Working Paper

The Contribution of Economic Theory to the Understanding of a Knowledge-Based Economy

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Preface

The research project on *Systems Analysis of Technological and Economic Dynamics* at IIASA is concerned with modeling technological and organisational change; the broader economic developments that are associated with technological change, both as cause and effect; the processes by which economic agents – first of all, business firms – acquire and develop the capabilities to generate, imitate and adopt technological and organisational innovations; and the aggregate dynamics – at the levels of single industries and whole economies – engendered by the interactions among agents which are heterogeneous in their innovative abilities, behavioural rules and expectations. The central purpose is to develop stronger theory and better modeling techniques. However, the basic philosophy is that such theoretical and modeling work is most fruitful when attention is paid to the known empirical details of the phenomena the work aims to address: therefore, a considerable effort is put into a better understanding of the 'stylized facts' concerning corporate organisation routines and strategy; industrial evolution and the 'demography' of firms; patterns of macroeconomic growth and trade.

From a modeling perspective, over the last decade considerable progress has been made on various techniques of dynamic modeling. Some of this work has employed ordinary differential and difference equations, and some of it stochastic equations. A number of efforts have taken advantage of the growing power of simulation techniques. Others have employed more traditional mathematics. As a result of this theoretical work, the toolkit for modeling technological and economic dynamics is significantly richer than it was a decade ago.

During the same period, there have been major advances in the empirical understanding. There are now many more detailed technological histories available. Much more is known about the similarities and differences of technical advance in different fields and industries and there is some understanding of the key variables that lie behind those differences. A number of studies have provided rich information about how industry structure co-evolves with technology. In addition to empirical work at the technology or sector level, the last decade has also seen a great deal of empirical research on productivity growth and measured technical advance at the level of whole economies. A considerable body of empirical research now exists on the facts that seem associated with different rates of productivity growth across the range of nations, with the dynamics of convergence and divergence in the levels and rates of growth of income, with the diverse national institutional arrangements in which technological change is embedded.

As a result of this recent empirical work, the questions that successful theory and useful modeling techniques ought to address now are much more clearly defined. The theoretical work has often been undertaken in appreciation of certain stylized facts that needed to be explained. The list of these 'facts' is indeed very long, ranging from the microeconomic evidence concerning for example dynamic increasing returns in learning activities or the persistence of particular sets of problem-solving routines within business firms; the industry-level evidence on entry, exit and size-distributions – approximately log-normal – all the way to the evidence regarding the time-series properties of major economic aggregates. However, the connection between the theoretical work and the empirical phenomena has so far not been very close. The philosophy of this project is that the chances of developing powerful new theory and useful new analytical techniques can be greatly enhanced by performing the work in an environment where scholars who understand the empirical phenomena provide questions and challenges for the theorists and their work.

In particular, the project is meant to pursue an 'evolutionary' interpretation of technological and economic dynamics modeling, first, the processes by which individual agents and organisations learn, search, adapt; second, the economic analogues of 'natural selection' by which inter-

active environments – often markets – winnow out a population whose members have different attributes and behavioural traits; and, third, the collective emergence of statistical patterns, regularities and higher-level structures as the aggregate outcomes of the two former processes.

Together with a group of researchers located permanently at IIASA, the project coordinates multiple research efforts undertaken in several institutions around the world, organises workshops and provides a venue of scientific discussion among scholars working on evolutionary modeling, computer simulation and non-linear dynamical systems.

The research focuses upon the following three major areas:

1. Learning Processes and Organisational Competence.
2. Technological and Industrial Dynamics
3. Innovation, Competition and Macrodynamics

(i) **Introduction**

When I was asked to present at this Conference what economic theory has to offer to the understanding of a knowledge-based economy, two opposite answers came to my mind. The first one was that in some sense , which I shall specify shortly, economic theory is intrinsically about knowledged-based economies. The opposite answer, which I consider at least equally true, is that most strands of current theory have very little to say by way of an analysis of the nature of that particular form of economy that one observes nowdays and the transformation in its knowledge bases. Some words on the first point might help in clarifying also the second one.

