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Dynamic Competences and Firm Performance

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Preface

This new research project 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 differencers 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 in different countries, 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 described above often has 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 interactive 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 will focus upon the following three major areas:

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

Abstract

This empirical study investigates the impact of competencies and knowledge capital on economic performance of firms. According to the dynamic capability approach, the profitability of a firm is determined by its position in strategic capabilities. The accumulation of capabilities is proxied here by levels and fields of education, which are assumed to correlate with the rate of learning. On the other hand, successful innovation is an indirect manifestation of dynamic technological capabilities. The effects of these capability measures on profitability are estimated with a panel data-set of 209 Finnish manufacturing firms. Of special interest are the complementarities between knowledge assets, accounted for with interactions between variables. Finally, the differences in the determinants of profitability between innovating and non-innovating firms are examined, because profiting from innovation is expected to be associated with different set of skills and competencies than “normal” business.

The main findings include that educational indicators of competence are significantly associated with profitability. Interactions between different levels and fields of education turn out to have the most important effects. For example, the positive effect of post-graduate level employees is conditioned by a sufficient amount of employees with general skills acquired in higher education. This suggests there indeed exist complementarities between different types of capabilities: Research skills contribute to profitability only if there are enough general competencies, which facilitate applying and commercializing the results of R&D. Interactions are also detected between innovativeness and competencies. Profitability of innovating firms seems to differ from that of non-innovating ones. In particular, educational competencies are more important for innovators. A successful “knowledge strategy” of the firm involves simultaneous choices of investment in R&D and capabilities in different functions of the firm.

Contents

Dynamic Competencies and Firm Performance

Aija Leiponen.

1. Introduction•

It is a well known stylized fact that there are persistent differences in performance among firms in an industry (Mueller 1986, Geroski and Jacquemin 1988). Traditionally industrial economists have assumed that any firm performs like the average firm in the long run. However, there seems to be more variance in performance between firms than within firms, implying that the possible equilibrating market forces work ineffectively enough to allow some firms to outperform others for considerable periods of time.

It may be argued that the question of firm performance is more in the realm of strategic management. However, in order to conclude anything relevant about industries, economists need to understand the behavior of firms. This "black box" argument has been frequently evoked in the context of the contract theory of the firm (e.g. Holmström and Tirole 1989). In spite of these theories shedding important light on internal processes of contracting and bargaining inside the firm, the view of "the firm as a nexus of treaties" (cf. Aoki et al. 1990) is essentially silent about long term dynamics and performance. Instead, in order to understand how firms and industries change over time it is necessary to study the fundamental dynamic processes of learning and technological change.

During recent years the students of technological change have in fact begun to examine the role of internal factors of firms (cf. Cohen 1995). This research draws both from the resource-based (Penrose 1959, Wernerfelt 1984 and others), and the evolutionary (Nelson and Winter 1982) views of the firm, which suggest that there are some organization-specific assets like knowledge, accumulated over long periods of time, which make one firm different from another, and enable some firms to perform consistently better.

Despite these initiatives, the roles of knowledge and capabilities in economic theories and empirical analyses of the firm remain underdeveloped. It has proven difficult to generalize across a broad range of firms and industries. Instead, many insightful but industry-specific case studies have been conducted (see e.g. ICC 1994 for a few).

This study aims at taking a step further in assessing whether something generally applicable can be concluded about firms' capabilities. The effects of knowledge capital on firms' economic performance are examined. By incorporating skills and innovative capabilities of firms in the analysis of firm performance, a more complete view is obtained, because of the fundamental role of accumulation of knowledge and competencies in long ruin performance of firms. The effects on profitability of different types and levels of competencies, acquired through education and innovation, and their interactions, are estimated. In addition, some light will be shed on the internal differences between innovating and non-innovating firms.

In the next section the theories underlying the empirical analysis are discussed. The data-set is described in section 3. Section 4 presents the empirical model and the method of estimation. Section 5 discusses the results and section 6 concludes.

2 Dynamic Capabilities and Firm Performance

2.1 Dynamic capability approach

The literature on firm competencies or capabilities asserts that a firm's long run economic performance depends ultimately on its capabilities and knowledge. Capabilities enable the firm to operate efficiently, whereas *dynamic* capabilities make it *dynamically efficient* (North 1990). Dynamic capabilities include the abilities to learn, to solve problems, and in particular, to find new problems to solve (Dosi and Marengo 1994, albeit they use the term 'competencies')[1]. They are thus the capacity to accumulate relevant new competencies and knowledge in the firm, without which the firm is not able to adapt to changes in the environment.

The dynamic capability approach, due to Teece and others, maintains that the strategic dimensions of a firm are the positions, processes ("routines"), and paths related to the strategic knowledge assets. Essentially, dynamic capabilities enable the firm to "*create new products and processes, and respond to market circumstances*" (Teece and Pisano 1994: 541). Positions and processes are thus basically the stocks and flows of knowledge in the firm, whereas paths refer to the opportunities that the firm is able to perceive, and the path dependencies that restrict this menu of alternatives.

[1] I use the terms 'competence' and 'capability' in line with Teece et al. (1996); 'competence' being a lower level concept related to a specific task or activity, whereas 'capability' refers to more generic abilities.

