ISO 9000 and 14000).

Examining decision making in this model offers insight into environmental compliance among Siberian enterprises. The firm engages in risk diversification behavior between formal and informal activities to reduce tax liabilities and ensure survival and non-observed profits. Formally, let φ be the maximum acceptable rate of non-payment and let *cf* be cash flow. The larger *cf*, the less leverage a firm will have and the more likely it will be to comply with environmental taxes. Then

(6.2) $$\varphi = f\left(\frac{cf}{k}, r\right) \qquad \text{with } f_1' < 0 \qquad \text{and } f_2' > 0$$

If the firm chooses to produce more cash goods, the firm experiences a decrease in φ, or the maximum acceptable rate of non-payment, because observable economic activity rises. The enterprise loses leverage to use noncompliance as a means of appropriating income. If the firm has the opportunity to engage in informal activities, a possible negative relationship exists between using an emissions tax and providing incentives for abatement.

Underlying this discussion is the assumption that production and pollution abatement require varying degrees of effort in the formal and informal sector. Formal activity incurs tax liabilities and monetary obligations to stakeholders. Formal products require higher standards and quality to be marketable or competitive. Prices and quality of goods may differ between the two spheres. A wedge is thus created between the returns of each, making up formal prices and informal shadow prices. The firm will choose a mix of formal and informal products based on the effort and rewards associated with each. A pollution tax increases the effort required to make formal goods (particularly those directed at export markets), pushing the firm to choose environmental noncompliance and possibly avoid abatement.

The relationships between effort and production allocation decisions can be formally expressed. Assuming that producing the same quantity of cash (q_c) and non-cash (q_{nc}) products (formal and informal products) requires greater effort (e) for the former.

(6.3) $$q_c = q_{nc} \Rightarrow e_c > e_{nc}$$

Production functions for the firm, for formal and informal markets, and the profit function, respectively,

(6.4) $$y_c = f(e_c, d), \quad y_{nc} = g(e_{nc}, r), \quad \text{and } \Pi = pf(e_c, d) + \hat{p}g(e_{nc}, r) - wl$$

Where p and $\hat{p}$ are the respective prices of cash and non-cash goods and *wl* are fixed costs of production such as labor. The enterprise will need a certain amount of cash to carry on normal production activities, such as wage payments, in addition to possible bribery payments, and the procurement of key inputs. Given the cash constraint ϕ, where $\phi = \frac{m}{m+x}$ represents the share of costs that must be paid for in cash, the manager will be most concerned about the method of payment for inputs (either in cash m or by barter x).

The firm's cash constraint depends on $\phi_i = h(-r_i, d_i)$. The greater the investment in r_i the greater ability the firm will have to avoid involvement in formal activities which attract tax authority attention. Substituting the effort constraint for the production function y_{nc} as $y_{nc} = g[(\bar{e} - e_c), r]$, gives

(6.5) $$\frac{p}{\hat{p}} = \frac{\frac{g}{\partial e_c}}{\frac{\partial f}{\partial e_c}}.$$

From diminishing returns, (6.5) indicates that a decrease in the relative price (for example via a tax imposition or increase) of formal to informal goods shifts effort to informal production. One would expect nominal formal prices to be higher than informal; however, the important issue is really after-tax profits. If we consider that shareholders also receive a portion of formal firm profits, then the manager may perceive $p < \hat{p}$.

Letting τ represent the total effective tax rate the director faces, (6.4) becomes

(6.6)

$$\frac{p(1-\tau)}{\hat{p}} = \frac{\frac{\partial g}{\partial e_c}}{\frac{\partial f}{\partial e_c}}$$

We assume that at least a share of τ must be paid in cash to avoid the government from pressing bankruptcy. Informal activities also incur taxes, but it may be possible to pay such in non-cash form, offsets, or other forms of barter. However, the greater the number of enterprises operating in the cash economy, the harder it will be for a single enterprise to engage in informal market production. The inverse also seems appropriate for Siberia and we see a sort of reinforcing game. If the cash constraint holds, an increase in taxation shifts effort to informal activities. Three important characteristics emerge which help us understand possible outcomes in regard to Siberia's pollution charge system. They relate to strength in numbers, the effect of tightening the cash constraint, and new firms and market participation.

6.4 Moving Siberian enterprise towards compliance

Strength in numbers. We can represent this dynamic in terms of effort, which may play a part as the ecotax evolves in the region. If a few firms engage in environmental noncompliance—be it over-pollution, underreporting, or nonpayment—it would be much easier to detect so more effort would be required to hide them (the ratio $\frac{e_c}{e_{nc}}$ would decline). In many industrial towns in Siberia, only one or two large sources contribute to the official pollution profile, making it obvious who is polluting and not paying, regardless of the number of firms operating in informal markets. However, because of the ability of such firms to pay for their taxes in offsets, they still are not forced to meet environmental standards. Town populations and local governments may be dependent upon the in-kind payments from firms and the barter economy which such firms support. It remains economically attractive to diversify risk in favor of informal market activities and substandard emissions behavior. Some notorious polluters such as the energy sector may comply with the pollution tax only as the regional economy becomes monetized (as opposed to barter-subsistence) and as its services face international competition (reducing its r_i) or until it becomes more profitable or less risky to produce for formal markets. As the number of enterprises involved in cash activities η expands, the costs of these activities fall and the relative price of cash to non-cash sales, $\rho \equiv \frac{p(1-\tau)}{\hat{p}(1-\eta)}$ falls in the enterprises engaged in the formal economy. As the number of firms operating in formal markets decline, the effective tax rate on formal activities rises and aggregate tax revenues decline. A larger η may motivate firms to join the cash economy, while a smaller η might encourage informal production. If the number of firms willing or able to participate in formal market activities rises in response to general institutional reforms, more firms will move into the region where compliance with current environmental standards and taxes imposes constraints. Inversely, the current inability or unwillingness to comply with environmental legislation and pollution charges may stem from the fact that many firms prefer to produce in informal markets. Factors which might influence the pollution fee policy appear to be the decision of where a firm will produce, in markets with stricter accountability and pressure to improve efficiency and reduce pollution per unit or informal markets with low accountability and a pressure towards inefficiency. The interesting variables for understanding the outcome of the pollution charge system in Siberia might not just be tax levels themselves, but encompass

(6.7) $$\frac{y_c}{y_{nc}} = f(\rho, r_i, d_i, \phi_i).$$

Aspects which indirectly, positively affect compliance with environmental taxes could include: an increase in the relative price of goods produced in either market (a possible reaction to changes in effective tax rates), less relational capital or shorter distances to the market, tighter cash constraints (implied by greater numbers of firms operating in formal markets).

It is unclear to what extent an increase in environmental charges would result in greater noncompliance by Siberian firms. However, the finding has significance for the general discussion about the use of pollution fees and taxes in transitional economies. Recommendations to environmental authorities employing such policies frequently include raising the level of environmental charges to an “effective” level (Golub 1997); (Air Pollution Working Group 1998); (Kozeltzev 1997). The authors involved assume that firms have no realistic alternative to operation in formal markets that reinforce ecotax compliance. One of the primary reasons for program weakness is not simply that charge rates remain too low, but that industry has the option of informal market participation as a means of risk diversification and survival. The institutional characteristics of Siberia’s regional economy defy standard economic interpretation and with it many of the standard implications of an environmental resource tax.

Tightening the cash constraint. Changing the relative prices of formal and informal production might effect enterprise response to the current air pollution policy. A possible way to move closer to ecotax compliance lies in tightening cash constraints for

Siberian enterprises. As this occurs, the relative cost of producing in informal markets where ecotaxes are not binding will increase and firms would be motivated to participate in the market. Before a market-based environmental policy can take effect, polluting enterprises must participate in that market. Opportunities for informal activities that encourage noncompliance, under-investment in abatement and efficiency-improving technologies, and which grant leverage through tax offsets severely weaken the emission charge.

Attaining such an objective, however, appears difficult. If the resource monopolies such as Gazprom accepted only cash for their goods and services, other enterprises might have greater incentives to enter formal markets to satisfy their taut cash constraints. One possibility to accomplish this would be to pressure such firms to pay overdue taxes in cash, which would presumably force them to collect cash payments from their customers. It isn't clear whether such a plan would work, and would depend on price elasticity and cross elasticities of products in formal and informal markets. If loss-making firms play an important role in nonpayment, then enterprises that could not cover their production costs could only increase cash payments for utilities by reducing cash payments elsewhere. Because the primary use of cash is to pay wages and taxes, increasing the cash constraint in this way might increase tax arrears and environmental noncompliance. Another option would be to shut down those enterprises which continually violate environmental standards and pollution charges, show negative profits, and which engage in informal production. However, the political costs of shutting down such firms (with high r_i) mat be too high for actual implementation. One more way to encourage firms to participate in formal markets and to make the ecotax and environmental standards binding would be to reduce the risk involved with investment in abatement technologies. Provision of subsidies and tax breaks for such activities have not proven effective, as enterprises appear to divert such cash resources away from environmental uses. Rather than employing subsidies, the provision of some type of environmental insurance may reduce the distance of d_i for firms and help them accomplish the restructuring necessary to produce formal goods and to improve environmental performance.

In addition to reducing the risk of abatement investment, imposing more effective management constraints could also move firms closer to formal markets and closer to an area where ecotaxes have meaning. An improvement in corporate governance amounts to an increase in the tax rate on non-cash goods, n, because it weakens the ability of the director to divert income from shareholders by engaging in non-cash production. In economies where accountability is high it is much more difficult to earn informal profits. Better corporate accounting and management reduces the tax wedge, inducing a shift towards cash production. The ability of the pollution charge to reach environmental revenue and abatement goals appears to depend on the opportunities which polluting enterprises have to produce in shadow markets.

New firms and formal markets. If the formal market in Siberia can attract new firms, they will be less likely to participate in informal markets, and more likely to comply with the environmental tax. There are several reasons for this expected behavior. First, it takes effort to enter the informal economy for new entrants. Double coincidence of wants already causes significant costs in barter transactions, but for the newcomer, establishing the relations necessary to facilitate such exchanges may be prohibitively high. In addition, if a firm is able to enter the Siberian market at all, it most likely has a low d_i, or it would probably not enter the market at all. Such firms are likely to engage in cash production and have greater incentives to invest in more modern production technologies. This implies a greater responsiveness to competitive standards, of which lower pollution per unit is one. This is an important feature of transition. In developed market economies new entrants are drawn from some distribution that resembles incumbents. In transition, the distribution of incumbents is heavily skewed.

Older enterprises may only learn about the costs of reducing d_i through actual investment in capital. Because investment increases the costs of engaging in informal activity, the enterprise may choose to invest in r_i rather than tangible capital. A firm that perceives a high d_i and a low return to such investment may choose to continue with non-cash production and to disregard air pollution charges as an incentive to pay for emissions or invest in abatement. Investment decisions and environmental use decisions depend upon the enterprise manager's time preferences and perception of current and future benefits of environmental noncompliance or investment. Older enterprises may have little concrete idea about their true d_i and are therefore provided with real incentives not to restructure and not to respond to economic tools for emissions abatement which involve costs without clear benefits.

6.5 Conclusions

This chapter has tried to establish a case for noncompliance in Siberia, and point out some of the primary problems of emissions tax implementation within the region's economic framework. Interestingly, official reports collected for different purposes and by different agencies (industries self-reporting vs. the Ministry of Health's measurement of ambient air quality in Siberian areas) have shown significant differences in the air concentrations that should have been recorded had officially reported emissions been correct, and those actually recorded by health officials. Although this non-rigorous deposition accounting made strong assumptions to reach the given estimates, given the magnitude of discrepancy it is reasonable to conclude that underreporting of emissions, particularly high-risk emissions associated with higher charges occurs.

Based upon these findings, the author investigated possible causes for noncompliance with the pollution charge system. Many firms in Siberia have the option of diversifying their production portfolios in informal, non-cash exchange and within formal markets. An enterprise's endowment of relational capital and its nearness to formal market operations largely determine whether a firm will begin to respond to the constraints and incentives imposed by the air pollution charge. Due to institutional characteristics of the tax system and the manifold issues surrounding market reform, it is incorrect to assume that a market-based tool such as the emissions charge will achieve abatement or revenue goals in Siberia. Under some circumstances, the pollution tax might actually exacerbate the emission situation by encouraging firms not to participate in legitimate market activities. The ability of many enterprises in Siberia to pay their bills and taxes through barter implies that tax arrears might grant leverage to a firm that, in a cash-based system where taxes are enforced, it might not have. This issue requires further research.

Better policy performance will occur as more firms move away from production activities (assumed to be worse in environmental terms) in informal markets towards those in formal ones. As viable firms move below the compliance response boundary, the emissions tax should have some impact. Once firms are at least within the boundaries for viability and market nearness, they might enter the compliance game with the environmental authority as described in the economic literature about environmental charges (Harrington 1988). Those firms which have a potential for only (or mostly) market production can enter a three-state game with the environmental authority, in which the first state allows self-reporting and lower monitoring probability, the second state imposes higher monitoring probability, and the third penalty state imposes constant observance. For firms under the compliance response boundary, the key abatement incentive becomes the probability of monitoring. Even for these market-producing firms, the actual rate of taxes is less important (for abatement goals) than the institutional setup and likelihood for getting caught in noncompliance. In this context, the ecotax loses much of what has been heralded as its unique ability to apply prices to natural goods and services, to abate pollution, increase investments in environment-improving technology, and raise revenue.

For those viable firms which stay above the compliance response boundary, the issue is whether over time they experience a general shift towards or further away from formal market activity. Given their distance from markets and demonstrated preference for investment in relations, such firms may respond more readily to environmental regulation rather than market incentives. However, informal markets probably demand lower quality standards from producers and may not be capable of internalizing economic externalities.

For Siberia’s regional economy, the severe institutional and economic conditions largely prevent the current abatement policy from either raising revenue for environmental hypothecation or abating existing pollution. Regional environmental institutions continue to show significant signs of weakness and official revenue reports of ecotaxes indicate gaps between expected and actual revenue, indicating noncompliance. This case likely extends to other areas characterized by imperfect information, segmented markets, and weak institutional frameworks.

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Chapter 7: A case study of Tomsk oblast

7.0 Introduction

Chapter seven turns attention to the implementation of the emissions charge system in one region in Siberia. The work has to this point reviewed the pattern of emissions in Siberia, including the most important chemical groups, industrial polluters, and a rough deposition pattern. It has reviewed the theoretical relationship between the environment and Siberia's economy, as well as the parameters for the program itself. Chapter five noted the expected pattern of firm response to the pollution tax, in the context of a standard profit-maximizing firm, a monopolist, and a non-profit-maximizing firm. This survey indicated that institutional changes are the important factor in the emissions charge program, rather than (as standard theory suggests) finding an optimal tax level. Throughout this discussion issues of market orientation and its effects upon firm compliance became salient. The current chapter illustrates the most important issues for the emissions charge system in the context of the economic and social situation in Tomsk oblast.

This case study of Tomsk illustrates the imperfect implementation of a market-based tool for emissions abatement in Siberia. The study shows that an imperfect institutional structure of a Siberian oblast effectively prevents the program from either reaching its revenue goals or its abatement targets. This analysis of the environmental tax system in Tomsk will evaluate the impacts of the current emissions charge system and some of the questions regarding the ability of a market-based tool to achieve several objectives (including abatement, revenue raising, and a possible cut in labor taxes) at one time. To accomplish this task, the study

- evaluates Tomsk's pollution profile, including its economic profile (i.e. which firms produce and pollute) and its degree of market-orientation (using compliance response boundary framework)
- evaluates the possibility of Tomsk achieving a double dividend under the current emissions policy. Double dividend theory postulates that, *ceteris paribus*, the emissions tax should be able to meet the threefold task of raising revenue, reducing involuntary unemployment and internalizing environmental externalities. The author explores the optimal tradeoff between public and private consumption, environmental quality, and employment (double or triple dividends) and evaluates whether Tomsk could achieve such a situation.
- estimates the impact of the pollution charge on employment, production output in formal and informal markets, firm emissions output, and the impact on evasion and compliance levels.