One of the central objects of inquiry of economic theory since its origin as a discipline have been precisely the interactions among a multitude of decentralized agents and the ensuing collective outcomes. (Everyone has heard of Adam Smith's "Invisible Hand" conjecture on the properties of decentralized markets...) But in an essential sense asking how a decentralized economy works is equivalent to asking how socially distributed knowledge is collectively put to work in ways that are not socially detrimental and, possibly, increase the welfare of everyone. A.Smith's conjecture (subject to several qualifications, many of which have been missed out by later theorists) was indeed that markets are able to elicit private knowledge, propelled by the pursuit of self-interest, and yield orderly outcomes, superior - in terms of welfare - to, say, an autarkic system of production and consumption. The point that an economy is basically a system of distributed, diverse, pieces of knowledge has been emphasized, among others by von Hayek. And, of course, this is also a way of reading the most rigorous formalization of the economy as an interdependent system, namely General Equilibrium Analysis as put forward in the 50's and 60's by Arrow, Debreu, Hahn, McKenzie. The existence

theorems,there, are a way of saying that, among all the imaginable worlds, one can also coherently conceive of an economy wherein every selfishly motivated agent, by making the best use of his own information, contributes to "share its use" with all other agents in ways that are mutually consistent and also mutually beneficial. (I am provisionally using here "information" and "knowledge" as equivalent concepts , but I shall come back to this later).

So, yes, in this general and rather abstract sense, economic theory has always been about interdependences in knowledge-intensive systems. However, it is enough to check the long list of assumptions that one has to make in the canonic General Equilibrium (GE) model in order to fully appreciate the distance between what it says and the interpretative requirements of any one historically observed economy. (Incidentally note that the very pioneers of the theory are well aware of this, unlike many of the following believers: compare the writings of Kenneth Arrow or Frank Hahn with any random sample of articles on the "Journal of Economic Theory" or "Econometrica". Indeed, when I see works on empirically applied GE models, I must confess I have the same feeling as when I saw a while ago at U.C. Berkeley the announcement of a seminar on "Applied Heidegger"!!)

The long list of restrictive assumptions is also an indicative proxy for the phenomena economic theory is unable to account for - at least in that analytical format - ; the progresses (and regresses) that have been recently made; the humility that economists should, but generally do not, put into their policy prescriptions; and, last but not least, the healthy amount of skepticism that non-economists should have when listening to the economists' wisdom...

(ii) Information , Knowledge and Economic Theory

As mentioned, GE is a very elegant, very parsimonious on the assumptions, representation of how agents use at their best the available information and interact with each other accordingly. But "information" is not an ordinary good

which can be treated, say, like a machine tool or a pair of shoes (again, on the economic characteristics of information Arrow is a pioneering reference). Shoes wear out as one uses them, while information has typically got a high upfront cost in its generation but can be used repeatedly without decay thereafter, or there might even be learning-by-using type phenomena (as from the first to the n-th time one applies Pithagoras' theorem in High School ...). Moreover, information might be appropriable , in the sense that other agents might have significant obstacles to access it (ranging from legal protections, like patents, all the way to the sheer difficulty to fully appreciate what a particular piece of information means: see also below). But information as such typically entails a non-rival use (in the sense that it can be utilized indifferently by one or one million people, which, again, is not the case of ordinary commodities like shoes or machine tools...).

In my view, some of the most important advances of the theory over the last two or three decades have concerned precisely the economic consequences of these features of information. Without entering any detail, one might telegraphically mention for example the wide literature on the "economics of information" (cf. for example the works by Joseph Stiglitz); on "principal- agent" models, most often studying the incentive implications of imperfect, asymmetric information, on the grounds of otherwise quite ortodox assumptions; on the organizational implications of information-related transaction costs and collective rents (cf. e.g. the works by Oliver Williamson and Masahiko Aoki); and on "new growth models" explicitly incorporating the generation of technological information (see the contributions of Paul Romer and colleagues).