The key processes that generate dynamic capability include the integration of knowledge sources in the firm, learning, and reconfiguration. These are dynamic and collective activities that require communication skills and common codes, and some shared knowledge, since they involve interaction between people within and across the organizational boundaries. Different types of learning demand also basic (technical) skills. Capacity to reconfigure the organization is crucial in an evolving environment, and necessitates capabilities to integrate into the markets and other external knowledge sources, combined with flexibility and "change culture" inside the organization. Setting the processes in place is a joint result of management actions and collective learning, but the firm can also invest in the underlying competencies that support the building of dynamic capability for instance via training and recruiting competent people.

According to the dynamic capability framework, the positions relative to competitors with respect to the strategic assets determine the market share and profitability of the firm. Key assets include technological assets, complementary assets like distribution channels and manufacturing capabilities, financial assets and locational/institutional assets. In this study we focus on the technological and competence assets, which have a significant bearing on the long run performance, but are still not very well understood.

Path dependencies constrain the strategic choices of the firm. They arise from the locality of learning. As learning is often an incremental process of trial and error, it is cumulative by nature. Also the opportunities perceived are a function of the current position in knowledge and other assets, which adds to the path dependency. Therefore, in order to ensure a large menu of opportunities and learning directions, the firm may have to maintain some redundant diversity in the knowledge base.

Dynamic capabilities are organizational, strategic, and consequently to a significant extent firm-specific, and they have to be developed internally. Moreover, building organizational knowledge is inevitably slow and gradual, as it is based on collective learning. However, accumulation of dynamic capabilities is by no means automatic. Initially, the firm's management has to be visionary enough to perceive business opportunities, which then necessitate investment in knowledge. This means, that the firm takes on an innovative, knowledge-intensive strategy. It invests in R&D, which enables it to develop technological knowledge internally, and to absorb it from the outside. Simultaneously, it has to ascertain that the human resources available are capable of applying, producing and marketing the firm's products and technologies. Technologies and competencies complement each other in every stage of the production process, as well in product development, manufacturing as in marketing. In a dynamic perspective, products, technologies and competencies co-evolve, because their coherence has to be maintained.

In short, the approach asserts that the competitive advantage of firms stems from dynamic capabilities, and that the *"(s)trategic problem facing an innovating firm in a world of Schumpeterian competition is to decide upon and develop difficult-to-imitate processes and paths most likely to support valuable products and services"* (Teece and Pisano 1994: 552).

The dynamic capability approach differs from the evolutionary theories of firm dynamics (Nelson and Winter 1982 and their followers) in some important respects. First, the firm has some deliberation in determining its knowledge strategy. Second, the firm has to keep investing in competencies, in order to renew the knowledge base, if it desires to continue on an innovative path. Consequently, there is some room for strategic choice, even though it is acknowledged that accumulation of firm-specific capabilities is a slow and path-dependent process. Therefore, a successful strategy has to account for the path-dependencies, which constrain and define the menu of profitable opportunities open to a firm.

Dynamic capability approach is a potentially powerful explanation of firm performance, but it is plagued by problems of measurement and conceptualization. Due to these, the operationalization of the framework with standard tools of industrial economics is difficult, the approach seems to lend itself mainly for case studies. It is hard to come up with general conclusions from the fairly idiosyncratic case studies. This study at hand attempts to find ways to proxy some aspects of capabilities and their accumulation, and thus contribute to operationalization of the concept of capabilities in firms and their implications for economic performance. To this end we now turn to examine capabilities from a slightly different angle.

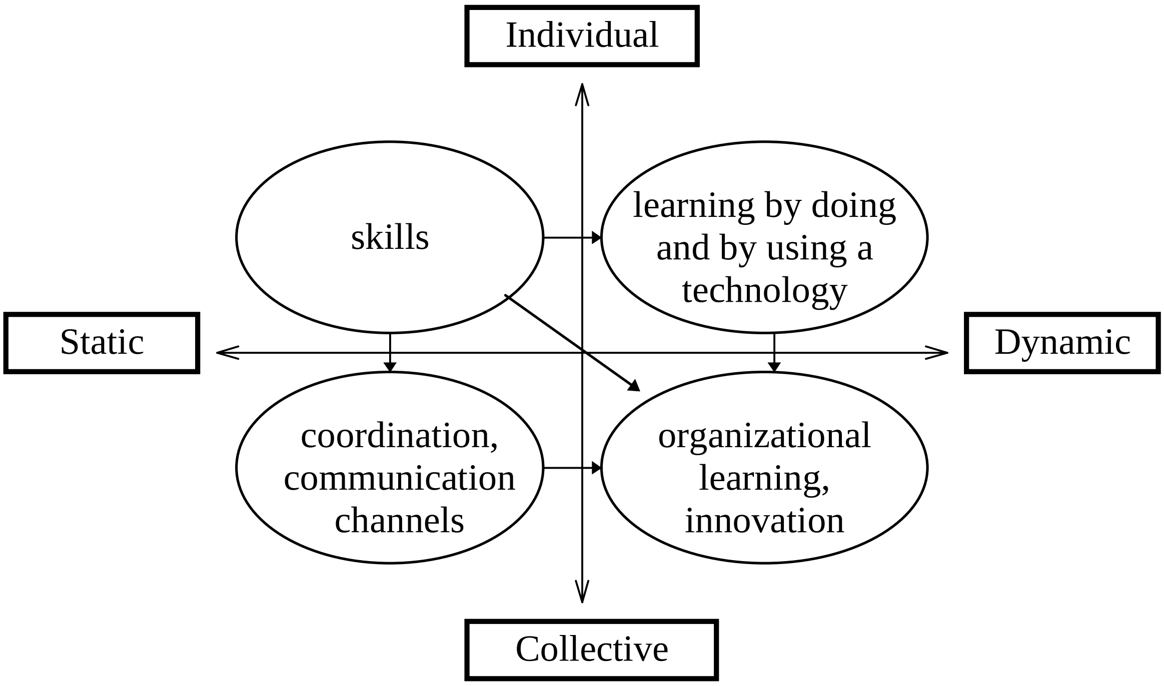
2.2 Dynamism and collectivity of capabilities

