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The Unexplored Effect of Skills and Technology on Firms' Performance

by

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Abstract:
The aim of this paper is to add new findings to the knowledge based view of the firm, where the cross-learning ability of individuals and organizations plays a fundamental role in the determination of firms' superior performances. Collective, non formal – informal, formal types of learning (learning drivers) contribute to shape the competitiveness of firms, especially in the present knowledge-based economy, where the necessity to respond effectively to frequent external shock (demand, technology, competitive environment driven) emphasizes the importance of being flexible and quickly adaptive. Nevertheless, focusing on learning capacities, and particularly on human skills, often leads to forget or ignore industry effects, such as innovative intensity, which increase the explanatory power of the learning drivers.
This work explores the conjoint effect of learning drivers and innovative intensity on firms' performance by showing some evidence from statistical data analysis on the Danish IDA (Integrated Database for Labour Market Research). A sample of firms belonging to the manufacturing industry is studied using data related to the year 1999.
The paper proceeds as follows: firstly, the role and relevance of human resources in the determination of firm's performance is presented. Secondly, a missing ring in the knowledge based view of the firm is detected: the R&D investments intensity. Thirdly, the data analysis process and the methodology adopted are illustrated. Finally, the results are presented and discussed.

Key words: Human capital, Innovative intensity, Knowledge, Learning, Manufacturing, Performance.
JEL Codes: C13; J24; L23; L6; O3

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1. Introduction

The present work gives new empirical evidence of the relevance of some concepts introduced and argued by what Foss (2003) describes as the dominant contemporary approach to the analysis of sustained competitive advantage, namely the resource based view of the firm (henceforth, the RBV). Besides, it includes some remarks on the importance of the industry structure and specifically of the industry technological intensity in the determination of firms competitive advantage.

According to Teece et al. (1997), two main models of strategy can be identified: one emphasizes the exploitation of efficiency (RBV perspective), the other emphasizes the exploitation of market power (Industrial Organization - IO - perspective).

The research aims to show how it is important to keep an integrated view of the two approaches[1], which can be simultaneously applied for understanding the determinants of firm's competitive advantage.

The resource-based approach to the theory of the firm initiated in the mid-1980s by Wernerfelt (1984), Rumelt (1984) and Barney (1986), and further developed by other writers[2], evolving from a "pure" form, so called resource (stock) based, to more complex forms, so called firstly competencies and secondly capabilities (flows) based. The RBV shares with the neoclassical theory the vision of the firm as "input combiner", but at the same time admits the possibility to obtain extra-gains from its activity thanks to isolation mechanisms, as Bain (1968) maintained from a monopolistic point of view. Furthermore the RBV sustains the power of innovation in the process of generation of Schumpeterian rents, which derive from the efficient coordination of the organization functions, and not from the structure of the industry to which the firm belongs (Brozen, 1971; Demsetz, 1973, 1974, 1982, 1989; Peltzman, 1977 (Chicago industrial organization approach) and Porter, 1980).

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[1] The topic has been faced by researchers from both sides (RBV and IO). Look for example at Porter (1991), Collis (1991), Amit and Schoemaker (1993). Recently, the "3e Cycle Romand en Gestion d'Entreprise", a conference that took place at the Université de Neuchâtel in March 24th 2003, aimed to present trends and gaps in the Strategic Management Research literature. One of the main issues faced by the lecturers (stemming from the seminal work of Bogner, Mahoney and Thomas, 1998) related to the possible integration of firm-level and strategic group-level explanation of firm performance.

[2] Think about the evolving concept of resources through the work of the following authors: Itami and Roehl (1987) and invisible assets, Prahalad and Hamel (1990) and core competencies, Grant (1991) and capabilities, finally Teece and Pisano (1997) and dynamic capabilities.

Finally, as Conner (1991) pointed out, this approach embraces the concepts of "asset specificity" and "small numbers" belonging to the transaction costs theory (Williamson, 1975; Dundas and Richardson, 1980; Rumelt, 1984).

Starting from the RBV assumption that causes of differences in firms performance have to be searched through firms' resources and not through external factors, this work focuses on the role of a specific firm asset: human resources. The objective is to explore the real impact of human resources on firms' performance (measured as labour productivity and profitability). Looking at individuals as repositories of knowledge and at firms as integrators of organizational and individual knowledge (Teece, 1998), four learning factors have been individuated (after having performed a factor analysis on a set of key-variables), and the evaluation of their effects on firms performance has been detected thanks to regression models. What would happen if the technology factor was included in the model? Could it improve the explanatory capability of the learning factors previously individuated?

Porter (1980), starting from a critics to the model of pure competition, which implies that risk-adjusted rates of return should be constant across firms and industries, affirms that different industries can sustain different levels of profitability.