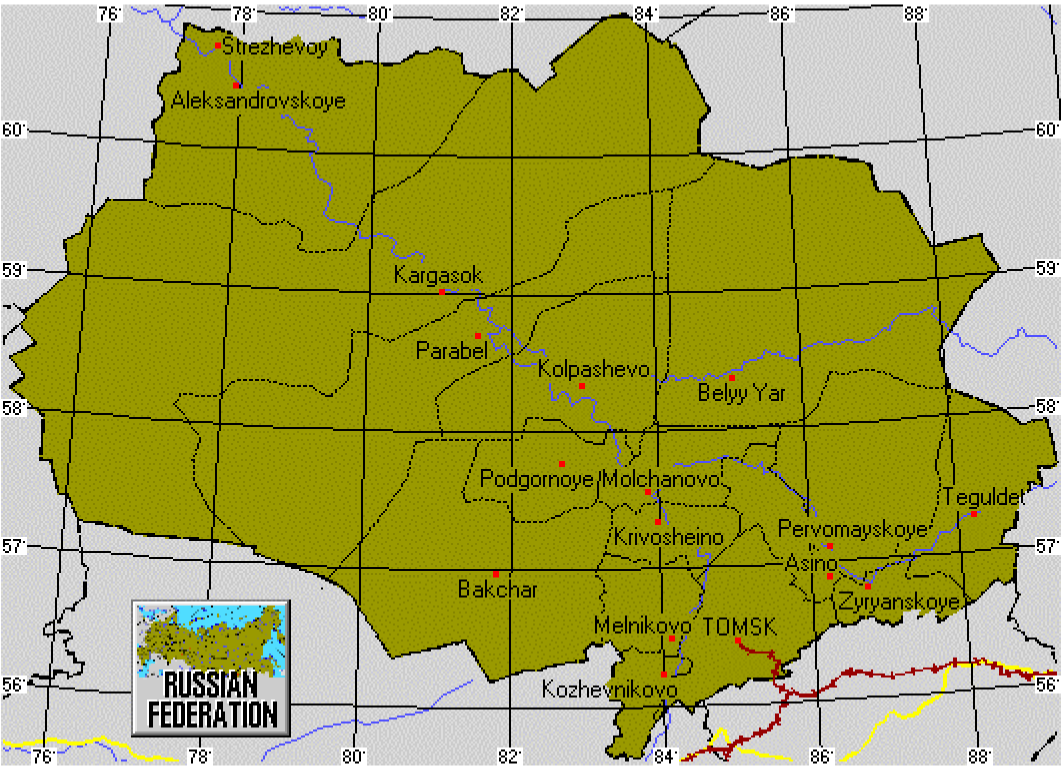
7.2 Characterization of Tomsk

A 57 hour, 3,501 km train ride from Moscow brings the curious visitor or travel-weary native to Tomsk oblast. Located in the southwest of the West Siberian Plain in the middle reaches of the Ob River, Tomsk Oblast borders on the Krasnoyarsk Kray, Kemerovo, Novosibirsk, Omsk, and Tyumen Oblasts. Its territory covers 316,900 km^2, roughly the size of France and the 14th largest area in Russia. The majority of the population live in urban areas (62 percent, with 80 percent of these living in Tomsk), important because of the pollution concentrations around factories in industrial centers located in Tomsk and Strezhevoy. Pollution is the area may impose particular damage upon intricate hydrologic systems, which cover nearly 35 percent of the total territory.

The most important enterprises in terms of profitable output are the fuel (gas and oil), and chemical industries, where oil and gas constitute 93% of exports. Tentative transport facilities dampen the ability of these exports to reach external markets. The most important in terms of employment are the machine building industry, forestry, and chemical production. Privatization has occurred in a majority of the firms, but a lack of management change makes it difficult to assess the degree to which privatization will actually move these industries towards the market. In addition, a lack of local processing capabilities mars the oblast's economy. This reinforces a common Siberian obstacle of providing a source of natural resources without participating in the economically more rewarding improvement of those products. While resource extraction proves profitable, industries such as oil, chemicals, and forestry have weak ties to other sectors in the oblast's economy and only feebly affect their degree of (formal) market-orientation and further development.

Geographically, economic activities are clustered around northern fuel fields and in the capital city of Tomsk itself. While Tomsk manifests relative economic diversity, the most important industrial sectors focus on extraction rather than value-added. Discussed below, this appears to limit the degree of market orientation of such enterprises and affects firm response to the emissions charge. Without higher levels of formal market participation, it is likely that the emissions tax will not be effective in motivating firms to abate pollution or to raise revenues for the environmental fund. Map 7.1 shows the position of Tomsk city in the extreme southern part of the oblast. Up to 75 percent of the oblast's population lives in this area, and up to 70 percent of all industrial pollution in the oblast is deposited here.

Map 7.1 Tomsk oblast, Siberia



Source: (RUSLINE 1999)

Tomsk has managed the transition phase relatively better than the Russian average, in terms of industrial restructuring, a reflection of economic diversity in the oblast. Huber *et al*. (Huber 1997) using the Herfindahl index found that Tomsk has a relatively low concentration of industry across branches. In addition, the authors employed the turbulence index (Gora 1995) to estimate that Tomsk has a better record of aggregate restructuring that the country average.[1] Perhaps as a result, from 1990 to 1993, nominal industrial production grew 10 percent faster in Tomsk oblast than in Russia as a whole, mostly due to more favorable industrial growth in that oblast (*ibid.*). In spite of less dramatic declines in output than Russian averages, labor and capital productivity

[1] The indicator is defined as the sum of the absolute change in shares across industrial branches and assumes values between zero (no structural change) and 100 (maximum structural change). The turbulence index is given by $TI = \frac{1}{2}\sum_i \left| s_t^i - s_o^i \right|$ where TI is the Turbulence Index and s_t^i is the share of industry *i* at time *t*.

remains lower than average, while wages remain higher. An imbalance exists between Tomsk's skilled, sophisticated labor force (up to one quarter have a university education) and its low-skill, low-value-added industrial base. If Tomsk firms evidence the market orientation necessary for a market-based policy such as the emissions tax to affect firm behavior, then we would expect that productivity must rise or wages must fall in formal markets. Section 7.4 returns to the model framework from chapter six to evaluate this question.

Tomsk possesses an above-average number of financial institutions, yet these typically are reluctant to finance investment activity in the current economic environment. This implies that investment in abatement technology in the region will remain a low priority given the current policy, relative to other types of business investment. Responsible factors include tight credit policies of the Russian Central Bank (RCB), asymmetric information (adverse selection and moral hazard), the lack of credibility of environmental investments, the lack of an effective credit-rating system, high inflation, and a poorly operating system of legal protection of the rights of creditors. Environmental technologies appear risky and expensive relative to other uses for credit, and the dividends for such investments improves social rather than private welfare. The huge number of government bonds used to cover the deficit in 1994 and 1995 provide a relatively more attractive portfolio investment opportunity for commercial banks than the financing of investment projects, particularly low-priority environmental ones.

Although Tomsk has lagged behind the Russian average for investments from 1980 to 1995 (behind by 12.1%), the ratio of investment to contribution to GDP is somewhat better, 1.53 during the same time. A decade later, Tomsk had further increased investments but after 1991 these levels lagged again, falling to 38th in the Russian Federation, but still with an investment-GDP ratio of 1.7 (Huber 1997). Given the market-oriented mechanisms introduced during the transition phase, Tomsk oblast appears less sensitive, an early indication that an incentive to increase investment in pollution abatement might also have lackluster performance. In addition, foreign investment plays a negligible role in the oblast, indicating that Tomsk industry may be less pressured to perform at international standards in terms of competitiveness, efficiency, and environmental standards. Declining investments in the petrochemical, and chemical industries (in 1996 investment amounted to only 9.75% of 1995 levels), possibly responsible for significant shares of unreported emissions, might further dampen industry incentives to abate pollution. On the other hand, the fuel industries receive the highest levels of investment, and many financial institutions link future investment with current profitability. The effect of an environmental policy upon profitability is ambiguous. Investments in improved production methods may also improve environmental performance and help a firm achieve compliance; however, profit-tied investments may encourage firms to disregard incentives to spend effort on environmental improvement that may not increase profit levels.

7.2.1 Tomsk industrial pollution, pollution profile

Interpretation of Tomsk oblast's pollution profile, and its impacts upon the natural environment, and human health meets with conflicting views. Several sources indicate that Tomsk oblast holds a relatively good position in terms of lower total emissions per km^2. Optimists cite that a list of "most polluted cities in the Russian Federation" does not include Tomsk city (*ibid.*). In addition, as in almost all other Siberian provinces, Tomsk oblast has experienced decreasing total emissions volumes from the 1991 to 1995 period. This corresponds roughly with declines in industrial output.

However, using the risk-ranking methodology from chapter two, Tomsk oblast's pollution profile reveals that its environmental performance might not be as positive as some reports suggest. While total volumes of pollution fall substantially below Russian oblast averages, the per capita emissions of such compounds as benzene and carbon soot for example exceed averages significantly. The profile of the most significant polluters implies that the fuel and energy production industries, the chemical industry, and to a limited extent the forestry industry account for nearly all emissions. Tomsk manifests only traces of heavy metal emissions, and other high-risk pollutants. Industry reports only traces of heavy metals emissions, reflecting Tomsk's lack of a significant metallurgical complex. This finding also reinforces the role that metallurgical firms play in other areas in Siberia where heavy metals and geriatric metal industries are present. Tables 7.1 and 7.2 provide comparisons for inorganic and organic pollution in Tomsk and in the Russian Federation.

Benzene, associated with oil extraction and energy producing industries in Tomsk, makes up 36 percent of total emissions by volume in that oblast. Although total volume of benzene is much lower than average, emissions per capita in Tomsk exceeded the Russian average by six times. Xylene emissions exceed the Russian average, although these emissions follow a general downward trend over a two-year period.[2] Reported acetone and styrene levels per capita are higher than average, reflecting the relative importance of the chemical industry in Tomsk.[3] Overall levels of formaldehyde exceed averages per capita, with the forestry industry accounting for much of this. Over the given period, toluene averages fall for Russia but rise in Tomsk oblast, possibly a result

[2] Xylene is used as a solvent and in the printing, rubber, and leather industries. It is also used as a cleaning agent, a paint thinner, and in paints and varnishes. It is found in small amounts in airplane fuel and gasoline. Styrene is primarily a synthetic chemical, also known as vinylbenzene, ethenylbenzene, cinnamene, or phenylethylene. Billions of pounds are produced each year to make products such as rubber, plastic, insulation, fiberglass, pipes, automobile parts, food containers, and carpet backing.

[3] Acetone is used to make plastic, fibers, drugs, and other chemicals. It is also used to dissolve other substances. Its environmental impacts are relatively benign, where about half of the total amount breaks down from sunlight or other chemicals every 22 days.

Table 7.1 Average Russian and Tomsk per capita emissions of selected organic chemicals, 1992-93

Chemical, % of Tomsk total emissions	Average Russian oblast emissions (th. tons), 1992/1993	Tomsk emissions (th. tons), 1992/1993	Russia average emissions per capita, (tons), 1992/1993	Tomsk average emissions per capita, (tons), 1992/1993
Benzene, 36%	8983391 / 8208198.5	393895 / 260301	60.6 / 55.4	389.3 / 258.2
Xylene, 24%	20956497 / 17859039	264118 / 223628	141.3 / 120.5	261.1 / 221.8
Toluene, 14%	26343296 / 21797795.5	156113 / 175655	177.7 / 147	154. 3/174.2
Acetone, 11%	14901692 / 11789386.5	124939 / 81516	100. 5 / 79.5	123.5 / 80.8
Butazulene, 3%	5507488.5 / 4590219	29537 / 25520	37.2 / 31	29.2 / 25.3
Formaldehyde, 2%	1990511 / 1829827	23349 / 21339	13.4 / 12.4	23.1 / 21.2
Methanol, 2%	3035453 / 2712074	27427 / 27390	20.5 / 18.3	27.1 / 27.2
Naphtaline, 2%	1509324 / 1514646.5	25323 / 36963	10.2 / 10.2	25.1 / 36.7
Styrene, 1%	968996.5 / 909841.5	10688 / 7172	6.5 / 6.2	10.6 / 7.2
Ethyl acetate, 1%	6354694.5 / 5046520.5	11842 / 14921	42.9 / 34	11.7 / 14.8
Source: (IIASA 1996)				

of rising pollution intensities in the production process, aging machinery, and increased outputs of fuels.[4] Enterprises such as the Tomsk Petrochemical Plant, an open joint stock company appear to emit these inorganic pollutants. Oil products production of polypropylene, methanol, formalin, carbamide resins, ethylene, propylene and high-pressure polyethylene typically result in emissions by-products like those described above.

Like inorganic emissions, the profile of organic pollution bears the marks of the region's principle industrial sectors. Almost all industry relies primarily on oil as an energy input for production processes, and as table 7.2 indicates, abatement ratios per unit of pollution output are relatively low. It is not surprising, therefore, that carbon soot appears as the most significant output of pollution in Tomsk oblast. Wasteful oil

[4] Toluene is a by-product of producing gasoline and other fuels from crude oil, of making coke from coal, and in the manufacture of styrene.

extraction processes in Tomsk spill or burn off much of the extracted fuel. A recent study states that "the most dangerous polluting objects are the enterprises of the oil-processing complex ("Vasuganneft," Luginetzkneft")" (*ibid*.). Carbon soot[5] emissions exceed Russian averages by a magnitude, implying that exposure per capita is also much higher for this medium-risk compound.

Table 7.2 Average Russian and Tomsk per capita emissions of selected organic chemicals, 1992-93

Chemical, % of Tomsk total emissions	Average Russian oblast emissions (th. tons), 1992/1993	Tomsk emissions (th. tons), 1992/1993	Russia average emissions per capita, (tons), 1992/1993	Tomsk average emissions per capita, (tons), 1992/1993
Carbon soot, 92%	53503998 / 6937054.5	4614904 / 5424922	360.8 / 316.5	4561.1 / 5380.3
Ammonia, 7%	35491517 / 27878972	346222 / 356522	239.3 / 188	342.2 / 353.6
Nitric Acid	527196 / 457513	14567 / 167578	3.6/3.1	14.2 / 166.2
Hydrogen Chloride	1981805 / 1537333	11017 / 9180	13.4 / 10.4	11 / 9.1
Sulphuric acid	19035218 / 16903194	7387 / 6224	128.3 / 114	7.3 / 6.2
Vanadium pentoxide	2839547 / 4079821	7266 / 5409	7.2 / 5.4	19.2 / 27.5
Hydrogen sulphide	12267780 / 9741207	6514 / 13348	82.7 / 65.7	6.4 / 13.3
Arsenic	516833 / 489417	2685 / 204	3.5 / 3.3	3 / 0.2
Source: (IIASA 1996)				

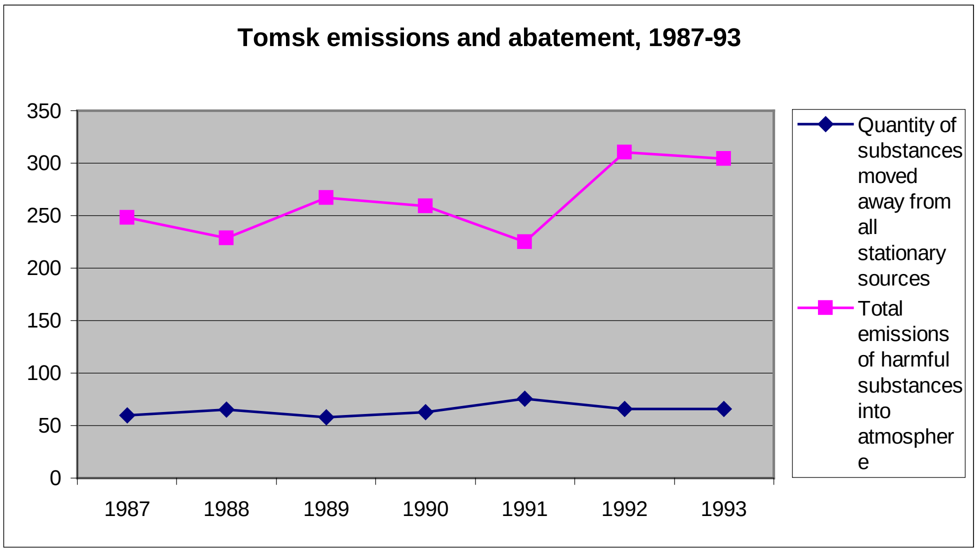
In addition to carbon soot, other fuel-related organic emissions such as ammonia and vanadium pentoxide slightly exceed the Russian average. Arsenic, whose compounds are used mainly to preserve wood, fell dramatically below averages in 1993. Nitric and sulphuric acids fall below Russian averages, and hydrogen sulphide levels fall far below

[5] Soots are a generic collection of undefined substances produced by fuels during uncontrolled combustion. The carbon particles in soot contain very high percentage of loosely retained tarry material which, in turn, contains large amounts of polycyclic aromatic hydrocarbons (PAH) (Ralph *et al*., 1982). PAH identified in carbon soot include phenanthrene, anthracene, benz[d,e,f]dibenzothiophene, benzo[a]acenaphtylene, pyrene, benzo[g,h,i]fluoranthene, cyclopenta[c,d]pyrene, benzofluoranthenes, benzopyrenes, dimethylcyclopentapyrene, indenopyrene, benzo[g,h,i]perylene, and anthanthrene. (IARC, 1982). Pneumoconiosis has been found in workers regularly exposed to carbon soot, with a radiological appearance of small round shadows and marking of bronchi and vessels. Cases of pulmonary fibrosis, bronchitis and emphysema have been reported. Structural changes in the lungs have been accompanied by functional changes exemplified by decreased vital capacity, respiratory volume, FVC and FEV1. The lowest exposure level reported to cause pneumoconiosis to workers was 8.4mg/m^3 for more than 10 years. Carbon soot dust irritates human skin. Workers exposed to concentrations of 10-1000mg/m^3 have reported skin irritation or skin diseases (Syracuse Research Col.(U.S.) 1985).

average. Given the products of the “TOMSKY NEFTEKHIMICHESKY KOMBINAT," this state-owned chemicals enterprise appears to emit many of these organic compounds. The enterprise produces polypropylene, methanol 471,566 tons (up to 97 percent of which may escape during the production process. Tomsk methanol emissions in 1992 amounted to 109,617,000), and synthetic resins. While emissions charges apply in theory to all enterprises in Tomsk, focusing policy on the most polluting industries would provide a cost-effective way to reach the abatement goal of the current policy. The fuel and energy complex, forestry, and chemical industry may be the most important polluters, but the ability of the emissions tax to motivate these firms to invest in abatement technology or otherwise reduce emissions, and to pay their charges to avoid fines appears limited.