Firms are evolving organizations, and it is useful to view capabilities along two dimensions: collectivity and dynamism (see figure 1). Static and individual skills are equivalent to what has been studied under the rubric of human capital (Becker 1964 and others), which is rather straight-forward in terms of economics - it is relatively easy to assign and appropriate the rents accruing to simple skills. However, the more collective and dynamic the knowledge is, the more complex the process of accumulation and division of returns become. Individual dynamic capability is the ability to learn on the job (“learning by doing”). Collective static capabilities are the collective interaction skills, including communication channels, and coordination and integration routines. Finally, dynamic collective capabilities describe the interactive processes of learning and innovation, and reconfiguration of the communication channels and integrative routines.

Dynamic collective capabilities are firm-specific, strategic, and difficult to replicate and transfer, which may be a source of competitive advantage and consistent economic performance. However, more static and individual capabilities matter, too, because of the interactions between the components. Skills and transferable capabilities, which may often be acquired through deliberate investment, enhance the accumulation of dynamic capabilities. Technical skills enable learning by doing and adoption of external knowledge. Communication skills and a broad general knowledge base facilitate interaction and knowledge diffusion within the firm. Breadth and diversity of knowledge base is also necessary to increase the number of available (perceived) opportunities and learning directions. Therefore skills and capabilities acquired for instance via formal education may enhance the rate of organizational learning and accumulation of knowledge.

Cohen and Levinthal (1989) have argued that prior knowledge is useful for assimilating new knowledge. Similarly, prior experience in learning and solving problems during schooling enhance learning on the job. Schooling provides employees with basic technical, communicational and social skills, and most importantly, it improves their abilities to learn and adapt. Hence, the role of education in the accumulation of dynamic capabilities is to give a set of tools and a solid base for further learning. Education, therefore, should not be viewed as a "factor of production," but rather as a "factor of learning."

Figure 1. Dimensions of capabilities



The foregoing gives rise to the first hypotheses. The dynamic capability framework asserts that firm performance, in this case measured by profitability, depends on the dynamic capability position. Dynamic capabilities lead to successful innovation. Therefore, interpreting innovations and patent applications as epitomes of dynamic technological capabilities, we hypothesize that technological capabilities enhance firm performance:

H1: Dynamic technological capabilities increase profitability

Since we are not able to measure directly the "stock" of dynamic capabilities, we utilize the preceding discussion of the dimensions of capabilities and their interactions, and propose that dynamic capability accumulation is a function of skills and competencies acquired in education, which indirectly affect competitive advantage manifested in profitability:

H2: A high level of skills and technological competencies increases profitability.

The shortcoming of the empirical analysis is that the data available does not allow investigating the lags in the effects of skills on capability accumulation. Furthermore, the skill levels are obviously only one factor that influences learning and cumulation of relevant knowledge. Other factors like external changes in technologies and markets, and management actions impact learning as well.

2.3 Complementarities between knowledge assets

Above it was briefly alluded to the co-evolution of technologies and competencies. More precisely, co-evolution means that technologies and different types of competencies complement each other. Complementarities are thus expected to appear between different capabilities. For instance, integrated models of innovation like Kline and Rosenberg's (1986) emphasize the knowledge flows and interactions between different functions in the firm. In addition, different kinds of capabilities are required in R&D, manufacturing, marketing, and distribution. In case one activity is insufficiently competent, the operations of others are hampered as well. Teece (1986) discusses the role of complementary assets in profiting from innovation, and submits that in many cases the lack of complementary capabilities explains the failure to profit from an initially very promising innovation.

In the empirical analysis of section 5, complementarities are assessed in a traditional way through interaction effects between the competence variables. According to Athey and Stern (1996), this does not really distinguish the presence of complementarities from simple positive correlation and possible confoundedness, but I expect it to give an initial assessment of this possibility. Hence the third hypothesis is:

H3: There are complementarities between technologies, technological capabilities, and other kinds of competencies, manifested in the interaction effects.

2.4 Complementary competencies in innovating firms

Lastly, I will compare innovating and non-innovating firms. Geroski et al. (1993a,b) suggest that there are generic differences between innovators and non-innovators, because innovation is a dynamic process of accumulating internal capabilities, which creates a firm-specific effect that affects the firms' evolution and performance through time. However, Geroski et al. do not discuss how and why this possible accumulation of capabilities happens in innovating firms.

I aim to shed more light on the differential patterns of evolution of innovating firms by estimating separately the factors influencing profitability for these two groups of firms. The underlying idea is that profiting from innovation depends, in line with Teece (1986), on complementary knowledge assets. It is suggested that innovators need more complementary capabilities and skills than non-innovators, because innovative operations are more knowledge and competence intensive than the "business as usual" of non-innovating firms. Innovation, as discussed earlier, necessitates flexibility and broad capability base in manufacturing and marketing, in order to be able to swiftly and profitably adopt the new product or technology.