Part of this difference in performance is due to industry structure. Porter (1980) proposes a framework that models an industry as being influenced by five forces: supplier power, threat of substitutes, degree of rivalry, buyer power and barriers to entry. The five forces are the determinants of the degree of competitive intensity and of industry profits.

The analysis here performed takes in account the industry structure by considering the amount of investment in technology. This consideration allows to distinguish between four "technology groups" (high tech, medium-high tech, medium-low tech, low tech; see the appendix for a specification).

What does the industry structure add to the understanding of firm's performance? Is it relevant to keep an eye both on the firm-specific assets and on the industry structure?

The paper proceeds as follows: firstly, the role and relevance of human resources in the determination of firm's performance is presented. Secondly, a missing ring in the knowledge based view of the firm is detected: the industry R&D investments intensity. Thirdly, the methodology adopted for data analysis is illustrated. Finally, the results are presented and discussed.

2. Theoretical background and hypotheses

Even if it is pretty clear that, from a RBV of the firm, resources are fundamental for reaching a competitive position in the market and earning superior returns, not all the resources have the right qualities to be entered into the pool that can guarantee a sustained competitive advantage. Barney (1991) is the first one to list the specific attributes of an advantage-creating resource, it has to be: valuable, rare, imperfectly imitable, not easily to substitute. Later on Grant (1991), Collis and Montgomery (1995), Amit and Schoemaker (1993) produce different and enlarged lists, that, according to Fahy and Smithee (1999), can be parsimoniously restricted to include three properties: value, barriers to duplication and appropriability.

As it is suggested by Barney (1991), resources can be distinguished at least into three categories: physical capital resources, human capital resources, and organizational capital resources. In this work I want to focus on human capital resources, which include "*training, experience, judgment, intelligence, relationships, and insight of individual managers and workers in a firm*".[3] Barney's concept of human capital resources includes all workers, but I think it is worthy and important to detect, among them, what can be called the crucial elements of the organization, or, better, "human capital".

It is widely acknowledged that individuals are the most important repositories for knowledge, and, that's more relevant, for tacit knowledge (Nonaka and Takeuchi, 1995; Argote and Ingram, 2000). In her book "Wellsprings of Knowledge", Dorothy Leonard-Barton (1998) of Harvard Business School tells the story of a firm, ELP, taking over a rival, Grimes, after a two-day visit to its site. The "inspectors" came back enthusiastic for what they had seen, so ELP proceeded with the acquisition. Few days later, ELP managers realised that they had not investigated below the surface of the apparently superior Grimes capabilities, Grimes' real competitive advantage had lain in the operating knowledge of its line employees, all of whom had been let go.

[3] Barney (1991), p.101

This is only an example[4] that shows how human capital can have a key role in the foundation of the competitive advantage of firms. Unfortunately, not the whole workforce employed in an enterprise is strategically relevant, not the sum of the totality workers' efforts is "human capital". For a smart definition of human capital we have to look at the classification of the workforce given by Stewart (1997), developed around two main variables: the difficulty to replace and the value added (Fig. 1).

Only workers that fit the upper-right quadrant are the "stars", using Stewart's words: *"...people who play irreplaceable roles in the organization and who are damn near irreplaceable as individuals"*[5].

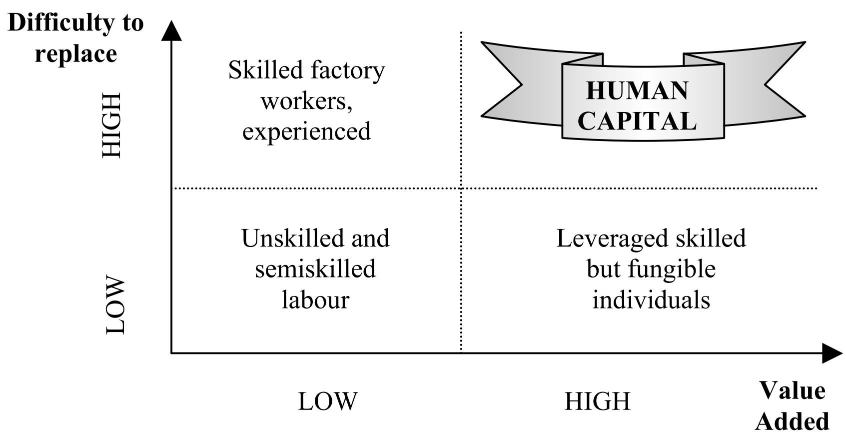

Fig. 1: Classification of the workforce. An elaboration from Stewart (1997)

People who are capable to add competitiveness to services and products form a company's human capital. Under these conditions, only "human capital" can be called *an asset*, the rest (other quadrants) is merely labour cost.