Closer examination of data for Tomsk further reveals that ambient air quality there may be lower than officially reported. It is likely that officially reported pollution levels are to some degree lower than actual levels, while reported abatement levels somewhat higher. Nevertheless, officially reported data still reveals a large gap between the two. Abatement technologies Discrepancies exist between officially reported pollution levels and abatement levels. Figure 7.1 compares total emissions with total emissions rendered harmless through the use of abatement technology (usually in the form of end-of-pipe filters). The figure illustrates that, uncommon for Siberia, Tomsk emissions actually rise from 1987 to 1993, possibly reflecting the energy-intensity and fuel-based economic activity in the area during the transition phase. Given falling industrial output, these rising pollution outputs indicate that the environmental situation in Tomsk may have worsened during this period.

Figure 7.1



Source: (IIASA 1996)

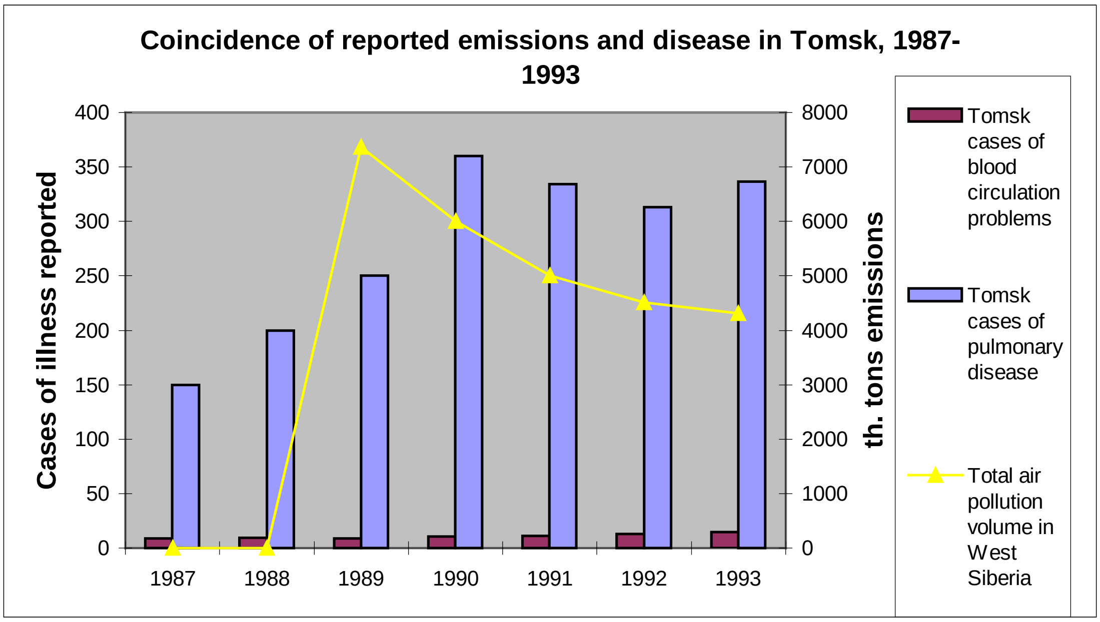
Table 7.3 notes the contribution by industry to total emissions in Tomsk oblast. Of note, some firms, the common suspects for major polluters identified in chapter two, might underestimate or underreport emissions or provide no information about emissions to local authorities.

Table 7.3 Industrial make-up of total emissions, Tomsk oblast, 1993		
Industry	Share of emissions output, (percentage of total)	Volume of reported emissions output, (th. tons)
Fuel	36%	397.85
Oil dwelling	34%	374.53
Energy production	8%	82.89
Oil-chemical	5%	58.46
Chemical	5%	56.14
Washing chemicals	5%	52.93
Forestry	3%	25.18
Other industries	4%	68.45
Total volume emissions	100%	1116.43
Source: (IIASA 1996)		

Without information about production technologies used, pollution intensities, and emissions charges, it is difficult to infer much about the functioning of the emissions tax in Tomsk. It appears officially that the oil and fuel industry plays largest role in terms of pollution output, but there may be others. A slight discrepancy exists between the output of the chemical industry (one quarter of the oblast's industrial output in 1993) and its emissions output (one sixth). Huber (*op.cit.*) reported that 85 percent of all pollutants are emitted by the Electric Power plant number 2 and the Thermo Electric Power Plant of the Siberian Chemical Plant. A large discrepancy emerges between these figures and those reported by Goskomstat (1994), where the energy production and large coal-burning electricity plants accounted for only 8 percent of total volume emissions. Given the assumption that emissions are a joint output with production, this appears inaccurate. In addition, official sources report deteriorating environmental conditions resulting from a concentration of the mining, chemical, nuclear, and timber industries. Yet for the given time period, none of these industries reported levels of emissions expected to correspond with given output levels. For remaining industries, we expect firms to report within a credible range of emissions and emit at or above reported emissions. The current system of monitoring and charging provides enterprises with incentives to underreport emissions and output and profit levels to avoid taxation.

Another weak correlation emerges between possible underreporting of high-volume chemicals and the occurrence of pulmonary and other respiratory diseases in Tomsk. Figure 7.2 illustrates that although officially reported emissions have fallen since 1992 and 1993, cases of pulmonary disease have risen slightly. This may reflect the reporting biases of the former and present systems whereas human health reports may indicate the actual pollution situation in the region.

Figure 7.2



Source: (IIASA 1996)

In 1995, Tomsk oblast spent a reported 5,579.90 million rubles for the "protection of nature." Roughly two thirds of industrial producers had some type of environmental project, with regional, local, and business leaders investing 170 mn rubles in those environmental protection projects. More detailed information about the parameters of spending and projects is unavailable, a problem throughout Siberia. The lack of clear guidelines for the use and definition and use of environmental spending, nature protection, and environmental projects makes it difficult to assess the extent of actual environmental investments or engagement in abatement activity in Tomsk, and leaves much leeway for noncompliance for enterprises. It appears that in Tomsk oblast, as in most areas in Siberia, nonpayment of emissions taxes, or the barter of emissions taxes for company-sponsored "environmental activities" relieves enterprises of a strict enforcement constraint. Definitions and monitoring remain lax and many firms appear to receive disguised subsidies to continue or increase emissions. The current emissions charge can be treated as a "write off" in general tax scheme by reporting that the enterprise is undertaking a certain level of environmental investments when in reality it may not. This may occur to a high degree with Tomsk's fuel sector, which is forced to deal in informal markets because of payment delays from the government and other firms. In terms of tax payments, a rate-of-profit constraint for the oil industry lowers revenue collection and dampens the ability of the charge system to influence abatement behavior (Goskompriroda 1994). It appears that in a substantial part of the oblast economy, the inputs for industrial production exceeded sellable output (Gaddy 1999). This negative value-added implies that imposing energy taxes or emissions taxes upon non-cash paying industrial sectors worsens the economic situation especially for the energy sector, vital for Tomsk oblast's economy.[6] Discussed below, rather than laying

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[6] The extraordinary disarray in payments is illustrated by the case of Gazprom. In late September 1998 it owed 139,000m rubles in taxes. At the start of that month it had been owed 90,000m rubles in domestic receivables due. In early summer of 1998 it had received only about 10 percent of its domestic "revenue"

off workers, Tomsk enterprise may choose instead not to pay its bills or produce for formal markets. Real effects of an emissions charge or other form of tax may not affect actual production levels.

7.3 Optimal public policy for Tomsk, and realistic policy

Scholars have devoted attention to the theoretical aspects of environmental taxes. Siberian officials considered the impacts of the emissions charge system, roughly defined revenue as a higher-priority goal and abatement as an important but secondary objective, and tried to find ways to implement the tax that would not cause more serious distortions in the economy. Our attention now turns to some of these preexisting distortions and their interaction with the emissions tax in Tomsk. Section 7.3 discusses the obstacles to achieving an optimum, set against the background of theory about what an emissions tax can and cannot achieve. The central issue is that emissions taxes often become negative for enterprises in Tomsk because firm can evade or avoid paying corporate, labor, and emissions taxes through official and unofficial means. Changing the price of polluting activities will affect behavior of a firm, but it is the framework of the market within which that policy is implemented which determines whether firms reduce pollution in formal markets. Due to institutional factors, the current tax policy may actually *subsidize* pollution output, encourage firms to increase production in informal markets, and increase nearness to relational capital (r_i) rather than markets (d_i). This basic aspect of many transitional economies casts doubt upon the ability of this abatement tool not only to achieve its primary goals of revenue and abatement, but to reach more ambitious goals identified in the literature. The section first briefly reviews the theoretical possibilities of the emissions charge in a second-best setting with involuntary unemployment and environmental externalities. It then turns to an analysis of the underlying assumptions, showing that many Tomsk enterprises are located relatively far away from market operation. This indicates that a market-oriented abatement policy will provoke few responses from such firms. The discussion then moves to a more detailed analysis of Tomsk's labor supply and employment status, and factor demand for industrial output.

7.3.1 Double dividend for Tomsk?

Several authors have analyzed the use of environmental policies to achieve optimal allocation of public goods. Most of the literature on the interaction between environmental and tax distortions deal either with revenue-neutral tax reforms (Goulder 1995); (Parry 1994); (Schoeb 1994), (Bovenberg 1995) or with optimal taxation in the

in money. The tax debt was equivalent to about 65 percent of July (one-month) GDP. State ownership stakes in both gas and electricity supply, including regional-government stakes in regional electricity companies remained high. What was happening was that policy-makers were, in effect, using the energy sector to keep large state and privatized enterprises alive.

presence of an exogenous revenue target (Sandmo 1975); (Bovenberg 1994). Bovenberg and van der Ploeg (Bovenberg 1996) extend the discussion by exploring the impact of such market failures on the optimal tax structure and on the marginal cost of public funds and the optimal level of public spending. This work proves useful to compare with the Tomsk case. Their investigation of optimal public policy and the components of social welfare integrates wage rigidities and environmental externalities, preexisting tax distortions, and impacts of a shift towards "greener" preferences. The tax shifting effect implies that if the reform shifts the tax burden from the overtaxed factor (the efficient environmental factor, labor) toward the under-taxed factor (the inefficient factor, pollution) the tax shifting effect alleviates initial inefficiencies in the tax system. However, these inefficiencies are exacerbated if the tax burden is moved into the factor that is already overtaxed in the initial equilibrium. Initial inefficiencies in the tax system provide both opportunities and dangers for environmental tax reform. A double dividend is feasible if, by shifting the tax burden towards the under-taxed factor, the tax shifting effect makes the tax system more efficient from a non-environmental point of view, and is large enough to offset the tax burden effects. Although Tomsk, and Siberia by extension, is not likely to be able to reach an optimal public policy by manipulating tax levels in the short term, the concepts provide insight into the institutional flaws that must be overcome in the current air pollution policy.

Within the framework set out in chapter three, we begin by analyzing enterprise and household response to an emissions charge. Firms face a concave production function *F(L, R, H)* and managers tend to view labor as a fixed input. Firms in Tomsk, and other areas in Siberia, seek to maximize an objective function by managing a portfolio of formal and informal market production. We assume that firms face exogenously determined producer wages w_p and producer price of resources q_p, leading to factor demand functions for labor and resources

$$(7.1) \qquad L = Hl(w_p, q_p), \qquad\qquad R = Hr(w_p, q_p),$$

To maximize the objective function, enterprises vary their demands for inputs, reacting to institutional factors such as tax policy, strength of enforcement mechanisms such as the legal system and government fines, and the relative costs and benefits of participating in the two kinds of markets. These aspects set the discussion of optimal government policy apart from those of the general literature. Studies by Bovenberg and de Mooij (Bovenberg 1995), Repetto (Repetto 1996), Carraro and Soubeyran (Carraro 1996), Lighthart and van der Ploeg (Lighthart 1996) assume that a perfect (formal) market framework already exists and that firms operate according to standard economic constraints and principles. In these models, although authors such as de Mooij and Bovenberg have evaluated second-best scenarios, firms cannot manage a portfolio across formal and informal markets, and it is always assumed that emissions taxes will remain positive. This allows the tax to provide incentives for enterprises to vary their production choices so as to abate pollution within formal markets.

In Tomsk, as in other areas in Siberia, empirical evidence suggests that these assumptions do not hold, varying in degree from industrial sector to sector. For example, a 1997 study by Leiter and Tedstrom estimated that the oil and fuel production sectors developed a sophisticated system for concealing the volume of extracted oil (Leiter 1997). They note, "in addition to incomplete reporting of extracting and processing crude oil (as well as oil products), informal activities include inflation of…production costs and commercial sales outlays; investment costs; costs for extraction equipment (ongoing outlays); and commercial expenditures connected with sale of the product on the domestic (or NIS) and export markets" (*ibid*). This evasive behavior masks revenues and protects the oil industry from some degree of taxation. Other sectors manifest similar market diversifying behavior. Budanov (Budanov 1997) reported that an estimated 15 percent of output by the metallurgical industrial sector in 1992 went unaccounted-for in formal markets. Tax avoidance and evasion appeared to motivate these firms. Although relatively small in terms of tax burden, the emissions charge is likely to elicit similar behavior from Siberian enterprises. The ability to "escape" into informal market production severely hampers the ability of a government to use the emissions tax to achieve goals even more ambitious than revenue or abatement.

Returning to our model for optimization, we observe a second-best situation in which involuntary unemployment exists, due to rigid wages. The government tries to maximize a utilitarian social welfare function

(7.2) $$W = M(C, N - L) + NZ(G) - ND(R)$$

which is made up of three elements: negative utility of environmental damage *D(R)*, utility gained from public consumption *Z(G)*, and utility of private consumption $M\left(\frac{C}{N}, 1 - \frac{L}{N}\right)$ enjoyed by individual households *N*. According to standard approaches, the government seeks to maximize social welfare *W* using *G* and taxes on labor t_l and resources t_r.

(7.3) $$W = M\begin{bmatrix} Hl(w(1+t_L), q(1+t_R)) + \\ (1-\tau)\pi(w(1+t_L), q(1+t_R)), \\ N - Hl(w(1+t_L), q(1+t_R)) \end{bmatrix} + NZ(G) - ND[Hr(w(1+t_L), q(1+t_R))]$$

The standard model next defines G, given consumer wage w, world price for resources q, and the government budget constraint

(7.4) $$G = t_L wHl[w(1+t_L), q(1+t_R)] + t_R qHr[w(1+t_L), q(1+t_R)] + \tau\pi[w(1+t_L), q(1+t_R)]$$

Furthermore, μ represents the shadow price (in terms of utility) of public revenue so that $\eta \equiv \frac{\mu}{M_c}$, or the marginal cost of public funds (MCPF). Using the modified Samuelson rule[7], MCPF is

(7.4) $$\eta = \frac{NZ'(G)}{M_c}$$

In Tomsk, the marginal cost of public funds was already high before the implementation of the emissions charge, as rigorous stabilization policies placed severe constraints on public sector expenditures. Poor tax collection now exacerbates this trend. In Russia, the percentage share of public sector investment in pollution abatement measures in total consolidated public budget expenditures was negligible between 1990 and 1996, reflecting the difficulty the tool may have in reaching even its primary goals.