H4: Innovating firms are more dependent on (complementary) skills and capabilities than non-innovating firms.

3 The Data

The data-set is compiled by Statistics Finland, and consists of firm-level data on the levels of education and financial state of a sample of Finnish firms in 15 different manufacturing industries. These data are combined with domestic patent applications and an innovation survey carried out in 1991.

The survey data contain 489 manufacturing firms, including the 100 largest firms and a random sample of the rest of the population. In this study I had to content myself with a time-series of 209 firms for the period 1985-1993 (every other year) for financial information and patent applications, and 1987-1993 for educational data (see table 1 below), because of the requirement to have at least 4 of the 5 observations[2]. There is thus one more observation of the dependent variable and predetermined control variables than explanatory competence variables. This observation is “used” for the lagged dependent variable and instrumentation (see section 4 for details).

Table 1. Variables

Vector	Variable	Definition
COMPETENCE	HIGH	Share of employees with higher education degree, % (1987-93)
	POST	Number of employees with post-graduate degree (1987-93)
	TECH	Share of employees with technical or natural scientific degree, % (1987-93)
	HITECH	- “ - higher technical or natural scientific degree, % (1987-93)
	POST*HIGH	Interaction terms
	PAT*POST	- “ -
	POST* TECH	- “ -
	PAT*HITECH	- “ -
INNOVATION	PROD	Dummy variable for new products launched successfully in markets between 1989-1991 (1991)
	PROC	Dummy for significant process innovations realized between 1989-1991 (1991)
	COMPR	Dummy variable for firms realizing both product and process innovation (“comprehensive innovation”)
	PAT	Number of domestic patent applications (1985-1993)

[2] For more about the data and a descriptive analysis, see Leiponen 1996a.

FIRM	SALES	Sales turnover, million FIM (1985-1993)
	MS	Market share, % (1987-1993)
	KINT	Capital intensity: machinery, equipment etc in the balance sheet in proportion to sales, % (1985-1993)
INDUSTRY	CON3	3 firm concentration ratio in the industry, % (1987-1993)
	$KINT_I$	Capital intensity in the industry, % (1987-1993)
PROFITABILITY	NET	Net profit margin (net profit in proportion to sales), % (1985-1993)

The dependent variable *profitability* is measured with net profit margins. The competence indicators include the shares of employees with different levels and fields of education. Their interactions are considered to assess the possibility of complementarities. Interactions are expected both between different levels and fields of skills, and innovation and skills. Innovation, an indirect measure of dynamic technological capabilities, is described by three dummy variables for firms undertaking either product innovation, process innovation or both, and by domestic patent applications, lagged by one period.

Firm-specific differences in size and growth patterns are taken into account with three indicators: sales, market share and capital intensity. Market share is measured as the proportion of the firm's sales to the total sales in the domestic 2-digit industry, as classified by Statistics Finland. Hence it is not an exact proxy of market power for firms that operate in several industries, have a significant share of their sales abroad, or for which the more narrow 3-digit industry is more relevant. However, for the time being I have no access to more accurate data.

Sales and capital intensity are instrumented, because they are assumed to be predetermined, i.e. influenced by past profitability. Market share is unavailable for the year 1985 due to a change in the classification of industries, otherwise it would have been instrumented as well. Industry-specificities are controlled for with the concentration ratio and capital intensity, in addition to industry dummy instruments. Time dummies are used as well, but they are not reported.

4 The Empirical Model and the Method of Estimation

The model for the empirical analysis is now formulated. It augments the market structure - firm performance approach with indicators of innovation and competencies. The model asserts that a firm's profitability is a function of its knowledge assets, lagged profitability, and some firm- and industry-specific characteristics.

The basic model reads

$$\pi_{i,t} = \alpha\pi_{i,t-1} + \beta' X_{i,t} + \eta_i + \delta_t D_t + \varepsilon_{it} \tag{1}$$

where $\pi_{i,t}$ denotes profitability of firm i in period t and $X_{i,t}$ are the explanatory variables. α, β and δ are parameters to be estimated, η_i is a firm-specific fixed effect, D_t are time dummies to capture macroeconomic shocks, and ε is a serially uncorrelated[3] white noise error term. More specifically,

$$\begin{aligned}(2)\qquad \pi_{i,t} &= \alpha\pi_{i,t-1} + \beta_1 COMP_{i,t} + \beta_2 INN_{i,t} + \beta_3 FIRM_{i,t} \\ &+ \beta_4 INDUSTRY_{i,t} + \eta_i + \delta_t D_t + \varepsilon_{it}\end{aligned}$$

where notation is as presented previously. Vectors COMP and INN consist of our measures for competencies and innovations (dynamic technological capabilities) respectively. FIRM and INDUSTRY vectors include a set of available proxies to control for firm and industry-specific differences in performance.

The analysis is carried out with the generalized method of moments (GMM), a two-stage weighted least squares estimator for panel data utilizing instrumental variables, as it was presented by Arellano and Bond (1991). The fact that the model includes a lagged dependent variable, fixed effects and some predetermined explanatory variables implies endogeneity and autocorrelation. Moreover, using this type of firm data may give rise to heteroskedasticity. GMM, however, enables consistent estimation of dynamic models in spite of heteroskedasticity and autocorrelation, which would blur the results if a method like least squares fixed effects was used. Furthermore, GMM is particularly suitable for short panels.