For the our purposes here , let me just recall three major implications of even the most rudimentary account of the specificity of information for economic theory.

First, the "invisible hand" properties of the canonic GE model do not generally carry over to economic models where the most restrictive informational

assumptions are relaxed (for example on the perfect access to information by all agents and on the fact that information itself drops freely from the sky). So, the theory may easily predict equilibria and growth paths that are socially sub-optimal, systematic divergences between rewards and marginal products, and also the possibility of long-term unemployment.

Second, the social distribution of information and thus the institutional architecture of the system matters a lot in terms of microeconomic incentives and aggregate performance.

Third, by adding the highly plausible assumption of locality of learning , one easily obtains path-dependent models of development - at the levels of individual firms, technologies,industries and whole countries - (cf. the contributions of Paul David, Brian Arthur , Richard Nelson, Sidney Winter and, in general, 'evolutionary ' models of economic change). Impressionistically, "locality" stands for the fact that you most likely learn by building upon what you already know (so that for example it is much easier to learn differential equations after having taken the course of calculus than without it.. ; or, even at an aggregate level, the probability that the next generation of microprocessors will be invented in the US, conditional on the past innovative performance in the field, is much higher than in Burkina Fasu..) . And locality/path-dependence stands also for the relative incremental coherence in the domains of exploration that individuals, organizations and possibly countries may attain (so that for example becoming a great economist does not make easier for you to become a good football player, being a competitive textile manufacture is not likely to help in competing in bioengineering, etc. ..).

Incidentally, note also that path-dependence in learning is likely to entail tricky dilemmas between "exploitation" and "exploration" - in the terminology of James March -, that is, between allocations of efforts aimed at impoving what one is already good at doing vs. activities of search for uncertain novelties.

Putting it somewhat bluntly, even simple accounts of some essential characteristics of information analytically shake the naive and Paglossian belief that unhindered market mechanisms yield the best of possible worlds . To use a term that I do not like too much, "market failures" are generally associated with the production and use of information. Intuitively, for this to happen it is sufficient to acknowledge the properties mentioned above concerning a) increasing returns and b) non-rivalry in the use of information. The former obviously tend to conflict with the idea that pure competition is normatively the best form of market organization (and also with the idea that competition can sustain itself as a viable market structure). The latter decouples the costs of generation and the benefits of use of information (after all, one could say that the cost of production of, say, Pithagoras' theorem was entirely born by Pithagoras himself, while all subsequent generations benefited from it for free). Relatedly, such a decoupling is likely to induce underinvestment in information generation (and attempts to tackle the problem via an increased appropriability of its benefits might even have perverse outcomes ..).

Moreover, as well known in the theory, necessary condition for some close link to hold between (marginal) productivities of inputs,relative prices and distributive shares are decreasing returns with respect to the use of the inputs whose productivity we are measuring (even neglecting the paramount difficulties in the measurement itself). Again , the acknowledgement of the role of information as a 'factor of production' breaks that link, because of increasing returns and externalities associated with its generation and use (Has one ever tried to measure the 'marginal productivity' of Fermi and Openheimer within the Manhattan Project? Link them to their relative price? Account for their inputs into subsequent "atomic bomb production functions"? Well, it follows from the economic of information that similar overwhelming difficulties apply to the GM, or Microsoft or Boeing "production functions", and , more so, to their aggregation, such as the "US production function").

I would like to emphasize that all the argument so far can confortably rest upon rather conventional assumptions regarding in particular the 'rationality' of the agents - at least in their ability of making the best use of the information they access (whatever that means) -, and on collective 'equilibrium' set-ups (which is a very strong assumption on the collective consistency of individual plans). Some economists (notably those with 'evolutionary' and 'institutionalist' inclinations) depart even further from the canonic assumptions and suggest the following points (admittedly more controversial among practitioners).