The first order conditions for the optimal tax rates on labor and resources are

(7.5) $$\frac{t_L + s}{1 + t_L} = \left[(1-\tau)\left(1 - \frac{1}{\eta}\right) - \varepsilon_{Lq}\left(\frac{t_R - p}{1 + t_R}\right)\right]\frac{1}{\varepsilon_{Lw}}$$

for labor and

(7.6) $$\frac{t_R - p}{1 + t_R} = \left[(1-\tau)\left(1 - \frac{1}{\eta}\right) - \varepsilon_{Rw}\left(\frac{t_L + s}{1 + t_L}\right)\right]\frac{1}{\varepsilon_{Rq}}$$

for resources.[8]

Rigid consumer wages and pollution externalities give rise to distortions: a virtual tax on labor (unemployment) of *s* and a subsidy for pollution *p*. Rationing of the labor supply in Tomsk implies a gap between an exogenous consumer wage and the virtual wage. The virtual pollution subsidy, implicit because polluters do not pay for the social

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[7] The sum of the marginal rates of substitution between private and public consumption should equal the product of the corresponding marginal rate of transformation (unity).

[8] Assuming that consumer wages and the price of resources are fixed, the elasticities for them are infinitely elastic and only demand elasticities enter (7.5) and (7.6). We define elasticities of input demand as $\varepsilon_{Lw} \equiv \frac{-w_p l_w}{l} > 0, \varepsilon_{Rq} \equiv \frac{-q_p r_q}{r} > 0, \varepsilon_{Lq} \equiv \frac{-q_p l_q}{l} > 0, \varepsilon_{Rw} \equiv \frac{-w_p r_w}{r} > 0$. Because in reality supply in Tomsk is less than infinitely elastic, supply elasticities would enter the given formulas.

costs imposed by their damaging activities, is proportional to the sum of the marginal environmental damages of pollution.

Given these model assumptions, we now examine the possible effects of the emissions tax on preexisting economic distortions. Because of already-observed problems with avoidance, evasion, and monitoring (Atkinson 1980), the government cannot adjust profit tax rates above 100 percent, meaning that either labor or emissions taxes must be adjusted in order to optimize social welfare under this scenario. Under the assumptions of a perfect formal market, the government might achieve an allocation of these two taxes in which a reduction of one (typically labor) and an increase in another (emissions charges, seen as a charge for negative economic activity) could increase employment[9] and increase environmental quality. This is the "double dividend" hypothesis. Scholars have speculated about other dividends of such a tax switch, such as an increase in the level of public consumption of non-environmental goods, and a general rise in profits (Ballard 1992).

Income taxes were of negligible importance under Soviet administration (Feldbrugge 1989) and apparently do not yet play a significant role in government revenue (Leiter 1997). It is therefore unlikely that labor taxes can be effectively raised to any optimal level. Empirical evidence suggests that profit taxes on corporations makes up the bulk of government revenue, and draconian measures are taken to unsuccessfully extract up to 200 percent profit taxes, with expected results of evasion and avoidance (Larson 1998); (Leiter 1997). It also appears unlikely that attempts at adjusting the emissions tax level (as seen in chapter five) could result in increased revenues, internalized environmental externalities, or an alternative for lowering taxes elsewhere. Unemployment effects of the environmental tax, discussed below, appear negligible.

In addition, attempts at tax switching could exacerbate deteriorating living conditions and real wealth of Tomsk's citizens. It is sometimes suggested that official estimates may overestimate decreases in income, given a possible increasing tendency to hide income from official monitoring. However, decreases in aggregate income seriously underestimate the problem of increasing poverty in Russia due to accelerating polarization in the distribution of income and wealth. Income distribution has become increasingly skewed in Tomsk. This leads one to suspect that any attempts to reach a double dividend with the emissions tax by cutting income taxes (were they significant to real income levels) might prove regressive. Table 7.4 notes the uneven income distribution in Tomsk, which is estimated to have become more extreme in later years.

[9] Assuming gains from tax cuts don't go to increasing the wages of currently employed workers.

Table 7.4 Income distribution among Tomsk population, 1994-1995		
Population quintiles in Tomsk	Percentage share of cash incomes in 1994	Percentage share of cash incomes in 1995
0-20%	4.9	6.3
21-40%	9.9	9.3
41-60%	18.4	18.2
61-80%	21.5	22.4
81-100%	45.3	43.8
Gini coefficient	**0.36**	**0.37**
Ratio of earnings of lowest and highest 10 percent	10.7	10.8
Source: [Goskomstat, 1995 #488]		

An increase in such taxes would likely not increase unemployment, but would likely encourage firms to switch to greater involvement in informal markets. Instead of laying off labor or reducing production to cover the increase in input costs imposed by an emissions tax, many enterprises in Siberia appear to decrease the payment of taxes. "Many Soviet-era enterprises, now privatized, [are] unable to pay their way, but were not being forced either drastically to alter their costs, product-mix and markets or to be liquidated. They were not, for the most part, being directly subsidized from federal or regional budgets. They were, however, indirectly subsidized, because they were being allowed to escape paying a large part of their bills—both to their suppliers, to the state (taxes) and to their workers. Arrears of payment to suppliers were heavily concentrated on energy suppliers, especially the Unified Electricity System (YeES) and the regional electricity companies affiliated to it, and the monopoly gas supplier Gazprom. Arrears did not account for everything; there was also nominal 'payment,' in barter and bills of exchange (veksels—of various kinds, but, basically, intents of payment"[10] (Hanson 1999). Charging a specific input tax on industrial uses of fuel, as the principle official polluter in Tomsk, will not provide sufficient funds to finance activities external to the already under-endowed environmental fund.

The Tomsk government will very unlikely be able to manipulate effective tax levels; therefore, MCPF will not become cheaper and we see that the current abatement policy instrument is likely to cause greater distortions rather than alleviate them. While the regional government probably does attempt to maximize social welfare, using a tax policy to increase social welfare through formal markets appears to have result in driving at least some enterprises to increase production in informal markets, amass emissions charge arrears, and simply underreport actual emissions. The consequences call into question the ability of an emissions tax in this framework to achieve aforementioned goals. The emissions charge system lacks the magnitude and the proper framework to achieve a double dividend.

[10] Gaddy and Ickes describe this problem as one of cash-flow and barter (1998).

7.4 Impacts of the emissions charge

Each sector in Tomsk manifests unique characteristics and response to changes in fiscal policy. The emissions charge may affect different sectors in varying ways, according to each firm's ability to vary labor and resource inputs, and particularly according to the endowment of relational and market-oriented capital. This section takes a closer look at Tomsk's labor market and the most important employers in the region. It reviews the results of a cluster analysis and links the market-orientation of Tomsk's most important industrial groups to the overall likelihood that the emissions charge will eventually become effective in reaching revenue and abatement goals. Using the framework from chapter six, an analysis indicates that the charge is likely to affect some firms more than others. Finally, this section reviews some of the important obstacles for the implementation of the emissions charge system in Tomsk oblast.

7.4.1 Evaluation of factor demand, labor supply, and involuntary unemployment in Tomsk

As the macroeconomic indicators of GDP show signs of stabilizing, virtually all analysts consider 1995 to be a year of general decline in income and most other welfare measures for the population as a whole. For the first half of 1994, real income was estimated by Goskomstat to have increased by 14 per cent. But the same estimate for 1995 was negative 7 per cent. Very rapid inflation in late 1994 and early 1995 decreased income and real wages significantly, and subsequent restrictive macroeconomic policies have not allowed nominal wages to catch up.

Table 7.5 Basic Economic Data for the Russian Federation

	1993	1994	1995	1996	1997
Real GDP, % change	-7.1	-11.6	-4	2	-2
CPU, % change	840	226	140	60	30
Unemployment	5.5	6	8	9	13
Trade balance (in $ billion)	10.8	13	13	10	2
Current account (in $ billion)	2.1	0.6	-4.4	-5	-7
Consolidated government budget deficit (% of GDP)	7.6	10	4	4	4.5

Source: (Goskomstat 1998). 1993 and 1994 data are Goskomstat recalculations of previously reported growth rates according to a new methodology.

Industrial sectors have accounted for between 31.1 and 24.7 percent of the labor force between 1985 and 1995 (Huber *op.cit.*), and average wages there increased more slowly than the average for Russia, moving from 0.3 percent nominal increase in 1990 to 585 percent in 1995 (*ibid.*). Given official labor shortages, wages may be seen as fixed in Tomsk. Per capita wages in Tomsk--69,920 per capita—exceed the Russian average of 58,698 rubles per annum. Adjusting for costs of living, per capita, real income falls 22 percent below the Russian average (Bradshaw 1996). Tomsk nominal production has increased 10 percent faster than the Russian average, appears favored by regional conditions, and manifests lower than average labor capacity (*ibid.*).

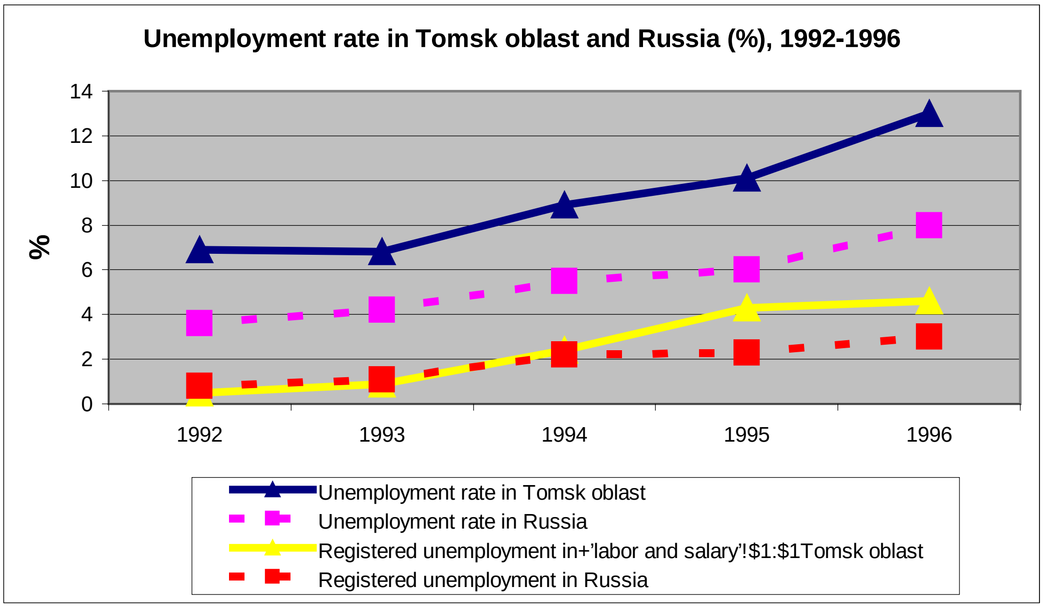
Tomsk's labor market exhibits increasing unemployment, rigid wages, and relatively inelastic demand for labor. The author estimates that elasticity for labor relative to capital production is 0.33 to 1.[11] Surveys between 1992 and 1996 revealed that, although Tomsk has a more favorable employment situation than other regions in Siberia, unemployment increased from 6.9 percent to 8.7 percent of the labor force (Vishnevskaya 1997). The growth of unemployment is hard to measure because many firms unofficially furlough workers but leave them on company rolls. This practice is a vestige of the paternalistic Soviet era, when the presence of workers in an enterprise often had no relation to that enterprise's actual production. Many of these furloughed workers find gainful employment in the private sector, where wages often go unreported. Such a system results in a haphazard, inefficient allocation of the labor force." WLO measurements indicated that at the end of 1995, Russian unemployment had reached 8.2 percent, with significant variations in Siberian regions. Another source, *Ekonomika I shizn'* estimated the figure at 8.6, or 6.3 million for the first quarter of 1996. These figures mask important distortions in the system, however. A 1995 survey of Russian enterprises reported that half of plant directors said that they had redundant workers.

Registered unemployment differed significantly from the figures above, but still increased from 0.5 percent (reflecting labor shortages in the region) to 4.6 percent during the same period. While these unemployment levels appear modest considering the economic duress in the region, Russian enterprises in general do not operate under normal market conditions. Unprofitable enterprises made up 33.8 percent of all existing enterprise in the oblast, nearly double the 16.7 percent average for the Russian Federation. Through 1995 an average of 19 percent of wages were paid late, and in January 1996 a total of US$2.1 billion was overdue in agriculture, construction, industry, and transportation. Goskomstat began keeping separate statistics for wages formally paid and those actually delivered. The payment record of privatized enterprises was worse than that of state enterprises, and in many cases workers were paid in kind rather than in cash. In early 1996, the average rates of overdue payment had reached 62 percent in ferrous metallurgy, 86 percent in oil extraction, and 22 percent in food processing. Underemployment (disguised to a degree in student enrollments, (Carlsson 1998)) and underpayment are the key characteristics of Tomsk's labor force. Many workers remain on forced part-time regimes or indefinite "unpaid vacations."

[11] R Square estimate: .330. Adjusted R Square: .323. Standard error of estimate: .1179.

Goskomstat (Goskomstat 1996) estimates that 5.5 per cent of the economically active population worked on reduced time at the beginning of June 1995.

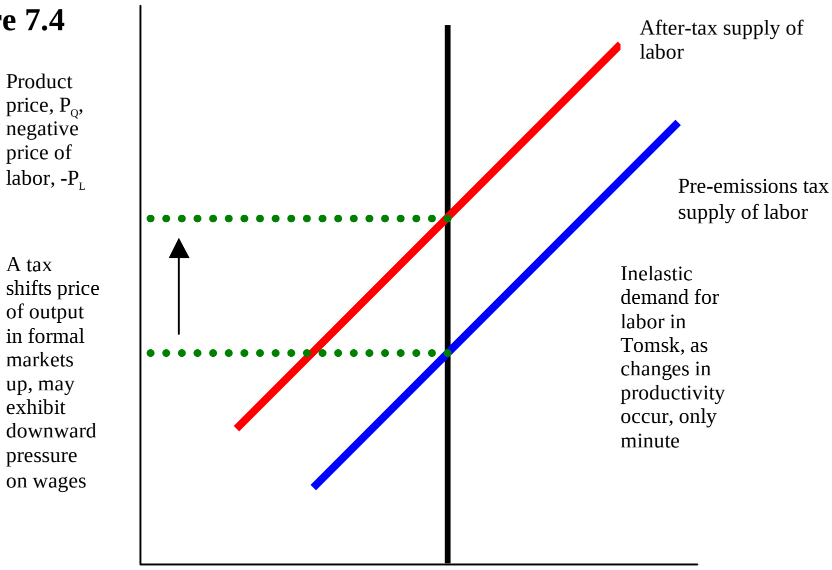
Figure 7.3



Source: (Goskomstat 1995)

Some seek employment in informal sectors when formal work slacks (Earle and Rose, 1996). With inelastic labor demand and a tendency to furlough rather than fire workers, it appears that an emissions tax will cause firms to shift taxes in ways that only weakly affect official employment levels. Figure 7.4 shows the typical analysis of full tax shifting when demand for labor is inelastic.

Figure 7.4



The affect on wages in given industrial sectors is ambiguous. It seems apparent, though, that instead of shedding its labor force, Siberian enterprises tend to incur either greater tax arrears or reduce production in formal markets and increase production in informal markets. No change in labor demand is observed and only prices for the enterprise output occurs. However, in the Tomsk economy, as in Siberia, the coexistence of formal and informal markets allows the firm to move away from formal production where taxes increase prices and decrease demand for output. We therefore expect that the emissions charge will, to an uncertain degree, encourage firms to increase production in informal markets rather than decrease labor inputs.

The impact of an emissions tax could affect industry disproportionally. For example, the sectoral wage pattern in Tomsk reveals that electricity production, fuel and nonferrous metallurgy (all but the last are the largest official polluters in the oblast) are the high wage sectors. These wages reflect skill-related differentials required in the different branches and reflect different productivity of the labor employed. The level of employment and wages, as well as endowments of relational and market-oriented capital will affect the degree of this shift between formal and informal market production.

7.4.2 Cluster analysis and market nearness

The theoretical impacts of the emissions charge appear small in Tomsk, but an interesting set of questions does arise. For example, could an emissions tax affect a cluster of industries and therefore affect regional development either positively or negatively? Which industries, if any, would have a greater tendency to operate in formal markets and respond to at least a degree to the constraints and incentives of the emissions tax? This section will examine the market orientation of the most important industrial producers, polluters, and employers in Tomsk to better discern the answers to these questions. From the pollution and industrial profile of the oblast, we see that four main industries play the leading economic and polluting role.

Huber (*op.cit.*) employed a cluster analysis to see the links between industry and market restructuring.[12] They postulated that, as the number of firms responsive to market mechanisms increase a collective pressure exists for all firms to rely more on the formal market and less on relations (this reflects changes in the relative costs of compliance, evasion and the costs of formal and informal market participation).