The model is estimated in differences to cancel out firm-specific, time-invariant fixed effects:

$$(3)\qquad \Delta\pi_{i,t} = \alpha'\,\Delta\pi_{i,t-1} + \beta'\,\Delta X_{i,t} + \delta'\,\Delta D_t + \Delta\varepsilon_{it}$$

Among the firm characteristics there are some predetermined explanatory variables, which have to be instrumented. The Arellano - Bond method constructs the instrumental variable matrix Z_i utilizing all the linear moment restrictions, as shown in equation (4) below. The lagged values of the dependent variable become valid instruments thanks to the assumption of second-order serial uncorrelation of error terms. π_i dating from t-2 and before are valid instruments for $\pi_{i,t}$. For the predetermined explanatory variables $X^p_{i,t}$, the values lagged one period are used as instruments. $X^p_{i,t-1}$ is a valid instrument for $X^p_{i,t}$, because it correlates with $X^p_{i,t}$ but not with ε_{it}. For the strictly exogenous variables $X^e_{i,t}$, lagged differences are valid instruments.

[3] because the model is an AR(1) process, only second-order serial uncorrelation is required.

(4)

$$Z_i = \begin{bmatrix} \pi_{i,1} & X_{i,1}^{p} & X_{i,2}^{p} & 0 & 0 & 0 & 0 & 0 \ldots & 0 \ldots & 0 & 0 \ldots & 0 & : \Delta X_{i,3}^{e} \\ 0 & 0 & 0 & \pi_{i,1} & \pi_{i,2} & X_{i,1}^{p} & X_{i,2}^{p} & X_{i,3}^{p} \ldots & 0 \ldots & 0 & 0 \ldots & 0 & : \Delta X_{i,4}^{e} \\ . & . & . & . & . & . & . & . & . & . & . & . & : \\ . & . & . & . & . & . & . & . & . & . & . & . & : \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \ldots \pi_{i,1} & \ldots \pi_{i,(T-2)} & X_{i,1}^{p} \ldots & X_{i,(T-1)}^{p} & : \Delta X_{i,T}^{e} \end{bmatrix}$$

The crucial assumption regarding the consistency of estimates is exactly the second-order serial uncorrelation of error terms. This will be tested and reported in the estimation results. Also, the validity of instruments is checked with the Sargan test of overidentifying restrictions (Arellano and Bond 1991).

5 Estimation Results

5.1 All firms

By and large, competence and innovation variables are found to be positively associated with profitability (table 2), supporting the hypotheses H1 and H2, albeit with some interesting exceptions. Higher education (HIGH), general technical skills (TECH) and higher technical skills (HITEC) correlate consistently positively with profitability, although only HITEC is statistically significant.

Research skills measured by the POST variable affect profits through the interaction effects with other competence variables. One of the most robust outcomes is that higher educated employees complement doctoral level researchers, in line with the hypothesis H3. The interaction term is positive and very significant. A sufficient number of employees with general capabilities seem to be necessary to make R&D activities, in which the POST employees tend to work, economically useful. A similar kind of interaction can be found with the technical skills and doctoral employees (POST*TECH).

Moreover, higher technical skills (HITEC) and research skills (POST) interact with innovation activities and technological capabilities. This is suggested by the strongly negative coefficients on PAT*POST and PAT*HITEC. However, the nature of the interaction cannot be properly determined with the data at hand.

The innovation dummies show some intriguing behavior. The comprehensive innovation dummy (COMPR) is consistently a positive and significant determinant of profitability. However, separating the effects of product and process innovation reveals that product innovation tends to have strong adverse effects on profit margins, whereas process innovation is equally strongly positively related to them. In line with Cohen and Klepper (1996), product innovators are on average significantly smaller than process innovators in our sample. The profitability differences may arise from life-cycle effects. At an early stage in the cycle, firms may be more concerned with creating new products and expanding, possibly even to the detriment of profits, than fine-tuning their processes and hence improving efficiency and profitability. However, firm size (sales) and market share are taken into account, and size is also instrumented, which should control to some extent for the life-cycle differences between small and large firms.

Athey and Schmutzler (1995) have suggested, that product and process innovation are complementary. Product innovation shifts out the demand curve, and process innovation lowers the production costs. The returns to process innovation are therefore increased by product innovation: the returns are larger over a larger output. A positive coefficient on the comprehensive innovation actually suggests this. Another interesting avenue would be to study, which kind of complementary capabilities are needed to make product innovation affect profitability positively, and what are the underlying dynamics.

The results with respect to process innovation are quite different. It has a rather stable and strongly positive effect on profitability throughout the specifications. This could reflect that process innovations are more likely to be accumulated as firm-specific organizational knowledge than product innovations, and hence the return may be more easily appropriated. In any case we cannot immediately confirm the hypothesis of Geroski et al. (1993a,b) that product innovation is associated with better profitability, reflecting accumulated internal capabilities. Educational competence variables appear to be as relevant proxies for the accumulation of internal capabilities as the innovation variables. More research on the processes of different types of innovation are called for, to understand their implications for capability accumulation.