(i) A distinction is drawn between information and knowledge. The former entails well stated and codified propositions about "states-of the-world"(e.g. ".. it is raining.."), properties of nature (e.g. "..A causes B ..") or explicit algorithms on how to do things. On the other hand, knowledge, in the definition I am proposing here, includes a) cognitive categories ; b) codes of interpretation of the information itself; c) tacit skills; and, d) problem-solving and search heuristics irreducible to well-defined algorithms.

So, for example,the few hundred pages of demonstration of the last Fermat theorem would come under the heading of "information". Having that, some dozen mathematicians in the world will have the adequate knowledge to understand and evaluate it. Conversely a chimpanzee, facing those same pages of information might just feel like eating them, and the majority of human beings would fall somewhere inbetween these two extremes... Similarly, a manual on "how to produce microprocessors" is "information", while knowledge concerns the pre-existing abilities of the reader to understand and implement the instructions contained therein. Moreover, in this definition, knowledge includes tacit and rather automatic skills like operating a particular machine or correctly driving a car to overtake another one (without stopping first in order to solve the appropriate system of differential equations involved !!). And, finally, it includes, "visions"

and ill-defined rules of search, like those involved in most activities of scientific discovery, and in technological and organizational innovation (for example, proving a new theorem, designing a new kind of car; figuring out the behavioural patterns of a new kind of crook that appeared on the financial market ..).

In this definition, knowledge is partly tacit , at the very least in the sense that the agent itself , and even a very sophisticated observer, would find it very hard to explicitly state the sequence of procedures by which information is coded, behavioural patterns are formed, problems are solved, etc.. This is certainly a major admission of ignorance on the part of the analyst, but there are good - almost 'ontological' - reasons for this : after all, as Arrow himself pointed out long ago, if an innovation is truly an innovation it is impossible for a finite observer to precisely forecast it. And, indeed, there are powerful uncomputatibility theorems that confirm this intuition. But 'tacitness' - some of us suggest - extends also to domains where little invention is involved (as mentioned, driving cars, operating machine tools, debugging computer programmes ... , and even more so , efficiently running production flows, interpreting market trends, etc. ...).

(ii) In modern economies, firms are major, albeit by no means unique , repositories of knowledge . Individual organizations embody specific "ways of solving problems" that are often very difficult to replicate in other organizations or even within the organization itself. In turn, organizational knowledge is stored to a good extent into the operating procedures (the 'routines') and the higher level rules (concerning e.g. "what to do when something goes wrong", or "how to change lower level routines") that firms enact while handling their problem-solving tasks in the domains of production, research, marketing, etc.

Dynamically, technological knowledge is modified and augmented partly within individual firms, and partly through the interaction with other firms (competitors, users, suppliers, etc.) and other institutions (universities, technical societies, etc.).

(iii) Over the last two decades at least a good deal of effort - within the broad field of the "economics of innovation" - has gone into a better understanding of the variety of processes by which knowledge is augmented and diffused in the economy (Major contributions in this area include those by Christopher Freeman, Nathan Rosenberg, Keith Pavitt, Richard Nelson, among others).

A first broad property - probably not surprising to non-economists, but with important analytical and normative implications - is the diversity of learning modes and sources of knowledge across technologies and across sectors. For example, in some activities, knowledge is accumulated primarely via informal mechanisms of learning by doing, learning by interacting with customers and suppliers, etc. In others,it involves much more formalized activities of search (such as those undertaken in R&D labs). In some fields, knowledge is mostly generated internally and specific to particular applications. In others it draws much more directly upon university research and scientific advances. I am mentioning all this also because recent research suggests that this diversity of learning modes might be a major determinant of the diverse patterns of evolution in industrial structures (for example,in terms of distribution of firm sizes, natality and mortality of firms, corporate diversification, etc.). Moreover, the identification of the sectoral specificities in the forms of knowledge and in learning patterns bears straightforward normative consequences (for example, R&D policies, or policies aimed at speeding up the diffusion of innovations are likely to have quite diverse effects in the textile industry or in bioengineering ...).