They estimated the productivity of the major industries in Tomsk, and investigated whether these industries will help move the oblast towards a market situation in which the emissions charge system would be more effective. They found that, accounting for

[12] Porter (1990) suggests that regional development –for our purposes development which enhances market nearness (d_i)—is associated with the development of industries that are “usually linked through vertical (buyer, supplier) or horizontal (common customers, technology) channels,” a feature called a cluster.

inflation in Tomsk in the early 1990s, both labor and capital productivity has fallen, and has been associated with a 22 percent decline in industrial employment. Given the inelastic demand for labor, it appears that layoffs were undertaken as a last resort, rather than as routine management attempts to improve labor productivity. Interestingly, they found that the legal definition of an enterprise's ownership status does not determine its objective function or serve as an indicator of its market behavior. Privatization does not provide satisfactory parameters for market nearness and may actually provide increased opportunities for informal market participation (Leiter 1997). Huber (*op.cit.*) noted that "the particular path of privatization chosen in Russia has led to constraints to more rapid restructuring and substantial rent seeking in firms of all types of ownership." A majority of firms in Tomsk (73 percent of the Huber sample) have undergone some form of ownership change. However, the impact of these changes upon firm behavior, and particularly firm objectives, is not fully clear. Changes in actual management appear rare. The Tomsk oblast pollution profile reflects this pattern, as both privatized and state-owned firms show similar levels of profits, losses, and pollution, as well as possible evasion levels.

For example, TOMSKENERGO (the only electricity producing firm in the Huber sample) is one of the biggest energy producers in Tomsk. The state-owned enterprise is responsible for a significant part of total oblast emissions, and experienced the largest increase in labor productivity and the second smallest decrease in capital productivity in spite of increasing employment rolls. This positive situation reflects the privileged situation of power, likely a high level of relational capital, and tax exemptions.

The results of the cluster analysis revealed that key industries—the oil and chemical industry—had few linkages to the oblast economy. Oil and chemical products are not used as inputs for Tomsk industrial output and are typcially processed elsewhere (Tomsk oil is transported to refineries in Krasnoyarsk). Forestry industries in Tomsk lack "sophisticated upstream users," reflecting low levels of both local value-added and demand for wood products. As with oil and chemicals, raw forestry materials are shipped elsewhere for processing. Assuming that linked, regional clusters exist in a region (Porter 1990), that economy should have greater chances of establishing a framework in which formal market-oriented firm behavior emerges. Conversely, the lower linkages between firms, the less pressure towards official, formal market behavior may exist. Fewer linkages may encourage firms to attain their objective functions through increases in "relational investments" (Gaddy 1998). Tomsk industries did not appear to have strong linkages. These findings have important ramifications for a market-oriented pollution control policy such as the emissions tax.

The results of a sample of Tomsk industrial firms can be compared to the market policy response framework to get a rough idea of the position of these firms with relation to the viability and compliance constraints. Although the actual position of these constraints is not entirely clear for Tomsk, empirical evidence about the firms surveyed suggests that firms in the forestry industry, machine building, and some forms of construction have a tendency to seek viability through investments in relational capital rather than formal market restructuring. Case studies performed by (Budanov 1997), (Leiter 1997), and

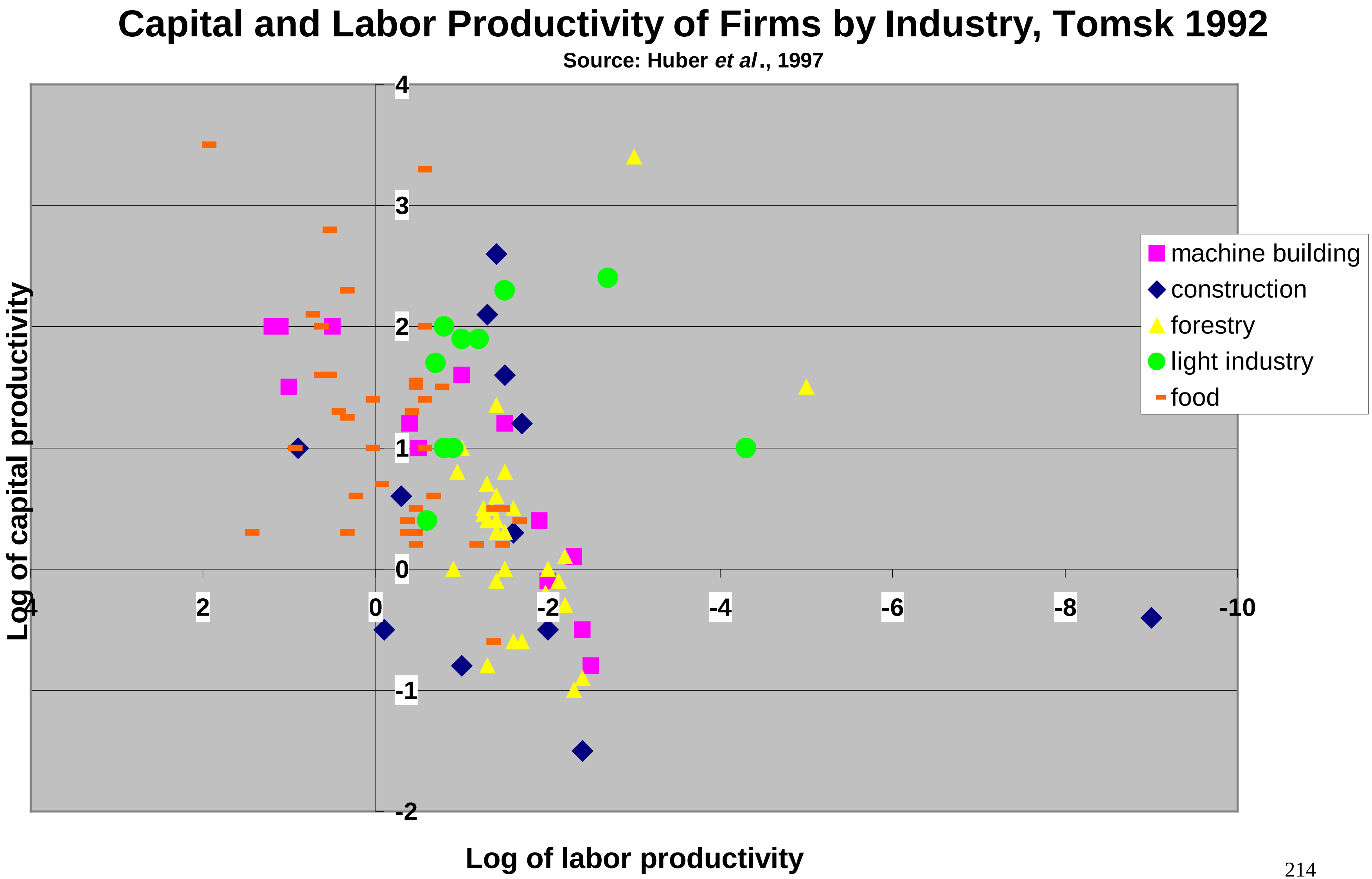
Burakovsky and Mohyla (Burakovsky 1997b), (Burakovsky 1997a) further indicate that oil and chemical sectors have a high likelihood to mask profitability in formal markets and increase activity in informal markets when possible (Kuvalin 1997). These findings indicate that the most significant polluters (as well as producers and employers) in Tomsk oblast will likely not respond to an emissions charge in the hoped-for way. Firm behavior will more likely be characterized by increased activity in informal markets, tax avoidance or evasion, and barter trade than by an increased investment in abatement technology or charge payments.

Figure 7.5 illustrates the log capital and labor productivity of various Tomsk enterprises in 1992, performed across a spectrum of over 200 enterprises (Huber 1997). The same study noted a dynamic by performing the same survey a few years later, noting that productivity declined in both labor and capital markets, but especially in capital markets. The data in figure 7.5 suggest that in 1992, capital tended to be very weakly productive, while labor tended to have weakly negative production levels. Downward trends indicate the possible interaction of several phenomena, including the possibility that although firms choose to continue employment (whether or not labor receives prompt payment for their services) and production, those firms may not choose to engage in legitimate market activity. Several other possible explanations present themselves, but due to lack of further concrete data, the author stops at this point. However, given the possibility that firms may be moving towards “virtual markets” at an increasingly pace, it is appropriate to ask which firms may comply with market-oriented policies such as taxation. To answer this question, one needs specific data about levels of market nearness and endowments of relational capital—or at least a reasonable indicator of such.

Lacking such specific data, the author attempts to plot arbitrary *VC* and *CRB* lines on the Huber case study data, based on an understanding of Tomsk industrial structure and general trends in the region. Figure 7.6 arbitrarily illustrates how labor and capital productivity levels can be plotted against the viability constraints and compliance response boundaries. The author has adjusted the two boundaries to fit the data trends, so that the viability constraint slopes downwards from about 0 capital productivity to about 0 labor productivity. This reflects the fact that as firms move towards the upper right hand corner of the graph below, they increase performance in formal markets. As formal market performance becomes more lucrative, this model assumes that firms will increase activities there and decrease noncompliance. The actual position and slopes of the boundaries depends on specific aspects of Tomsk’s regional economy. For example, the relative costs of increasing relational capital vs. the payoffs of formal market investment will affect the position of the *CRB* and *VC*. In addition, general market stability, the number of firms maximizing participation in formal markets, and the level of formal market restructuring will all affect the actual constraints faced by firms which determine formal or informal market participation.

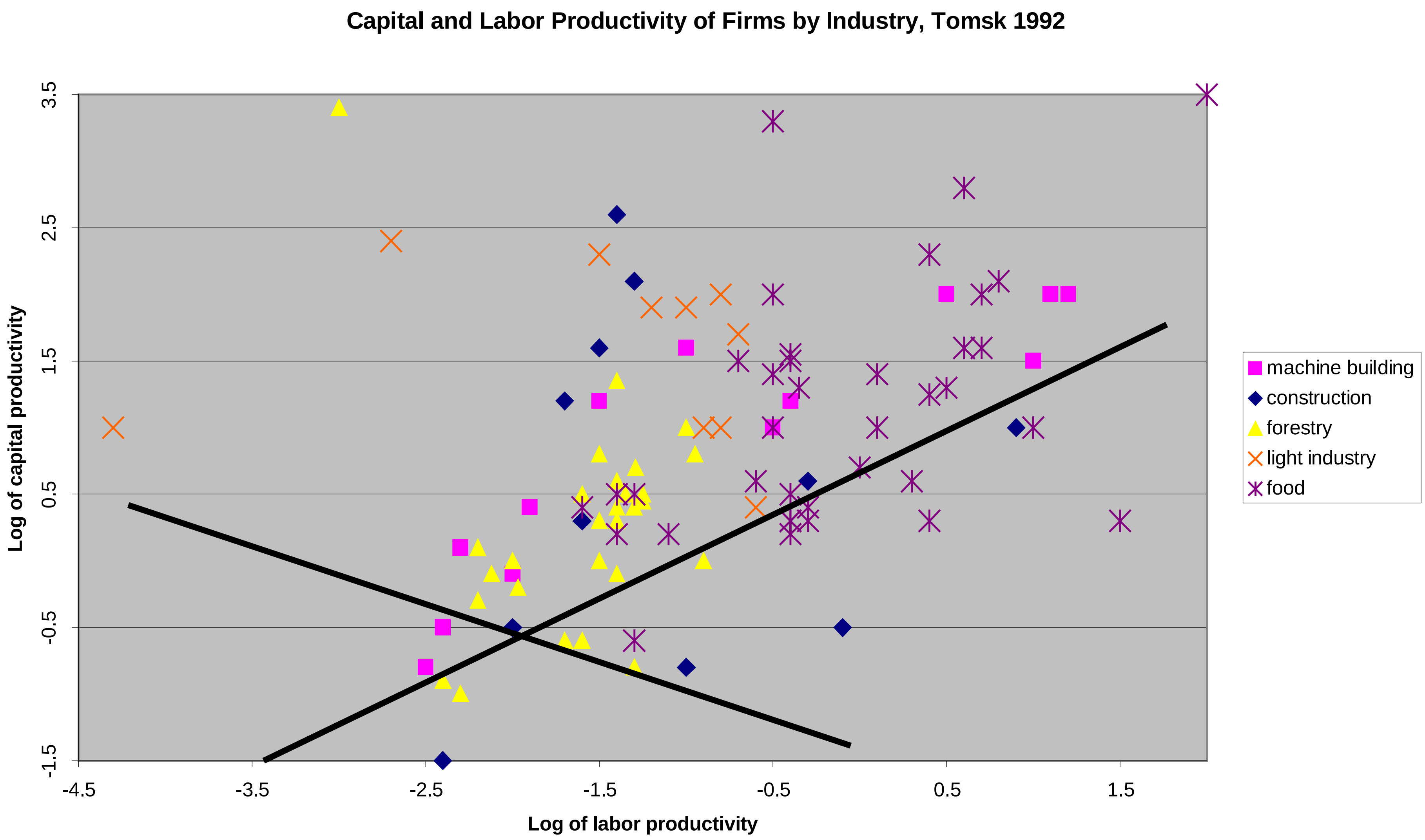
From the data set presented in Huber (*op.cit.*) it appears that forestry would be less likely to participate successfully in formal markets and less likely to respond to market-oriented incentives such as the emissions tax. This industry reports low levels of productivity and profitability, and due to its resource-intensive nature may engage in barter trade to survive. The food industry, on the other hand, appears to have higher productivity in formal markets, is characterized by high degrees of competition which may serve to move firms towards formal markets where rules of competition are more perfectly established, and may be expected to respond to market-based policy instruments. Machine building, although characterized as a value-added sector, has traditionally had a high level of informal market participation (Leiter 1997). One study reports that "During the reform period as motivation for production inflation declined motivating factors for underreporting increased sharply…the accelerated growth of the tax burden…led to underestimating and concealing production volume and gave rise to new forms of informal activity" (*ibid*).

Figure 7.5



Capital and Labor Productivity of Firms by Industry, Tomsk 1992
Source: Huber *et al*., 1997
4
3
2
1
0
-1
-2
4
2
0
-2
-4
-6
-8
-10
Log of capital productivity
Log of labor productivity
machine building
construction
forestry
light industry
food

Figure 7.6



Capital and Labor Productivity of Firms by Industry, Tomsk 1992
Log of capital productivity
3.5
2.5
1.5
0.5
-0.5
-1.5
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
Log of labor productivity
machine building
construction
forestry
light industry
food

Assuming that the above VC and CRB bear some relation to reality, one might expect firms to the upward left of the VC and CRB to maintain viability by investing in r_i and enough d_i to earn necessary hard cash. These firms may have little incentive to more any farther towards formal market participation and will likely not comply with market-oriented policies such as the emissions tax. Firms that lie above the VC and below the CRB (to the lower right hand corner) have a greater likelihood to move towards formal market participation, to make greater investments in d_i, and to respond at least to a degree in market-based policy instruments. Unfortunately, although lacking data the largest polluters in Tomsk do not appear to operate within this area. Oil and fuel, chemicals, large energy producers, and other major polluters actively balance a portfolio in which informal market participation plays an important role in keeping firms viable, even profitable. It is therefore unlikely that the emissions charge system will impose the incentives it was intended to in Tomsk oblast.

7.5 Conclusions

This chapter has evaluated the emissions charge system within one region in Siberia. This analysis has revealed some of the practical, important issues that affect the actual outcomes of market-based instruments in an economic setting where firms vary production across informal and formal markets. This ability to avoid the constraints of formal markets changes the analysis so significantly for Siberia, that the author concludes that the current emissions tax policy will likely not motivate enterprises to either increase abatement activities or investments nor pay their actual environmental taxes. This finding deviates from theoretical work which assumes only formal market participation and positive emissions tax levels.

A closer look at the economic context of Tomsk oblast, including its pollution profile, industrial and employment characteristics indicates that the emissions charge faces significant obstacles to effective implementation. Like other areas in Siberia, Tomsk regional authorities have no greater access to resources or monitoring facilities than others, making enforcement difficult. The standard self-reporting mechanism is fraught with underreporting, intentionally or not, and the charges themselves change frequently within the labyrinth of Russian tax law. This obliges taxpayers to either interpret the charge payments "creatively" or avoid taxation. Journalists in the region have reported cases in which managers would prefer to comply with the tax code, but do not know how because the code is under constant revision (Leiter and Tedstrom, 1997). The opaque and complicated tax system within which the emissions charge is embedded discourages compliance. In addition, any attempts to raise emissions charges in order to increase government revenues and ease the tax burden for labor or corporations may cause increased evasion or avoidance, a decrease in collected revenues, or both. Were the regional government successful in reducing labor taxes, it is very likely that this policy would be strongly regressive, as more wealthy workers might be freed of a tax burden and less wealthy could suffer from reduced access to government funding as government revenues decline. The pollution profile of Tomsk oblast indicated that environmental conditions are likely worse than assumed. However, it is positive to see that only traces of the highest-risk chemicals such as heavy metals are emitted in the region. Health risks associated with Tomsk emissions appear to be most heavily concentrated around pulmonary and skin irritations, which bear a lower political cost than cancer, higher infant mortality, spontaneous abortion, and other acute or chronic disorders associated with high-risk chemicals. While this is good news for the Tomsk population, it suggests that relative to pressing economic concerns, environmental concern and the willingness to pay for environmental damage will likely remain low.