Table 2. Estimation results for net profit margins (209 firms)

	Variable	(1) Coeff. (t-stat)	(2) Coeff. (t-stat)	(3) Coeff. (t-stat)	(4) Coeff. (t-stat)	(5) Coeff. (t-stat)	(6) Coeff. (t-stat)	(7) Coeff. (t-stat)
	CONST	-1.159*	-2.438*	-2.013*	-1.439	-2.078*	-1.816*	-2.268*
		(-2.326)	(-3.309)	(-2.290)	(-1.475)	(-2.297)	(-2.084)	(-3.316)
	NET_{t-1}	0.081	0.112	0.056	0.048	0.058	0.056	0.122*
		(1.372)	(1.829)	(0.874)	(0.740)	(0.874)	(0.895)	(2.065)
INN	**COMPR**		2.194*					2.087*
			(2.265)					(2.186)
	PROD			-5.512*	-6.181*	-4.297*	-4.925*	
				(-3.698)	(-4.510)	(-4.022)	(-3.586)	
	PROC			5.895*	5.976*	5.196*	4.957*	
				(4.454)	(5.040)	(4.763)	(4.073)	
	PAT_{t-1}	0.054*	0.029	0.078*	0.178*	0.189*	0.228*	0.172*
		(2.734)	(1.236)	(3.882)	(4.391)	(3.598)	(3.425)	(2.772)
COMP	**HIGH**	0.305	0.407	0.208	0.179			
		(1.078)	(1.421)	(0.733)	(0.660)			
	POST	-0.453*	-0.707*	-0.093	-1.377*	-1.023	-0.842	-1.294*
		(-2.241)	(-2.391)	(-0.217)	(-2.103)	(-1.362)	(-1.810)	(-4.545)
	TECH	0.040	0.056			0.037		
		(0.489)	(0.675)			(0.440)		
	HITEC						0.769*	0.891*

							(2.639)	(3.080)
	POST*HIGH	0.037*	0.043*	0.023*	0.096*		0.061*	0.069*
		(4.530)	(3.822)	(2.058)	(3.438)		(3.533)	(5.477)
	PAT*POST				-0.006	-0.004		
					(-4.098)	(-3.287)		
	POST*TECH					0.043		
						(2.085)		
	PAT*HITEC						-0.007*	-0.006*
							(-5.093)	(-5.286)
FIRM	**MS**	1.128*	1.149*	1.875*	1.659*	1.361*	1.823*	1.318*
		(3.608)	(4.041)	(4.715)	(3.996)	(3.335)	(4.742)	(3.561)
	SALES	0.001	0.001	0.001	-0.001	-0.0003	-0.0001	0.0002
		(1.013)	(1.456)	(1.579)	(-1.003)	(-0.435)	(-0.256)	(0.460)
	KINT	-0.222*	-0.237*	-0.189*	-0.218*	-0.195*	-0.185*	-0.237*
		(-5.807)	(-5.475)	(-4.702)	(-5.013)	(-4.736)	(-4.231)	(-5.418)
INDUSTRY	**CON3**	0.081	0.087	0.053	0.055	0.082	0.079	0.101*
		(1.771)	(1.908)	(1.147)	(1.209)	(1.731)	(1.722)	(2.176)
	$KINT_I$	-0.046	-0.092*	-0.073	-0.066	-0.077*	-0.097*	-0.106*
		(-1.437)	(-2.567)	(-1.877)	(-1.701)	(-2.024)	(-2.572)	(-2.947)
Test statistics (d.f.)	**2nd order serial correlation**	-0.547	-0.49	-0.137	-0.198	-0.500	-0.118	-0.361
	Wald test for joint significance	254.93	228.88	237.40	188.79	258.27	160.63	178.62
		(11)	(12)	(12)	(13)	(13)	(13)	(12)
	Sargan's test	33.39	29.01	27.65	28.97	30.68	28.11	29.10
		(35)	(34)	(33)	(33)	(33)	(33)	(34)

Note: SALES and KINT are instrumented. Industry dummy instruments and time dummies are used.

The coefficient of the lagged dependent variable, NET_{-1}, is positive (although not significant). This suggests that firms that have been performing well tend to do so also in the future. There does not seem to exist any strong mechanism balancing the profits, at least not in the short run. Among the economic control variables, firm capital intensity (KINT) and capital intensity in the industry ($KINT_I$) are significantly negatively associated with profits, which may capture the poor productivity of the heavy investment carried out in many Finnish industrial firms during the boom of the late 1980s. As expected, profits increase with market share and the concentration of the industry.

The overall validity of our model is good, according to the Wald test of joint significance. In all the cases reported in table 2 we have assumed NET_{-1}, SALES and KINT to be predetermined, and they have been instrumented in the optimal way. Additional instruments are used for the industry dummies. Instrumentation is very important for the significance of the estimation. It is of crucial importance to take the implications of endogeneity into account.

The validity of instruments is tested with the Sargan test. Under the null hypothesis of valid instruments the Sargan test statistic is asymptotically distributed as chi-square. In all specifications we can accept the null within a 95% confidence interval. The null hypothesis of the second-order autocorrelation test is no autocorrelation, and the statistic is asymptotically distributed as N(0,1). The critical value for 95% confidence in having no serial correlation is +/-1.96, and our estimations do not come close to these limits. The estimates should thus be consistent.

5.2 Innovators vs. Non-innovators

In this subsection we further examine the nature of innovativeness. It was hypothesized that profiting from innovation requires complementary capabilities. Hence the skills and competencies needed for profitable business may be different for innovators and non-innovators. Something to this effect was suggested by the high significance of innovation dummies and the interactions between innovation and education in the previous section. To test this hypothesis we study the determinants of profitability separately for innovating and non-innovating firms. Innovators include the comprehensive innovators (both product and process innovation), while non-innovators carried out neither type.