Relatedly, an important step in the understanding of the "anatomy" of contemporary systems of production and knowledge accumulation has involved taxonomic exercises (Keith Pavitt's taxonomy is probably the most famous one), trying to map 'families' of technologies and sectors according to their sources of innovative knowledge and their typical innovative procedures.

At the same time, one has tried to identify possible invariances,which hold

across technologies, in the patterns of learning (notions like "technological paradigms", "regimes" and "technological trajectories" belong to this domain of analysis), and descriptive indicators for these same patterns. So, for example, variables like the levels of "innovative opportunity" associated with each technological paradigm, the degrees of "cumulativeness" displayed by technical advances , etc. have turned out to be quite useful in interpreting the determinants of the particular 'trajectories' of innovation that one observes.

(iv) Building upon the considerations made so far on the nature of technological learning and on the ways organizations incorporate knowledge, a few scholars have started to explore an explicitly co-evolutionary view , whereby the accumulation of technological knowledge is shaped and constrained by the nature of the organizations and institutions where this knowledge is embedded, and , conversely, new forms of knowledge demand and possibly trigger changes in corporate organizations and broader institutions.

To sum up: it seems to me that various strands of research, within the fields of the economics of information, the economics of innovation and organizational theory have recently contributed a lot to our understanding of how knowledge-rich economies work (and ,equally important, of how they cannot work !!). However , the thrust of most of the works that I have discussed so far is a microeconomic one. This does not mean to say that they are void of macroeconomic content: on the contrary, it turns out to be relatively easy and highly promising to incorporate some of the mentioned findings on the economics of information and learning into macroeconomic models.

So , for example, self-sustained growth can be shown to be a general property of knowledge-based economies, even indipendently from capital accumulation (of course, in less abstract models, knowledge accumulation and capital accumulation are interwined, and self-propelled dynamics, more so, apply ...).

The introduction of asymmetric information into simple macro models generally yields "Keynesian" outcomes , such as persistent unvoluntary unemployment, credit rationing ,etc. (cf. the "New Keynesian" contributions pioneered by Stiglitz and colleagues).

And an expanding family of evolutionary models , microfounded in a multitude of heterogeneous agents that imperfectly learn and are selected by the market, is proving capable of accounting for a wide set of aggregate regularities, ranging from the patterns of international growth of incomes and productivities all the way to "meso" phenomena such as size distributions of firms and their persistent asymmetries in efficiency (cf. the works spurred by Richard Nelson and Sidney Winter's evolutionary theory of economic change).

All this notwithstanding, it seems to me equally true that there is still an enormous gap between the wealth of microeconomic findings, on the one hand, and the understanding that we have of how knowledge is distributed in the economy as a whole and the ways this affects its performance and dynamics, on the other. This holds at analytical level and bears all its consequences at a normative one. For example, the theory is still ill-equipped to tackle questions like the conditions under which "technological unemployment" emerges, the effects of particural patterns of technical change on growth, or the collective impact of specific institutional arrangements. Correspondingly it is particularly weak in answering policy questions like those concerning unemployment in knowledge-based economies.

Let me briefly turn to theses issues.

(iii) From micro to macro ....

It is interesting to notice that within the economic discipline, the progressive attention, over the last 2-3 decades, to the intricacies of the generation and use of

knowledge in an economy has been paralled, within a good deal of macroeconomic theory, by a movement in the opposite direction.

It is impossible to enter here the fine details of macroeconomic controversies, and, less so, their sometimes bizarre epistemological justifications. As a first and rough approximation, notice the following. It has been remarked above that most advances in the interpretation of the role of knowledge in economic coordination and change might be understood, with reference to a canonic General Equilibrium model, as more or less radical departures from its most demanding assumptions, regarding, e.g. the institution-free environment, the information available to individual agents, their basic omogeneity (apart from differences in their preferences and initial endowments), their rational ability to understand the world they live in, exploit the opportunities it provides and forecast the future. Well, the trend in a lot of current macro theory has been , if anything, toward increasing demands upon the rationality and forecasting abilities of individual agents, and toward assumptions of even greater homogeneity among them .