In terms of possible “double dividends” from increases in emissions taxes to fund decreases in labor or corporate taxes, the author found that there are few possibilities to find such a tax mix where firms will not evade the tax, even if taxes are cut elsewhere. Effects upon employment, whose demand appears relatively inelastic in Tomsk and in Siberia, appear negligible when emissions tax levels change. However, shifts in the price of emissions could raise the price of output in formal markets, lower the wages of workers, and offer firms incentives to switch production into informal markets. In some cases, given possible barter trade of tax arrears, it is even possible that the current emissions charge provides a subsidy for polluting activities. This depends on the enterprises relative position within the oblast. Given that sectors such as oil and fuel, and energy providers monopolize local markets for heat, as well as employment, the emissions charge could feasibly give such firms greater leverage with the regional government. Many authors have noted that clients (including the government) are unable to make cash payments to fuel-related enterprises. It has been observed that such enterprises must engage in barter trade due to the cash crisis, and often tax arrears are also bartered. Instead of paying emissions charges, which go into the environmental fund and are hypothecated for abatement and other environment-improving activities, charges become negative for polluting activities for such enterprises in Tomsk. The effect of the emissions charge on private and public consumption appears ambiguous. Effects upon environmental quality appear neutral.

The case study of Tomsk illustrates some important lessons for the implementation of a market-oriented policy instrument in a transitional economy.

Investment conditions matter. Implementing a market-based tool for abatement assumes the tool provides incentives for investment. This case study of Tomsk indicates that the economic conditions must be stable enough that its safe (and profitable) for a firm to invest and for a financial institution to make funds available.

(Formal) Market-orientation of enterprises matters. Those enterprises which can maximize some objective function by varying production in informal and formal markets have a lower tendency to respond to market-oriented policy tools. Settings where informal markets make up a large portion of overall economic activity might prove poor contexts for policy instruments geared towards changing the prices of formal market activities only.

Privatization not necessarily an indicator of formal market responsiveness. Officials expressed great initial enthusiasm for privatization as the key mechanism for moving centrally-planned, former USSR economies towards the market. Yet results from studies of Tomsk (Huber *op.cit.*; (OECD 1996); (Radaev 1997)), the Russian Federation (Kovalevskii 1995), and other transitional economies have shown that the effects of privatization on restructuring and market performance are ambiguous. Employing market-oriented policy tools within a context where firms, although officially privatized, bear significant non-market characteristics implies poor firm response. The experience with the emissions charge system illustrates this case.

Easy movement between informal and formal markets makes a double dividend unlikely as the government tries to change relative prices of positive and negative economic activities. It appears unlikely that an increase in emissions taxes could be significant enough to fund more than the environmental fund. Although serious distortions in the tax system and labor markets do exist, reducing these through repricing of environmental goods and services will not impose a hard constraint in the current system. Hence, lowering corporate taxes and substituting emissions charge revenues to fill the public fund will likely enhance distortions, particularly for the lowest income groups in Tomsk as the marginal cost of public funds rises (i.e. public funds become more scarce).

Finally, the economic context into which market-based policy tools are set appears to make all of the difference in Tomsk. Current institutional rules preclude perfectly operating markets. As one author notes “the growth of Russia's vastly expanded "hidden" economy owes its vitality as much to the new regime's restrictions as to its permissiveness. Concealment may be viewed as a rational reaction to the government's tax and regulatory policies: the desire to evade what is perceived as unacceptably high taxes, or, in many cases, to pay any taxes to a government that is seen as corrupt, unreliable, and incapable of utilizing tax monies to provide the population with social services and protective guarantees; the desire to get around norms and rules limiting the size and sphere of commercial activity; the desire to save on transactional [compliance] costs; and, inherent in all the above, the desire to maximize profit or to survive economically for marginal firms” (Leiter 1997). It is likely that the emissions charge system will only begin to function more effectively as firms move into the theoretical space above the viability constraint and below the compliance response boundary. Encouraging compliance with an environmental program involves in the short to medium term general economic restructuring, not necessarily an increase or reductions of tax levels themselves. “Getting the prices right” might occur as a natural process, but it probably won’t occur before policy makers get the context right for such policy instruments.

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Chapter 8: Conclusions

8.1 Introduction

Environmental taxes have captured international attention as a cost-effective and flexible policy instrument for air pollution abatement. Studies from prominent organizations began reporting in the early and mid 1990s that environmental and tax policies should be made compatible and mutually reinforcing as a way to improve environmental conditions, raise revenue, and provide a host of other benefits to societies using them. A 1994 OECD report noted that the experience with environmental tax instruments "indicates that tax instruments can also provide 'a rich seam of economic efficiency' for countries in transition to tap for their environmental policies." Although, it continued, "the countries of Central and Eastern Europe face many challenges in adapting existing environmental tax systems to the conditions of emerging market economies and to the goals of the new environmental policies," the report remained positive about the benefits which could accrue from a market-oriented abatement policy. This study has investigated the situation of pollution, the theory behind and implementation of emissions charges, firm response, and economic impacts of Siberia's emissions charge system. Unlike the conservatively cheerful reports of such charge systems in transitional economies (OECD 1994b), (Bluffstone 1997), (Klaassen 1995), this study failed to find the "rich seam" of either economic efficiency or actual abatement incentives. Siberia shows only meager results for revenue and abatement under the emissions charge

Did these authors overestimate the scope and opportunities for the emissions tax in transitional economies? Why have the outcomes for this policy been so poor for Siberia, and what implications do these findings have for other transitional or developing economies considering using an emissions tax to improve environmental quality or raise revenue for these or other purposes?

The underlying assumption for most of these discussions has been that formal markets, which rely on monetary transactions, provide the framework for market-oriented policy tools. Theorists, grounded in the assumptions of Western economic models, provided a host of information to policy makers of transitional economies about the issues that arise in using a tax instrument to achieve environmental objectives. Typical concerns of policy design such as selecting the appropriate target set of pollutants, setting appropriate tax levels and fine-tuning the interaction between taxes and preexisting regulatory frameworks have dominated general discussions of tax instruments for abatement (OECD 1994a); (Klaasen 1994); (Klaassen 1995). Those writings aimed specifically towards the emissions charge in transitional economies focused on inflation indexing and the privatization of ownership structures as determinants of firm response to the tax (OECD 1994b). Yet the literature dealing with market-oriented environmental policy up to this point—and that very literature which analyzes the implementation and impacts of environmental charge systems in transitional economies—has missed the fundamental obstacle to such policy instruments in imperfect market economies.

The literature assumes that while evasion and forms of noncompliance exist, formal market institutions are strong enough to constrain most firms to limit the majority of their activities to observable, taxable scenarios. These works largely overlook the growing presence of informal, non-taxable, barter-oriented markets in transitional economies. The ability to "escape" to informal markets where tax arrears are avoided or paid in kind foils the emissions charge system. Siberia's extreme case illustrates that the institutional framework for formal, capitalistic market activities (and enterprise orientation towards the formal market) must dominate if a policy tool such as an emissions tax is to be effective.

Although decision-makers expected such instruments to function imperfectly in economies moving towards market societies, the issues excluded by the key assumptions of how tax policy operated became the moving obstacles to effective implementation. The critical assumptions underlying the environmental tax instrument did not hold, particularly in Russia. One of the key obstacles in the implementation of a market-oriented instrument—an emissions tax—in Siberia is that a major part of the economy is demonetized. A barter system exists both to evade taxes and to pay taxes, a situation not dealt with in standard economic models, and one which prevents the potential economic incentives for abatement, as well as the benefits of tax revenue from the emissions charge. Most authors have acknowledged weaknesses but have given relatively positive reports about the policy instrument and its implementation (Bluffstone 1997); (Klaassen 1995). These works have implicitly stressed the idea of an environmental Kuznets curve (Andreoni 1998): that once economic growth takes place, once all firms are privatized, once the emissions tax levels are raised, once the administrative structure is improved the emissions tax will function according to theory. However, we find that if Russia does continue to operate one formal economy based on monetary transactions and one informal economy based on non-monetary transactions, the prospects for an effective emissions tax that provides incentives for Siberian enterprises to reduce emissions is rather dim. Without the market orientation necessary to feel the constraints of a market-oriented tool, Siberian firms will likely not decrease emissions, and may increase emissions as a by-product of wasteful production methods that are part of the distorted economic system.[1]

The literature assumes that while evasion and forms of noncompliance exist, formal market institutions are strong enough to constrain most firms to limit the majority of their activities to observable, taxable scenarios. The literature largely overlooks the dual, growing presence of informal, non-taxable, barter-oriented markets in transitional economies. The ability to "escape" to informal markets where tax arrears are avoided or paid in kind foils the emissions charge system. Siberia's extreme case illustrates that the institutional framework for formal, capitalistic market activities (and enterprise orientation towards the formal market) must dominate if a policy tool such as an emissions tax is to be effective.

Chapter eight summarizes the findings of this study and outlines the most important lessons learned, which differ from those found in the literature published on the topic during the 1990s. Section 8.2 reviews the major questions raised in this study, as well as the possible links and relevance to other economic areas considering implementing an emissions tax. Section 8.3 reviews the experience of other transitional economies with the emissions charge and asks which variables account for success and failure of each case. The findings suggest that those countries with market frameworks in place and a relatively high degree of formal market orientation among firms had a more successful experience with the charge. This underscores the central thesis of this work. Section 8.4 summarizes the major findings of each chapter. Section 8.5 uses these findings to draw the major "lessons learned" from the Siberian case study, and its relevance for other areas. It draws the final conclusions about air pollution policy in economies in transition.

8.2 Major questions and findings

The study set out to discover the most important variables affecting the success or failure of an emissions tax, in the context of a transition economy. An evaluation of the Siberian Pollution database (IIASA 1996) confirmed that pollution is a problem in the area and that air pollution policy might improve the situation. Moving from the fact that the region has implemented an emissions charge system, the author began to examine the general literature about market-oriented abatement tools, which identified the following as some of the key variables explaining the degree of success of an emissions tax:

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[1] Gaddy and Ickes (1998) refer to such firms as value-destroying.

- Appropriate valuation methods to measure the divergence between private and social costs imposed by pollution
- Determining the appropriate price level for taxes
- Finding optimal tax levels to maximize technical and economic efficiency
- Enforcement and monitoring (Downing 1974), (Harford 1978)

The literature devoted to market-oriented policy tools for transitional economies discussed:

- Inefficient administration, with understaffed, under-trained, and underpaid personnel assigned to monitor and enforce the policy in an area too vast for continuous control
- Institutional history of the former system such as state-owned firms and soft budget constraints
- Methodologies of collecting and reporting emissions information (Inconsistent measuring and reporting)
- Prices, which appear too low to encourage abatement (reflecting the primary revenue-raising goal of the tool).
- Privatization, which is deemed in most of these pieces to be the key to firm response to the emissions tax. The common analysis is that persistence of state-owned firms encourages widespread lack of clear profit maximization objectives, which in turn reduces the sensitivity of firms to market incentives for pollution control.

After evaluating these variables, the author finds that most writings have underplayed or missed the most important factor affecting the implementation and functioning of an emissions tax in a transitional economy. Before implementing a market-oriented environmental policy, firms must respond to formal, monetized market incentives. These sources viewed the restructuring and environment problem as a problem of moving firms closer to formal markets, about which most Western models make their assumptions. However, as the compliance response boundary framework points out in chapter six, at least one other dimension plays a role and influences whether firms respond to the incentives and penalties of a pollution tax or do not comply. Because firms can survive by investing in relational capital and market-oriented choices, we must know where firms are in this scheme before implementing a policy tool to reduce pollution. If firms, as those in Siberia, fall outside of the compliance wedge (above the viability constraint yet below the compliance response boundary), policy makers might expect the emissions tax to perform poorly in meeting policy goals of abatement and revenue. In this case, the tax provides few benefits in terms of enhancing efficiency, improving environmental conditions, or allowing “double dividends.”

The questions which emerged in examining Siberia’s case of emissions charges and pollution focused on the following five points:

1. Given the current pollution profile in the region, could an emissions tax address ambient air quality and provide effective incentives for abatement?
2. What are the most important variables that affect the implementation of an emissions tax in imperfect markets?
3. How does the actual program differ from theory and what lessons can be drawn from Siberia's experience with the tax?
4. How do firms react in this economic context to the tax and could the policy instrument achieve multiple objectives?

The analysis has ignored a significant and important set of issues for the implementation of market-oriented abatement tools. Considering the institutional framework of these economies is vital in assessing the actual impact of such policies; however, analysts have missed a key variable. For example, the OECD estimated that the "soft budget constraint" of the former USSR system was the main obstacle to implementing market-oriented policies. A 1993 report said the "Many transition countries have inherited systems of environmental taxes and charges from previous planned economies. These systems did not provide any incentive to reduce pollution, because, under central planning, enterprises were protected from the risk of bankruptcy, facing only "soft budget constraints," so they could pay fines environmental fines and charges without regard to cost. In addition, state-owned enterprises in planned economies were often able to evade environmental requirements through negotiation." This interpretation blames the inefficacy of a tax system in a centrally planned economy on the failure of the price mechanism to function (the soft budget constraint). However, the findings of this study have shown that, at least in Russia, it is not only the soft budget constraint in formal markets that circumvents effective tax incentives. Instead, the ability for firms to act in informal and formal markets simultaneously is the key factor preventing the emissions charge from imposing real incentives. The price mechanism in our analysis works fairly well, but due to the ease of producing in informal markets where the tax instrument does not reach, firms may have incentives counterintuitive to those intended. In particular, this study illustrated that economies such as Siberia's manifest a type of dual economy, where firms manage their production portfolios across informal and formal markets. Because of the apparent ease of operating simultaneously in both types of markets, a market-oriented policy tool such as the emissions charge system cannot be expected to operate well.

To evaluate the strength of these variables in the success or failure of Siberia's emissions tax, the author evaluated Siberia's pollution profile. Siberia's unique characteristics--concentrated economic operations around population centers, readily identifiable stationary pollution sources, and a lack of mobile pollution sources—makes it feasible to assess the causes of pollution. The key questions included which groups of chemicals and industries figured most prominently in regional pollution. The majority of all air pollution is generated by large industrial centers, and that most of that pollution is deposited within a reasonably near area to those sources.[2] Pollution in the

[2] Some of course is transported over long distances, but these were outside the scope of this study.

region is highly concentrated, with remote areas hardly affected and populated areas heavily affected in terms of degradation of human health, and environmental health, measured by proxy in terms of forest health. Pollution is not distributed evenly throughout industrial sources, particularly for high-risk emissions such as lead and mercury. The worst polluters, in terms of volume and risk, currently "escape" the emissions charge officially and unofficially. The worst pollution depends on the industrial processes of these heavy polluters, which appear in turn to be a function of the ability of these firms to survive in the current context. If these firms remain viable through bartering and increasing r_i rather than d_i, we can expect a worsened emissions situation for high-risk chemicals. If these firms move towards the markets, they should have an incentive to invest in new production processes that are less pollution intensive, if they fall under the compliance response boundary, they will reduce emissions even further.

The author explored the theory of how an emissions tax should work, to further evaluate the strength of the noted variables. Chapter three examined the assumptions of an allocation model, first without, and then with negative externalities from pollution. Because the emissions tax imposes costs upon polluting industry and because pollution imposes constraints on the output of industry (in terms of lower-grade inputs such as labor and natural resources) the model assumes that a tax can promote efficiency and effective abatement. In theory, an emissions charge on firms producing only within formal markets would effectively address a large percentage of Siberia's pollution problems. Siberia's pollution tool does charge higher rates for chemicals with more detrimental human health impacts, roughly reflecting scientific findings. Theory predicts that the charge would successfully impose a constraint upon firms and an incentive to reduce the emission of the most costly types of pollution, such as those in the "high risk" category. Given the assumptions that firms operated only in formal markets where transactions take place based on monetary exchange, the variables of most importance appeared to be the way that policy affected a firm's production function, which assumed that emissions were a joint input of production. In theory, setting the appropriate charge level to equate social and private damage, and the effects of that tax on technological and economic efficiency were primary concerns.

Yet the actual structure of the charge system in Siberia deviates from theory. The program has significant weaknesses; almost every aspect of the policy—from setting charge levels, to monitoring and measurement methodologies, to administrative tangles—appear extemporaneous. No discussion of setting shadow prices for pollution equal to social marginal damage of pollution appears to have occurred. Political reality and the pressing economic concern with survival dictated that key polluting firms are excused from payment obligations, and that the levels charged to other industries reflect the ability of industry to pay more than the actual damage imposed by particular pollutants. These include administrative limitations and obstacles, inflation, and sporadic monitoring and imprecise enforcement of taxes and penalties incurred by firms. Measured against policy goals of revenue collection and pollution reduction to meet human health standards, the policy tool has not yet experienced success. Expected revenues fall drastically short of actual collections, while pollution intensity actually appears to have increased.