Table 3. Profitability of innovators vs. non-innovators

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Innovators (N=278)			**Non-innovators (N=176)**		
Variable	**Coeff. (t-stat)**	**Coeff. (t-stat)**	**Coeff. (t-stat)**	**Coeff. (t-stat)**	**Coeff. (t-stat)**	**Coeff. (t-stat)**
CONST	-0.991*	-1.001*	-1.219*	0.279	0.840	0.566
	(-2.234)	(-2.190)	(-2.798)	(0.349)	(1.108)	(0.731)
NET_{t-1}	-0.040	-0.042	-0.016	0.442*	0.400*	0.312*
	(-0.903)	(-1.022)	(-0.412)	(3.466)	(3.587)	(3.043)
PAT_{t-1}	0.133*	0.136*	0.030*	-3.143*	-2.628*	-1.014*
	(6.876)	(7.177)	(2.040)	(-3.996)	(-3.281)	(-2.027)
HIGH	0.516*			-0.038		
	(2.432)			(-0.183)		
POST	-1.780*	-1.824*	-1.323	-3.335	-4.124	-5.808*
	(-3.436)	(-3.699)	(-1.934)	(-1.372)	(-1.617)	(-2.217)
HITECH		0.685*	0.650*		1.970*	1.542*
		(2.836)	(2.667)		(2.797)	(2.552)
POST*HIGH	0.080*	0.076*	0.037*	0.373*	0.332	0.262
	(4.663)	(4.882)	(2.032)	(2.020)	(1.466)	(1.059)
PAT*POST	-0.006*			-6.107*		
	(-10.132)			(-4.732)		
PAT*HITECH		-0.006*			-0.433*	
		(-10.541)			(-3.565)	
MS	0.382	0.990	0.749	-3.072	-4.734*	-7.359*
	(0.368)	(1.092)	(1.112)	(-1.196)	(-2.337)	(-3.706)
SALES	0.006*	0.004	0.005*	-0.010	-0.006	0.030*
	(1.966)	(1.487)	(2.129)	(-0.997)	(-0.811)	(4.135)
KINT	-0.125	-0.143*	-0.091	-0.417*	-0.441*	-0.382*
	(-1.860)	(-2.355)	(-1.443)	(-14.210)	(-12.276)	(-14.039)
CON3	-0.010	-0.013	-0.031	0.382*	0.383*	0.358*

	(-0.237)	(-0.357)	(-0.770)	(4.567)	(4.822)	(4.867)
$KINT_I$	-0.082*	-0.090*	-0.097*	-0.105*	-0.096*	-0.079
	(-2.204)	(-2.623)	(-2.628)	(-2.361)	(-2.334)	(-1.902)
Second-order serial correlation	-0.781	-0.692	-0.961	-0.741	-1.149	-0.895
Wald test for joint significance (d.f.)	281.18 (11)	292.50 (11)	171.20 (10)	1845.95 (11)	10633.25 (11)	10520.24 (10)
Sargan test (d.f.)	36.053 (35)	36.66 (35)	34.48 (36)	24.15 (21)	23.71 (21)	25.92 (22)

According to the results in table 3 above, the determinants of profitability indeed differ between innovating and non-innovating firms. Overall, patenting and educational competencies are more important for the profitability of innovators[4]. Patenting is actually negatively related to non-innovators' profit rates. Only higher technical skills (HITECH) are robustly significant for non-innovators' profits. The coefficient is also clearly larger for non-innovators. Instead, the interaction term POST*HIGH is in most cases not significant for non-innovating firms, while for the innovators, higher education (HIGH), higher technical skills (HITECH) and research skills (POST) are all very significant. Again, positive effect of research skills is conditioned by general skills in the form of higher education. For both groups the interaction between skills and current patenting are strong and significant, suggesting that technological capabilities do not necessarily translate to better profitability, if the coherent accumulation of other competencies is not taken into account.

The profitability of non-innovating firms seems to be determined mainly by other factors than competencies. The autoregression term (NET_{t-1}) is significant suggesting that successful non-innovators tend to remain successful due to factors outside our model. Interestingly, market share correlates negatively with their profit rates, i.e. non-innovators with market power tend to be less profitable. Furthermore, the negative impact of firm capital intensity is strong compared to innovating firms. On the other hand, positive effects of industry concentration are more important, too.

NET_{t-1} is insignificant for the group of innovators. The size of the firm seems to be an important determinant of profitability for innovators, again pointing to the life cycle differences among firms. Market share and concentration do not come into play with innovating firms' profitability.

To sum up, hypothesis H4 is supported, since the profitability of innovating firms is influenced differently by the factors considered, than that of non-innovating firms. In particular, the role of education in the accumulation of competencies is more important for innovators. Economic performance of innovating firms relies to a more significant extent on the employees' competencies and technological capabilities.

[4] The firm may have applied for patents during 1985-1993 even if it did not innovate between 1989-1991.

5.3 Product Innovators vs. Process Innovators

This subsection briefly investigates, whether there are also differences between different kinds of innovators. The profitability model is estimated separately for product innovating and process innovating firms. A companion paper (Leiponen 1996b) found that product innovation and process innovation are associated with different competencies. The analysis was based on a preliminary taxonomy on different types of innovation being related to different competencies, by Malerba and Orsenigo (1993), building on Pavitt's (1984) taxonomy of industries. Now we examine if the observed differences in competence requirements carry over to profiting from product and process innovation.