As a rough but vivid illustration of this statement, it is revealing to compare any sample of intermediate-to-advanced macro textbooks, say, thirty years ago, with what is mostly taught nowdays (parallel comparisons of state-of-the-art publications would only reinforce the argument). In the former, you find a good deal of macro-statements based upon comparative statics exercises involving relationships among aggregate entities (e.g. the "aggregate propensity to consume", the "multiplier", the "accelerator", "IS-LM curves", etc. ...). I personally do not find any difficulty in ackowledging the ad hoc nature of too much of that reasoning, the clumsy microfoundations, the appeal to unstructured intuition as the basic justification of even the sign of a derivative .. (And indeed I still rembember my own sense of uneasiness having to understand for example the relationships in "Keynesian" models between interest rates , demand for money, savings and investments ...). But, right or wrong, with hindsight, one must admit that there was at least some naive empirically-based induction and some institutional

conjectures in those models , no matter how rough (for example they were stylizing some apparent behavioural differences among social groups, their differentiated impact upon collective dynamics, etc.). And they also displayed the most rudimentary form of 'informational imperfection' and 'bounded rationality', namely, - most often - crude adaptive expectations, "money illusions", and the like.

Obviously, a way forward could have been a much greater refinement of the microeconomic foundations, interactive dynamics, information processes, learning mechanisms, institutional assumptions, etc. Unfortunately,what happened in the maistream of the discipline has been the opposite (for reasons - partly internal to the sociology of the discipline itself, and partly due to a broader *zeitgeist* -, which I do not have the time to discussed here): the "rational expectation"/"new classical economics" paradigm is an extreme example of this tendency.

So, most often, the enormous gap between the assumptions implied in the 'General Equilibrium ' model of economic coordination, on the one hand, and observed behavioural traits and institutional conditions, on the other, is written away with an act of faith, and a more elegant account of macrodynamics is derived from the optimizing behaviours of representative agents. (This, notwithstanding a lot of handwaiving concerning for example the derivation of 'representative agents' themselves from a GE setup - cf. profoundly disruptive observations of Alan Kirman, among others -, or the general impossibility of generating models whereby even fully forward-looking, 'representative'', agents learn their equilibrium behaviour). Moreover, as regards the "rationality" attributed to the agents, thirty years ago they were assumed to be able to take moving averages and recognize the sign of derivatives; nowdays they ought to be able to solve complicated inter-temporal optimization problems (or, at least, behave in equilibrium *as if* they did).

I am mentioning all this for two reasons.

First, from a theoretical pont of view, if one were to accept such a macroeconomic view, it would be an idle waste of time to discuss issues such as

"the implications of a knowledge-based economy": simply put, no matter how high is the level of knowledge incorporated into any one economy, if agents fully mastered it, and if we also ruled out the specificities of information and knowledge discussed in the previous section, no problem would arise. Indeed, one could think of a macrodynamic summarizining a sequence of optimal adjustments by fully rational agents to exogenous shocks all the way from the Stone Age to the Microprecessor Age (..in this respect, readers not too familiar with exoteric debates of economists are invited to check the interpretations that the professional community takes seriously about e.g. the Great Depression of the '30's !!).

Second, and relatedly, a good part of policy discussion draws rather closely upon the agenda set by macroeconomic theory: however, in the current agenda there is very little room for questions concerning for example the specificies of particular forms of socially distributed knowledge and their effects on unemployment, income distribution,growth, etc.. At the same time, there seem to be a dangerous tendency to derive policy prescriptions from the original acts of faith inbuilt into the theory regarding the self-adjusting properties of the economy (To caricature only a little bit, no matter what the policy problem at hand, one often hears the answer "...just let the market work..". But the questions are precisely how do markets work? how are they affected by different informational structures and mechanisms of knowledge generation? And indeed we still know very little about the answer).