Given the weaknesses of the policy implementation, we further examined possible firm responses to an emissions tax. While a major part of the research assumes that price-taking, privatized firms will respond better to the tax than other forms of enterprises, both theory and experience refute this claim. Under Siberia's particular program parameters, one can expect firms of all types of ownership to respond similarly to the emissions tax. Instead of ownership structure and price levels, the important variable appears to be charge capping, and widespread noncompliance with the emissions tax program. Studies indicate (Leiter 1997), (Huber 1997), (Fischer 1998) that privatization and the structure of firm ownership doesn't necessarily reflect that firm's degree of market orientation or the degree of sensitivity a firm will manifest toward market-oriented policies. The status of privatization—enterprise ownership structure—and the level of charges appears less important as explanatory variables.

A framework which accounts for the dynamics of firms moving through the transition either towards or away from formal markets (Gaddy 1998) predicted that firms will comply with an emissions tax only under special circumstances, which currently do not apply to the majority of enterprises in the region. Charge levels also play a much less important role in providing incentives for abatement or compliance with the emissions tax. Instead, this framework clarifies what types of firms may comply with the emissions program, and which may not. Using this model, we expect that firms with a high degree of formal market orientation are more likely to feel the constraints and incentives provided by such a market-oriented emissions abatement tool. Viable firms with a higher degree of "relational capital" may choose to balance operations between informal and formal markets. Such firms would have an increased incentive for noncompliance as emissions charge levels rise, because a change in the cost of pollution changes the relative cost of production for formal and informal markets. In this setting, the emissions charge may have perverse effects, causing firms to choose operation in informal markets where no premium is set on pollution rather than paying taxes or abating pollution in formal markets. Cash-shortages and the magnitude of the informal sector, as well as institutional reinforcement of tax evasion or noncompliance, make it unlikely that the emissions charge will impose real abatement incentives or increase environmental fund revenues. In the worst case, the current interaction of informal markets, the tax may actually subsidize further pollution.

A case study of Tomsk revealed a similar pollution profile to that of Siberia. A handful of industries takes responsibility for almost all industrial pollution. These industries also employ a majority of workers and manifest a relatively low degree of orientation towards formal markets and international trade. Most value-added activities for the natural resources withdrawn in Tomsk occur elsewhere, giving enterprises fewer incentives to invest. Underreporting of emissions appears to be a problem in the oblast, although the emission of high-risk chemicals appears lower in Tomsk than in other Siberian areas. An emissions tax increases production costs for formal markets, so the author explored labor effects related to this policy. The imposition of an emissions charge has little or no impact upon the inelastic demand for labor in Tomsk. However, price changes due to the imposition of an emissions tax may change the relative costs of production in formal and informal markets, lower the wages of workers, and offer firms incentives to switch production to non-taxed areas. Tomsk enterprises, like many oblasts in Siberia (particularly the most polluting ones, such as energy generation), may economize on cash transactions by bartering tax arrears for needed goods and services. Anecdotal evidence hints at the existence of this phenomena, suggesting that an emissions tax might provide a weak subsidy for polluting activities, rather than an incentive for abatement. The case study pointed out several important "lessons learned" about the Siberian emissions charge program, which have relevance for this policy tool in similar contexts.

8.3 The emissions tax in other transition economies

A brief survey points out the differing degrees to which the countries in question were able to achieve several objectives simultaneously. It first provides a general overview of the programs and distinguishes which countries' charge systems have proved effective in raising revenue and in providing incentives for abatement and environmental investment and which have not. It further reveals the important variables that led to the ability of each program to reach its goals, relying on indicators from macroeconomic data and performance of the emissions charge system in these economies.

As figure 8.1 shows, all of the systems made pollution reduction an official goal. Like the Russian charge system, however, in an atmosphere of limited government budgets and extreme financial constraints, as well as high inflation and poorly developed credit markets, finding the financial resources for environmental investments became difficult. Hence, a tax became the preferred policy choice for its apparent ability to raise revenue. Experience has shown that actual revenue raised by each program correlates with the responsiveness of firms to formal market incentives, shown below. Some of the countries mentioned in figure 8.1 tried to achieve cost effectiveness as well, but this goal has not been a chief motivation, in spite of the academic attention it receives. An brief overview of the charge systems in Hungary, Latvia, Lithuania, Poland and Slovenia support the thesis that an emissions charge works in proportion to the degree that firms operate within formal market framework and respond to the incentive posed by the emissions charge. The ability to escape into informal markets frustrates the efficacy of an emissions tax. If the pattern in other pollution charge systems follows that of Siberia, we would expect those countries with successful emissions tax policy to have a higher degree of viable firms and formal market orientation. Those with less successful programs should possess fewer viable firms with higher opportunities to participate in informal and formal markets.

Research has focused on reporting the structure and legal framework for pollution charge systems in transition economies. Few concrete performance reports exist, making it more difficult to confirm or reject the above hypothesis. Until more data becomes available, however, several indicators do exist which do assert market nearness (or distance) and the performance of the emissions tax. These indicators include the estimated share of formal and informal economic activity as a percentage of GDP, and some recently reported general macroeconomic indicators from Fischer *et al*. (1998).

In addition, pollution-related data such as energy intensity, reports of profits and tax collection shortfall from the charge program, and abatement investment as a percent of GDP and GDP per capita indicate the degree to which pollution abatement might occur in these economies. At the very least, such indicators give a relative picture of the possible efficacy of using a market-oriented tool for abatement in transitional economies. The following discussion reviews available data and compares the performance of Siberia's charge (within the larger context of Russia) to the emission taxes of other economies.

Figure 8.3 reports that none of the programs, excluding Poland, generated incentives for abatement investments. Some raised revenue, and some were successful in achieving varying degrees of compliance. Those with the lowest degree of formal market participation as a percentage of GDP, however, appeared to have the poorest results using the emissions charge. The correlation is not robust and requires additional systematic research. However, the general pattern does follow the thesis of this work.

Both Latvia and Lithuania appear to have effective programs. Latvia reports nearly 100 percent compliance rates for a sample study (Vincent 1997). Yet this may be due to administrative aspects such as generously granting permits for temporary standards when it becomes clear that a firm cannot meet the standards (Lithuania 1995). In the Czech Republic, environmental authorities also struggle with enforcement and monitoring, although the system is much more advanced and well-equipped than that in Russia. However, up to one-third of all polluters undertook no abatement action in 1995. A common reason is that polluters have no access to financial resources. A solution to rampant noncompliance is to delay requirement to meet standards until 2005. Hungary's charge system appears theoretically sound but the charges remain too low and firms use the legal system to appeal paying their taxes. This example of avoidance does indicates that enterprises use legitimate market institutions to avoid market incentives and penalties rather than informal markets to evade the charge. Major polluters find it cheaper to pay their fines than to clean up, but signals that they do respond to the charge in expected patterns. Hungary possesses a good system of monitoring and verification of self-reporting. However, because many firms are not viable, bankruptcy or subsidies prevent the collection of much of the emissions charges. Revenues from the charges have fallen since the transition, perhaps due to legal loopholes, low fines, high inflation, and opportunities for low-cost means of avoiding or reducing fines.

Figure 8.1 General features of emissions tax systems for air pollution in transitional economies, 1994							
Country	Objective	Penalty multiple	Number of pollutants charged	Revenue leaders	Charges vary within country	Factors influencing charge levels	Inflation indexed
Czech Rep.	Revenue	15	90	SO_2	no	Compliance costs, environmental damage, political factors, revenue needs	no
Hungary	Compliance, abatement	n.a.	150	SO_2	yes	Compliance costs, environmental damage, political factors, revenue needs	no
Latvia	Compliance, abatement	4	7	SO_2	no	Environmental damage, political factors	no
Lithuania	Cost effectivenes	10	All	--	no	Compliance costs, environmental damage	yes
Poland	Compliance, abatement	10	62	SO_2	yes	Environmental damage, revenue needs	yes
Russia	Revenue	5	>100	--	yes	Compliance costs, enterprise profitability, revenue needs	yes
Slovakia	Compliance, abatement	1.5	123	Particulates	no	Compliance costs, enterprise profitability, revenue needs	no
Source: (Vincent 1997)							

A general pattern emerges in which those countries with the greatest general levels of market orientation among firms appear more likely to have a successful program.

Poland has the most successful and aggressive emissions charge program. It has performed well in the transition period (relative to others) and has endowed its environmental authority with the power to shut down firms. Environmental officials have “black listed” particularly bad polluters for closer monitoring and charges rates that provide a significant economic incentive for firms to change production processes. Collection shortfalls are the lowest in the region, amounting to only about 10 percent in 1994 and afterwards. Poland’s firms appear to operate largely in formal system, although they do receive soft loans for investment in abatement, to pay their charges, etc. As a result, emissions have decreased by 67 percent and energy intensities have declined (EAP 1998), (Vincent 1997). At least a portion of these reduction is attributable to the decrease in economic output of these enterprises during 1990-93, but the majority of these reduction are generally attributed to actions taken by enterprises to reduce emissions” (Anderson 1997).

The ease of making the transition from an industrial structure with heavily polluting enterprises to those using cleaner production processes may also indicate whether an emissions charge in economies characterized by the presence of informal markets will experience success. Figure 8.2 shows the energy uses of several transitional economies. Russia contrasts sharply in its energy efficiency to other transitional economies, with energy intensity increasing since the early 1990s. Although energy use per capita in general in these economies is higher than European countries, figure 8.3 illustrates the large gap in energy efficiency between Russia and its neighbors. Given the relative profitability or likelihood for survival in formal and informal markets, Slovenian, Hungarian, and Polish enterprise appear to operate with lower costs per unit of output in formal market settings where energy prices and associated pollution charges increase the price of energy inputs. Although the price of energy is rising in all of these economies, it remains lowest in Russia, encouraging firms not to restructure industrial processes or engage in formal market activity. In addition, previous discussion has highlighted the key role which the energy sector plays in generating cash for this economy. Siberian firms rely largely on bartering of taxes and payments to survive in the current period. Local industry may choose to increase production of value-deteriorating goods (Gaddy 1999) for barter and payment of tax arrears rather than decrease the costs of production in formal markets.

Figure 8.2 Total primary energy supply, 1995

	MTOE, 1995	TOE per capita, 1995	TOE per unit GDP
Hungary	25.10	2.44	0.41
Lithuania	8.50	2.29	0.69
Poland	94.47	2.45	0.44
Russia	604.46	4.08	0.88
Slovenia	5.58	2.80	0.26
OECD Europe	1554.32	3.34	0.22

Source: (EAP 1998)

Figure 8.3 Transitional economies characteristics and performance of emissions tax programs

Country	Estimated % share of formal and informal markets in GDP [f]	Emissions charge stimulates abatement investment?	Emissions charge creates efficiency and cost effectiveness?	Apparent degree of compliance with emissions charges	Main administrative obstacles	Economic tools effective for abatement and/or revenue (yes/no)?
Czech Rep.	Formal: 80-85% Informal: 15-20%[a]	No	No	Data unclear, but likely no greater than half of all firms under the charge system. Up to 30% of all polluters took no abatement action in 1995, payments appear even lower.	Poor enforcement and monitoring, poor access to credit for abatement projects.	Abatement: No Revenue: No
Hungary	Formal: 70-75% Informal: 25-30%[b]	No	No	Data unclear, however, major polluters appear to pay at least a portion of their charges.	Charges too low and not inflation-indexed, legal loopholes allow avoidance, bankruptcies and subsidies make collection of charges difficult.	Abatement: No Revenue: Limited
Latvia	Insufficient data	No	No	Unclear, probably about one third of all firms pay some amount of their emissions charges.	Poor administrative structure, poor enforcement and reporting system.	Abatement: No Revenue: No
Lithuania	Insufficient data	No	No	Appear moderately good, but temporary permits for noncompliant firms very generous[e]	Poor administrative structure, poor enforcement and reporting system.	Abatement: No Revenue: No

Figure 8.3 continued.

Poland	Formal: 82-90% Informal: 10-18%[c]	Yes	Somewhat	Up to 90 percent payment of charge rates with lower degrees of compliance for emissions	Ambiguity and overlapping authority for enforcement and monitoring	Abatement Yes Revenue: Yes, with some of the highest emissions charges in the world
Russia	Formal: 30% Informal: 70%[d]	No	No	Poor. All major pollution sources officially exempt, others evade/avoid	Poor administrative framework, poor enforcement and monitoring, unclear methodologies for reporting, informal markets distort economic incentive of emissions tax	Abatement: No Revenue: No

Note:

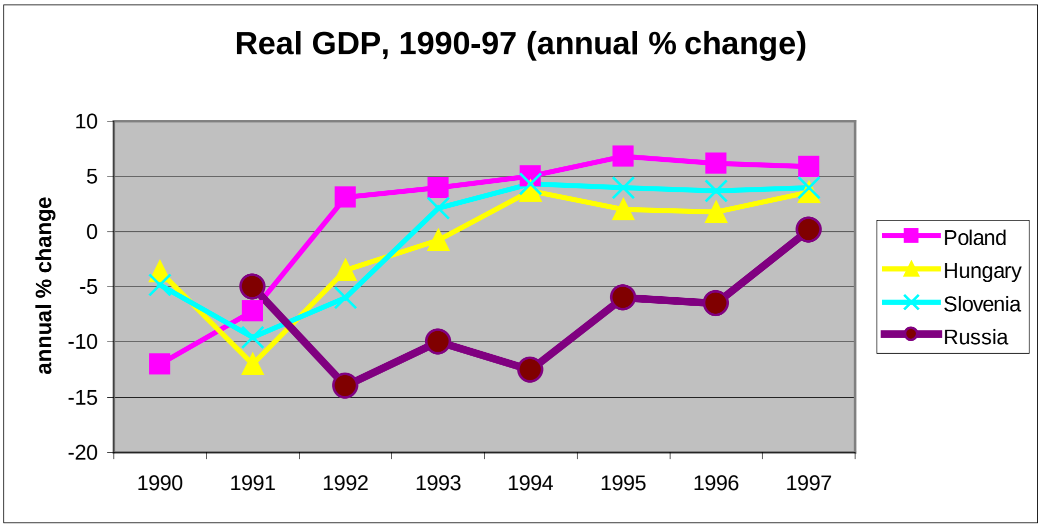
[a] (UNIDO 1997), [b] (Ékes, 1997; Piacgazdaság Alapítvány; GKI; Kopint-Datorg), [c](Bureau for Economic Statistics and Polish Academy of Science), [d] (Gaddy 1998) [e].(Lithuania 1995) [f.] Estimates for percentage of formal and informal market participation as percentage of gross national product.

Source: (Fischer 1998); (Bluffstone 1997); (Ubelis 1997); (Farrow 1997); (Stavins 1995); (Hendley 1998)

Other macroeconomic indicators have begun to appear which suggest the overall degree to which transitional economies have moved towards formal market systems (Fischer 1998). Compared with meager reports on the performance of emissions charge systems in the respective countries, we see a broad correlation between those countries which have moved closest towards formal markets and those whose firms appear to respond to the greatest degree to market-oriented economic policies.

While even official data sources are flawed, figure 8.4 shows the change in growth in real GDP in several transition economies. Poland, Hungary, and Slovenia follow an upward trend, while Russia experiences negative real GDP until 1997. This might indicate that in countries where economic growth in formal markets occurred, the returns to enterprises were great enough to encourage participation there, even with associated taxes.

Figure 8.4



Source: (EBRD 1997)

Discrepancies appear in this data. Gaddy and Ickes note that Goskomstat reports positive GDP in 1997, but at the same time reports negative growth for Moscow (Gaddy 1998). They write "[Goskomstat] asks us to believe that Russia outperformed Moscow. The paradox here is that if Russia is really on the road to recovery, if that point has been reached where GDP growth signals success in restructuring-then clearly Moscow should be leading the way. The fact that Moscow under-performs Russia indicates that this point may not yet have been reached. We suggest, rather, that what is happening is that the increase in industrial output is due to increased production in 1997 of what might be called 'soft goods'…noncompetitive goods produced by precisely the category of enterprises we identify as the old, unrestructured sector." Official data understate Russia's move towards formal markets, underscoring the likelihood that enterprise there will not respond well to policy tools oriented towards mature formal markets.

Figure 8.5 correlates weakly with a pattern of those successful and less successful emissions charge programs. It appears that countries such as Hungary and Poland, which appear to have problematic but promising charge systems, show a higher level of progress towards formal market systems which may indicate firms' formal market orientation, or at least the general environment in which polluters operate.