Despite some overlap in the two groups, the results indeed reveal differences in the determinants of profitability between product innovators and process innovators. The coefficients indicate that patenting is more important for product innovators, although the coefficient is positive and significant for both groups. This is in accordance with Levin et al. (1987), that protection of intellectual property via patenting is more important for product innovation. Higher education is more useful for process innovators, whereas the magnitude of the coefficients on research skills (POST) and the POST*HIGH interaction term are larger and more significant for product innovators. This may be interpreted, that in respect of product innovation, R&D has to interact closely with other activities to ensure that innovations make economic sense. Among the control variables, the main differences are that the profitability of process innovators is more affected by market share, and firm capital intensity seems to decrease the profit margins of product innovators more seriously.

Table 4. Determinants of profitability for product and process innovators

	(1) Product Innovators (N=315)	**(2) Process Innovators (N=355)**
Variable	**Coeff. (t-stat)**	**Coeff. (t-stat)**
CONST	-1.062*	-1.004*
	(-2.240)	(-2.462)
NET_{t-1}	0.034	-0.067
	(0.646)	(-1.072)
PAT_{t-1}	0.188*	0.095*
	(4.381)	(4.003)
HIGH	0.366	0.747*
	(1.640)	(3.648)
POST	-1.355*	-0.407
	(-2.075)	(-1.584)
POST*HIGH	0.074*	0.035*
	(3.309)	(2.265)

PAT*POST	-0.006* (-6.638)	-0.003* (-3.248)
MS	0.738 (0.736)	0.912* (4.214)
SALES	0.004 (1.808)	0.0002 (0.457)
KINT	-0.121* (-7.078)	-0.004 (-0.078)
CON3	-0.021 (-0.485)	0.006 (0.155)
$KINT_I$	-0.065* (-2.014)	-0.114* (-2.385)
Second-order serial correlation	-0.979 (89)	-0.689 (99)
Wald test for joint significance	483.48 (11)	187.23 (11)
Sargan test	35.09 (35)	42.87 (35)

In conclusion, even with this limited and overlapping sample of firms, the result emerges that the accumulation of capabilities in product innovating firms differs from that in process innovating firms. However, a more thorough inspection of the innovation processes themselves, and how their results are incorporated in the organization, would be needed to understand the kinds of competencies needed and accumulated in each.

6 Conclusions

Overall, the educational competencies and technological capabilities have a considerable role as a determinant of profitability of manufacturing firms. Evidence was found of the positive but in some cases conditional effects of competencies on profitability. In addition, there are interesting interactions between competencies and innovation. Educational measures seem to capture some aspects of internal knowledge accumulation in firms. The interpretation advanced here is that skills acquired in education are useful, because they facilitate building organizational knowledge via learning and interacting on the job.

The interaction between the number of employees with a post-graduate degree, which reflects the research orientation of the firm, and other types of competencies is significant. In order that the post-graduate level employees improve profitability, there need to be sufficiently general competencies in the firm. This is intuitive, in the sense that even very ambitious and productive research and development may not be useful, unless there are enough competencies in other parts of the organization to make use of the knowledge produced, and to enable communication and interaction between R&D and marketing, production and administration. This suggests there exist substantial complementarities between different types of competencies. To confirm these preliminary results, complementarities would need to be modeled and estimated more explicitly, and employees' occupations should be accounted for in the data.

Factors influencing profitability of innovating firms differ from those of non-innovators. Both educational competencies and patenting are more important for innovators, whereas the profitability of non-innovators correlates more robustly with previous performance, and firm- and industry-specific factors. This supports the idea that complementary capabilities are necessary for successful profiting from innovation.

Some differences in the determinants of profitability of product vs. process innovators were detected as well. The coefficients of research competencies and their interaction with general higher education are larger and more significant for product innovators. Instead, higher education contributes more significantly to the profitability of the process innovators. These results suggest that the complementarities between research competencies and general capabilities are more important for successful product innovation, whereas process innovation tends to rely on learning on the job, which is enhanced by general skill level.

Product innovations as such did not appear to be associated with better economic performance, contrary to the results of Geroski et al. (1993a). Part of the reason may be the poorer quality of our innovation data compared to that used by Geroski et al. Also the stage of the product innovating firms in the product life-cycle may have contributed to this result. Another explanation would be that product and process innovation are complementary (Athey and Schmutzler 1995).

The empirical analysis has some problems and shortcomings, particularly arising from the availability of data. A reasonably detailed analysis would require more accurate firm-level data on innovation processes and better measures for competencies. Industry-specificities should also be considered more carefully. Furthermore, in order to fully grasp the dynamics of knowledge accumulation and lags involved, longer time-series are needed. For instance, refuting the claim that investment in skills is predetermined by profitability, and thus endogenous, would require longer time-series.

Interesting issues to consider in future work would be the complementarities between the modes of organization, technological change, and competencies. Innovation studies (see e.g. Iansiti and Clark (1994) on product development, and Lundvall (1992) on national innovation systems) have emphasized the importance of integrating into crucial knowledge sources inside and outside the firm. Knowledge integration necessitates establishing communication channels and integrative routines. What kind of organizational choices are related to different types of innovation, and which kind of competencies are needed therein? Finally, the organizational aspects of complementary capabilities needed in successfully profiting from innovation would be an important theme to explore.

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