In brief, my view is that a major and urgent task ahead is a sort of reconstruction of macroeconomic theory building upon the rich insights on knowledge, corporate organizations, institutions briefly reviewed in the previous section (and of course drawing upon the quite a few existing macromodels that already try to do it). Short of that, I shall just put forward some scattered remarks, without any claim to coherence.

Going from detailed micro descriptions of "knowledge-intensive" economies to necessarely more concise aggregate accounts demands also important

commitments about the mechanisms of coordination and adjustment among agents who are diverse in terms of the knowledge that they embody and the institutional position they occupy. One way out, clearly, is to assume some implicit GE and get on with the job. However, all what said so far makes that assumption particularly doubtful. But then those mechanisms have to be explicitly identified and possibly formalized.

As an illustration consider the following. Start as a reference, again, from a GE. There, the intuitive image of how coordination occur is a multitude of agents bringing their goods to the square of the village and trading with each other; "adjustments" occur via the way people "go up" supply curves and "go down" demand curves as notional prices change; and, finally, at the end of the day everything that there is to know is summarized by the ensuing prices. Moreover, with the appropriate modifications , one may extend the same image to a GE with production (with people also buying and selling inputs) and to economies where people think of what they might want tomorrow (technically, things are much more complicated than that, but for our purposes this metaphor is sufficient).

Conversely, a "knowledge-based view" is much more 'Hayekian' in spirit. People might still meet in the village square, but their purpose is not only to trade goods but 'to do things' on the grounds of their disperse pieces of knowledge (someone is good at designing engines and someone else at selling them ...). As we know, 'trading knowledge' is difficult because one cannot fully appreciate its value before having applied it. In any case it would be hard to price it due to increasing returns (And 'trading services' of people that incorporate knowledge does only little to mitigate the problem).Also, incentive compatibility problems probably emerge. Moreover, this is likely to be a world of complementary rather than substitution (design and marketing knowledge are useful only together ..) . And finally, people might augment their knowledge just by talking to each other. One can clearly see that in such a world 'going up and down demand curves', alone, is not likely to do the trick of coordination: one will require some further

specifications on the way people get together, talk to each other, organize what they do... That is , in order to understand how that system coordinates and change over time one will need to know much more on its istitutional architecture and on the patterns of learning . Even more so, all this would apply if one were to abandon the metaphor of the village square and rather assume that agents are also physically dispersed and interact with only a subset of the population.

Unfortunately, current economic theory - even in its 'evolutionary' and 'institutionalist' versions- still falls short of providing comprehensive taxonomies of coordination and learning mechanisms which could then be 'reduced ' into tractable macro models: so, in the above illustration, one would like to have some sort of archetypical patterns of the way people share their knowledge, sell their services, organize their production activities, etc., and then study the collective dynamic properties of different institutional set-ups. Promising theoretical attempts are there, but one is still quite far from the goal.

Let me mention three rather different examples in this direction. First, one starts seeing exercises of 'comparative institutional analysis' which continue to share with the GE world the focus upon equilibrium situations and also the assumption that agents are entirely capable to make the best use of the information they get, but the interest of the exercise rest precisely in allowing different systems to distribute differently the information -therefore also providing different incentive structures -, and also to socially distribute different menus of available courses of action (works like those by Stiglitz or M. Aoki head in this direction). Second, a forthcoming generation of 'evolutionary' models - which are more "bottom-up", in the sense that they explicitly represent a multitude of agents which interact with each other without any prior commitment to any collective equilibrium - seems well suited to handle also thought experiments concerning the aggregate effects of different distributions of knowledge and different interaction mechanisms. Third, one finds in the institutionalist macro literature - especially French, under the name of "Regulation approach"- various attempts to

identify and sometimes formalize a sort of historical taxonomy of "regimes" governing the interaction mechanisms in the various markets , e.g. products, labour, finance, etc. (cf the works by Michel Aglietta, Robert Boyer and Benjamin Coriat, among others). Certainly, the approach is much more "top-down" in the sense that it oftens starts from daring assumptions on functional relationships among aggregate variables (e.g. wages and productivity, income growth and productivity growth, etc.), but in fact, even beyond its contribution to historical analysis , it might turn out at the end to be a complement and a challange to more 'bottom-up', behaviourally richer, models.