Figure 8.5 Selected transition indicators

Country	Transition index, 1997[1.]	Private sector % share of GDP, 1997[2.]	Cumulative FDI inflows, 1989-1996 per capita (US$)
Hungary	3.6	75	1300
Lithuania	3.0	70	76
Poland	3.3	65	140
Russia	2.9	70	40
Slovenia	3.1	50	372

Source: (EBRD 1997)

[1.] Since 1994, the EBRD has presented an annual appraisal of certain dimensions of the state of transition to analyze and compare progress in the transition process. Each dimension is given a numerical score 1 through 4; 1 indicating no progress in the corresponding area and 4 indicating standards and performance typical of industrially developed economies. The table shows the average score of eight economic transition indicators and one legal transition indicator.

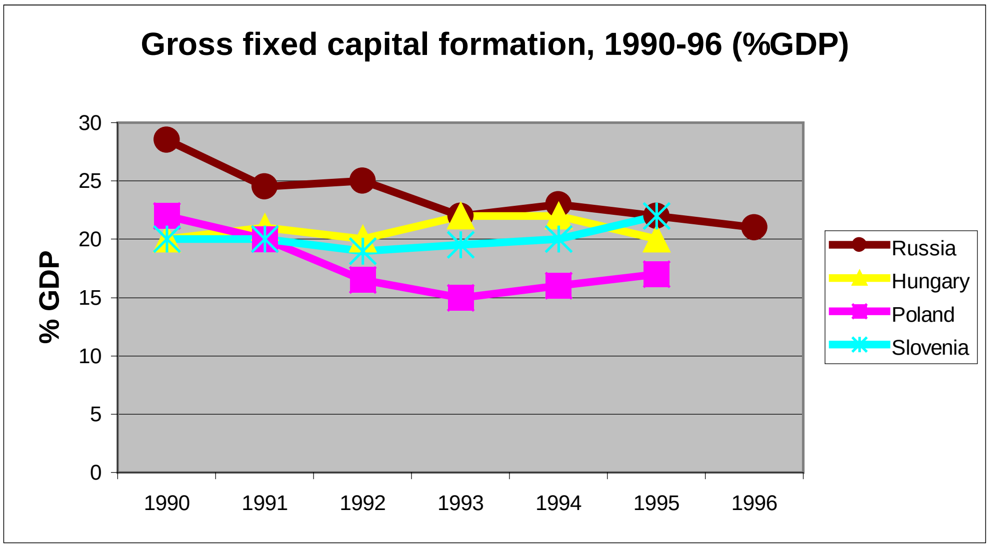
[2.] The private sector share of GDP represent EBRD estimates, based on available statistics from official and unofficial sources. The concept of private sector value-added includes income generated by private entities in formal and informal markets.

In addition, private shares of GDP appear relatively high in Russia (they are measured to include informal activity), yet official GDP is very low. A possible explanation is that informal activity makes up a very large share of private activity, indicating an orientation towards informal rather than formal markets. In contrast, Poland shows a relatively low share of private enterprise making up share of GDP, yet its emissions charge program is successful, indicating that its firms respond to a market-oriented policy. Three possible factors could explain this pattern. Firm ownership structure doesn't matter as much as market orientation b) institutional environmental framework for countries like Poland are more serious in terms of applying penalties and closely monitoring for compliance and c) orientation towards formal market activity is greater in such countries than in Russia.

Fischer *et al*. (1998) point out that the timing of stabilization may have been important in the outcomes of market-based policies in these countries. Their study finds that Poland, Hungary, and Slovenia pursued stabilization policies which first established formal markets and then emphasized the implementation of market-based tools. Environmental policy reforms coincided with these stabilization policies. Russia implemented its emissions charge system in 1991, but introduced economic stabilization policies only in 1995, which appears to have given firms ample time to expand opportunities in informal markets. Some speculate that informal markets may have become institutionalized (Leiter 1997), making the efficacy of an emissions charge in formal markets questionable. In Russia firms trade tax arrears and resort to barter trade in informal markets to survive economic instability and overcome their distances from formal markets. Poland, Hungary, and Slovenia did not manifest these characteristics.

Gross fixed capital formation as a percent of GDP, may serve as an indicator of the degree of capital renewal, industrial restructuring, and the directionality of change in formal market orientation (EAP 1998). The trend to reduce gross fixed capital formation in Russia hints at a move away from formal market production. It has experienced nearly continuously declining investment ratios, compared with Hungary, Poland, and Slovenia, which appear to stabilize or increase slightly with time. The lower overall percentages of gross fixed capital formation in the latter countries may suggest a higher productivity of such assets in formal markets, or indicate under-utilization of such assets in Russia. However, given increased pollution intensity per unit of output and decreasing official levels of production, this may indicate production diversion into informal markets.

Figure 8.6



Source: (WorldBank 1996); (OECD 1997)

Finally, Russia's emissions charge program under-performs its more market-oriented neighbors. In all countries, revenues from the emissions tax are used to fund investments in pollution abatement and control (PAC). Therefore, while the emissions charge instrument itself does not motivate enterprises to invest in abatement measures spontaneously, the policy does generate revenue which are then used in these countries to fund such abatement investments. The degree to which the funds generate revenue largely determines the ability of regions to invest in PACs and can be used as a rough measure of the relative success of such programs. We therefore compare the PAC investment levels for each country. PAC investments per capita are lowest in Russia and highest in Poland, reflecting the strong performance of Poland's charge system in generating revenues for the environmental fund (EAP 1998). Golub suggests that PAC investments in Russia are even lower than official statistics indicate, although investment levels have increased in the 1990s (Golub 1997).

Figure 8.7 PAC investments per capita, 1990-96 (US$ at current prices and exchange rates)

	1990	1991	1992	1993	1994	1995	1996
Hungary	--	--	--	--	--	--	--
Lithuania	--	13	26	21	35	26	27
Poland	11	21	23	22	24	34	59
Russia	--	--	1	4	7	9	11
Slovenia	--	--	10	19	44	41	33
Source: (EAP 1999)							

These findings indicate that those countries with greater formal market orientation also showed better results for market-oriented pollution control systems. Successful examples still had problems with tax levels, inflation, lack of sufficient monitoring capabilities. The problems with each individual program spanned a range from formal market institutional problems (administrative, tax level setting, legal questions) to the problem of dominant informal markets and lack of restructuring. While combinations of these problems led to particular outcomes, the most important variable for the success of Poland, Hungary, and Slovenia was that their firms possess formal market orientation and a degree of viability. In general economic terms, Eastern Europe out-performed Russia in its emissions charge policies.

8.4 Conclusions

This study has deepened understanding for the outcome of the implementation of a market-based tool for air pollution abatement. The findings reflect a new tangent in research on both the outcomes of market-oriented abatement tools and the nature of industrial restructuring in transition economies (Gaddy 1998), (Fischer 1998), (Leiter 1997). Like this new strain of writing, findings from this study of Siberia contrast with earlier theoretical work on the impacts of an emissions tax on an economic system. Rather than increasing cost efficiency and investment in abatement technology—two of the key assumptions about the benefits of the emissions charge—Siberian environmental authorities observe a decline in environmental quality and large-scale avoidance of the tax. In addition, the emissions tax has not generated observable investments in abatement and has not notably increased cost-efficiency in environmental standards enforcement. The conclusions of this study are much more qualified, if not a little pessimistic, about the merits of an emissions tax policy within an economic environment that defies common assumptions of the way market systems work.

This section reviews the key findings for the study of Siberia relevant for other areas, drawing attention to the applicability of "lessons learned." The most important factor in the success or failure of an emissions charge—or other market-oriented pollution policies—is the degree to which firms viably operate in formal markets. When many firms in the economy operate at some space far away from formal markets, they may prefer to invest in relational capital and produce non-cash goods. The relative costs of increasing market nearness will in part determine the ability of firms to respond to market-oriented policies. These constraints will differ among countries and regions, but it is reasonable to assume that they do affect firm response to an emissions tax. To the extent that Siberia bears resemblance to many developing economic regions, its case has applications and relevance. Although the extreme economic perversions of Russia's current economic situation are unique to its institutional history, some common characteristics do exist.

- *Limited environmental authority*. Many developing areas have few resources to devote to pressing environmental concerns. Environmental agencies may have some legal authority to monitor and impose penalties upon polluters, but their real ability to accomplish such tasks is often hindered by poor staffing and funding.
- *Limited access to credit for abatement investment*. Like Siberia, many economies face limited access to capital. This increases the relative costs of investing in abatement and might increase the attractiveness of tax avoidance or evasion. Without a counterbalancing availability of low-interest credit to invest in abatement, an emissions charge will have lower chances to improve ambient air quality.
- *Formal markets may not dominate an economic system*. Informal markets, characterized by non-cash exchange and non-transparency to tax officials or other government agencies, play an important role in many developing economies. The ease of movement between informal and formal, cash-based markets play a key role in the impact an emissions charge has upon revenue and abatement, among other possible goals.
- *Evolving tax systems*. In an effort to make tax systems more efficient or effective, many government experiment with their tax systems, creating labyrinths of sometimes contradictory and sometimes oppressive taxes. Firms may feel justified in avoiding or evading such taxes, or may not know how to pay them if changes occur too rapidly (as they do in Siberia).
- *Weak institutional frameworks at many levels*. Not only are strong environmental agencies needed, but the presence of an array of market institutions may be necessary for an emissions charge system to work. Lacking such institutions, a charge in the context of a developing economy might encourage investments in relational capital or rent seeking to accomplish a task rather than direct formal market activity.
- *Need for restructuring the industrial sector with uncertainty regarding the costs or risks involved*. Many countries face the need to restructure their industrial sectors, not only to reduce pollution, but to increase productivity and competitiveness in world markets. High degrees of uncertainty, combined with limited availability of money to undertake restructuring, may encourage some industrial leaders to merely

"survive" in the short run. Although it could be economically efficient to have such firms exit an industrial sector when unable to accomplish restructuring, such a step may prove unacceptable socially, in terms of jobs and output lost. An emissions tax may increase the cost of that restructuring and could discourage managers from taking this step.

In these and other ways, Siberia's experience with the emissions charge may prove insightful for those economies considering such a policy for the improvement of ambient air quality.

The most important lessons learned from this case study differ surprisingly from other research on improving economic instruments in transitional economies. Unlike Bluffstone *et al*. (1997), the author emphasizes the need to first establish the institutional framework for a market-based tool before focusing on important secondary issues such as tax levels, number of pollutants in the charge system, etc. Without the constraints imposed by effective market institutions, an emissions charge will not prove effective. Below, the author summarizes key lessons relating to market orientation. Following this, secondary lessons are reiterated.

The market-orientation of the actors involved matters. The compliance response boundary framework and model help us see the principle constraints in the imposition of an emissions tax in Siberia. Because an emissions tax affects the price of operating in formal and informal markets, the initial position and ability of firms to move either towards or away from each respective market will serve as guides to policy makers seeking to understand possible impacts of an emissions tax. In the real world, and particularly in settings where institutional frameworks tend to be very weak, evasion is a constant reality and key problem, monitoring covers only a fraction of pollution instances, and reporting and collection often appear sporadic.

Those enterprises that can avoid performing efficiently in formal markets manifest lower tendencies to respond to market-oriented policy tools. Developing countries with mostly state-owned enterprises might therefore carefully consider other alternatives to air pollution policy than an emissions tax. In this case some regulatory policy may be more effective in abatement. In reality, emissions taxes may prove no more efficient than regulatory tools. At best some combination of tools designed carefully for the economic context of the country of implementation might achieve the best revenue and abatement results.

Initial infrastructure conditions matter. Because emissions charges affect the cost of production in formal markets, initial infrastructure conditions matter. Although the ability for firms that have previously not invested in abatement measures to achieve very high relative returns for initial reduction in pollution, the costs of doing so might be prohibitive. Firms in developing and transitional economies, as well as selected aging industries in better-developed countries, often must undertake a significant degree of industrial restructuring. If a firm can manage to survive by altering its production portfolio to involve informal markets where emissions taxes do not reach, then such a policy will not only miss achieving its goals but may also actually encourage firms not to make the effort to restructure. An emissions charge in such cases might be augmented with an accompanying policy that provides some type of financial assistance that lowers the cost of restructuring and abating. This underscores the need for greater complementarity between policies, and coordination of economic and regulatory rules. Simply selecting a market-oriented tool based on good theoretical reviews will likely elude the achievement of meaningful change in environmental performance or tax collection.

Focus first on building necessary institutional capacity. Before trying to achieve an optimal tax level, maximize efficiency or social welfare, policy makers must establish institutions necessary for proper tax collection and enforcement. Imposing a charge on emissions has not provided a sufficient motivation for most Siberian enterprises—or most other enterprises in transitional economies—to invest in abatement solutions or to otherwise reduce their pollution or pay their pollution taxes. The opportunities for misreporting, outright noncompliance with tax programs, and other forms of avoidance or evasion significantly weaken the current emissions charge program. Emphasis upon improving the institutional framework within which the policy operates will more effectively improve program performance than changing tax rates. The single most important factor for the implementation of a market-oriented policy is the ability for institutions to encourage and enforce economic activity within the sphere of formal markets.

Investment conditions. Implementing a market-based tool for abatement assumes the tool provides incentives for investment. This case study of Siberia has illustrated that economic conditions must be stable enough to reduce risk and uncertainty for an investing firm. As Bluffstone and Larson (1997) note, “While most environmental authorities think that their pollution charge systems increase incentives for investment in pollution control, very little evidence exists that charge systems actually do provide such incentives. Investment decisions in these regions take place in highly uncertain market and regulatory environments, and under such conditions the relationships between current charge levels, future charge levels, and investments in pollution control are not simple” (see also (Magat 1978), (McCain 1978), (Pindyck 1991), (Larson 1996)). It is likely that other developing areas face similar challenges in terms of abatement investments.

The study pointed out other important issues, of secondary importance to emissions charge systems and policy design.

Conflicting program goals. The structure of the program in Russia is designed to give firms to an economic incentive to reduce all classes of pollution. However, as in most transitional economies, firms easily avoid or evade charge payments, which are generally too low to induce abatement behavior even if evasion or avoidance is more difficult. If abatement of pollution and an improvement of ambient air quality were the highest-priority goal, then the program would impose higher charge rates, strictly enforce standards, and base rates and penalties upon strictly enforced environmental standards. The current system strikes an ineffective balance between a need to raise revenue and a desire to improve ambient air quality. The framework for tax collection remains weak and abatement incentives low. A possible solution would be to charge an emissions tax on one or two high-volume chemicals such as particulates and SO_2 (Golub 1997). This might encourage a long-term shift towards greater fuel efficiency in Siberia, and possibly in other developing areas that rely heavily on coal and fossil fuels for energy. It might also be easy to target those polluters emitting the greatest amounts of such chemicals and reduce noncompliance.

Hypothecation/environmental funds need close monitoring and disbursement criteria. Close examination of Siberia’s fund reveals lack of clarity regarding operating practices, and a lack of evaluation of the environmental and economic effects of the investments made. In cases where pollution charges are earmarked to environmental fund systems, charge revenues are often derived mainly from private sector or public enterprises subject to hard budget constraints. Environmental funds may become politicized and treated as grants rather than loans. The focus on giving gifts rather than overcoming capital market failures means that project appraisal processes generally are not transparent and the reasons for distributing funds are not based on objective environmental and economic criteria. At the municipal level, environmental funds may be treated as part of the general budget and officials often use these resources in ways unrelated to air pollution control. These uses are usually not monitored or controlled. Accountability or a sense of urgency to improve environmental conditions do not mark current earmarking practices. Over time, however, both environmental funds and pollution charges may create identifiable projects for which environmental outcomes are known. This can economize on monitoring and enforcement because these instruments offer incentives for enterprises to reveal private information about their activities (problem with informal market producers). They also provide a set of estimates of abatement costs that can be used to set appropriate charge rates (Zylicz 1994), although this assumes that definitions for environmental investments are broad enough to encompass both end-of-pipe investments and process changes.

Future research will focus on implementing a mix of tools. This and many other empirical studies show no clear advantages of regulatory or market-oriented tools. The theoretical advantages of a charge system such as efficiency and gains in social welfare do not appear to play a significant role, even in advanced industrial countries. Rather, policy tools rely very much upon the context into which they are set to achieve any set of objectives. Future research will investigate the design and implementation of complementary policies to achieve reductions in air pollution. While other objectives may eventually also be accomplished using a mix of policy instruments, it appears most prudent at the outset to focus on improving ambient air quality.

Many other aspects of design become important (Bluffstone 1997). However, the single most important factor in implementing a market-oriented pollution policy tool is the response of firms to that tool. If firms can easily escape the penalties and higher costs of the formal market, policy makers should expect poor results for an emissions tax. If firms operate within economies where market institutions are highly developed, where the costs of operating in informal markets are relatively high and where costs of developing relational capital exceed those of developing market-oriented endowments, the emissions charge has a much better likelihood of succeeding.

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