(iv) By way of a conclusion: many more questions than answers on the contemporary economy ...

If I were to end here I would simply summarize this quick overview of the contribution of economic theory to the understanding of knowledge-based economies with a qualified optimism on the ability of the discipline to shed some light on some important aspects of them. In particular, I have argued, recent developments in the economics of information and of innovation have brought important insights into the processes of generation and diffusion of knowledge, and their economic consequences, althought many streams of macroeconomic analysis are lagging behind in taking them on board.

In the whole foregoing discussion, the emphasis has been put on the toolkit of analytical categories, models and conjectures that economists have to offer in general rather than on the interpretation of the specific contemporary trends. In fact, it follows from the perspective that I have tried to outline here that in an essential sense all economies that we know of are profoundly knowledge-based: they were a century ago and they are now .. But, with an adequate toolkit one might able to identify also what distinguishes the contemporary role of knowledge from that, say, which Marshall or Schumpeter were observing. Few crucial questions (to

which I shall not attempt any answer), directly based on the interpretative categories introduced above illustrate the point:

- how have the sources and procedures of knowledge accumulation changed?

- have new relationships emerged between accumulation of knowledge and accumulation of physical capital ?

- is it true that the balance between economically useful tacit knowledge and codified information is shifting in favour of the latter? and with what consequences?

- what are the patterns in the social (and also international) distribution of knowledge?

- how does all this affect market interactions?

- if new modes and directions of knowledge accumulation are identified, what are their implications in terms of corporate organization and strategies?

- what kind of new istitutional arrangements have emerged, if any?

- and, last but not least, what are the implications of all this in terms of employment,growth and income distribution ?

Note that it is an improved theoretical kit that allows us to pose with precision these very questions (even if we are still far from satisfactory answers !).

A general conjecture here is that one is currently witnessing a secular technological transformation which is affecting the basic economic mechanisms of demand formation, accumulation, employment generation and together the very fabric of society. The basic massage of this presentation is that, yes, economic theory can contribute to its understanding but there is still a long way to go.

There are major analytical issues to which the economic discipline can potentially offer a lot but to large extent has not delivered the goods yet : consider just as examples the question of "compensation effects" of technical progress (that is, under what circumstances the employment-destroying effects of innovation is compensated by employment-creation of equal or greater magnitude?; or the stabilizing/destabilizing effects of faster/wider access to information upon market

dynamics (e.g. what is the impact of new information technologies on financial markets and their boader consequences in terms of real aggregate variables and policy making ?).

There are other major questions with respect to which economic theory can only be a part of wider interdisciplinary endeavours. For example, I do not think it is an exageration to say that the very structure of a democratic society rests upon forms of knowledge distribution that are not too asymmetric , allow a sufficient social mobility, and imply a reasonable ability of all citizens to understand the content of collective decisions. In turn, a urgent issue regards precisely the maintenance of these conditions also in the coming "information society". Economists can contribute to the understanding of all this, but only together with sociologists, political scientists, etc.

So these conclusions are also a plea for scientific humility, or, putting it more vividly, given the current stat-of-the-art of the discipline, do not believe any economist who comes to you with simple answers and magic bullets !!

This apply even more so to the policy level: after all, among the few things we know there is the fact knowledge-based economies are likely to always embody unexploited opportunities for technological but also organizational and institutional innovation. And it is also with respect to the exploration of these opportunities that a fruitful dialogue can be established between economists and policy makers.