Skills and knowledge embodied in firm's communities of employees are the great engine of a creative mechanism of new knowledge[6] and can be referred to as wellsprings of innovation, as Stewart (1997) nicely argues: "*Money talks, but it does*

[4] Similar reflections can be found already in Hall (1993), when the value of intangible resources of know-how, culture or networks (which are people dependent) is underlined.
[5] Stewart (1997), p.90.
[6] The innovative role of communities of workers and especially of professionals has been deeply developed by Lave and Wenger (1991), Brown and Duguid (1991), Wenger (1999, 2000a, 2000b), who firstly (as far as I know) introduced the concept of "Community of Practice".

not think; machine performs, often better than any human being can, but do not invent."

Following these reflections, it seems pretty interesting to understand the role of human resources in the determination of firms performance: to what extent are they able to explain firms turnover?

According to the RBV approach, human resources can lead to competitive advantage, and this idea seems to be enhanced by the discourse around the relevance of human capital as driver for knowledge transfer. Grant (1996) introduces the knowledge based view of the firm (henceforth, the KBV) by positioning it right at the intersection between RBV and knowledge theories. Following his intuition it appears as fundamental to look at the individual contribution to the knowledge creation and application within the firm, as an extremely important determinant of its returns. Empirically few studies have been conducted to explore and eventually verify these statements. It comes to be useful to test the following hypothesis:

Hyp.1: Human resources and their specific characteristics influence positively firm's performance.

At the same time a lack of attention on the role of technology in the process of achieving competitive advantage leads to integrate the RBV and the emergent KBV with the analysis of its explanatory value added to the firm's performance. The RBV of the firm, in fact, doesn't take in account the effects of the industry structure on firm's performance. On the contrary, this view tends to focus on business units rather than industry specificities. Rumelt (1991) shows with his empirical analysis on US manufacturing that *"business units within industries differ from one another a great deal more than industries differ from one another"*[7]. But productivity and profitability are influenced not only by the capability to organize internal firm-specific resources, but also to the type of industry to which the firm belongs (as Porter, 1980 points out).

These observations drives to the formulation of the second hypothesis tested below:

Hyp.2: Adding information on industry technology intensity to the characteristics of firm's human resources allows to explain better firm's performance.

[7] Rumelt R.P. (1991): p.182

The process of testing these two hypotheses leads to the construction of an analytical framework that looks at the role of intangibles in the formulation of business strategy. Intangibles, or knowledge assets, are not a new phenomenon, but are crucial in the process of determination of firm's strategy (Baruch, 2001; Baruch and Feng, 2003; OECD, 1992). This is particularly true nowadays, with the enlargement of the competitive arenas and the introduction of new information and communication technologies (Rullani 1998, 2004; Arthur, 1996; Castells, 2000). One of the major nexuses of intangibles, as Baruch (2001) claims, is human resources. Among the few empirical studies on intangibles it is worthy to be mentioned the work of Hall (1992), who tried to rank importance and contribution of intangible resources to the overall success of the business in 1987 and 1990. A survey addressed to a sample of 95 company's chief executives throughout the UK (minimum 100 employees) revealed that company reputation, product reputation and employee know-how were the perceived most important contributors to company success. Lately the result was confirmed by six case studies (Hall, 1993). The negative aspect of looking at intangibles as determinants of competitive advantage is the difficult choice of how to measure them. Rare are, in fact, the possibilities to have detailed information on firm's human resources practices. In the following there is an attempt to measure the so called intangibles, or knowledge assets, by registered data on Danish workforce, thanks to the application of some statistical tools. Basically, following the operative definition of intangible assets given by OECD, this work aims to capture their impact on firm's performance, proposing some proxy for their measurement (Tab. 1).

Intangible assets (OECD, 1992)	Intangible assets (Present work)
Intangible investment in technology: ▫ R&D ▫ Design and engineering ▫ Acquisition of patents and licences ▫ Scan and search activities	Technology groups based on innovative intensity: ▫ High tech ▫ Medium-high tech ▫ Medium-low tech ▫ Low tech
Enabling intangible investment: ▫ Training ▫ Information structures ▫ Organizational structures	Learning drivers: ▫ Collective learning ▫ Non formal-informal learning ▫ Formal learning ▫ Internal division of labour

Tab. 1: The importance of intangible assets, an attempt to verify it empirically

Stemming from seminal works of Porter (1991), Collis (1991), Amit and Schoemaker (1993), which underline the relevance to establish linkages between the industry analysis framework and the resource based view of the firm, the following scheme (Tab. 2) is derived.

In Tab. 2 there is an attempt to propose a comparative/operative framework that, while pinpoints differences (nature, scope, measure) in the perception of intangibles in the two models of strategy presented, it tries to integrate them in practice.

The type of analysis here performed tends to overcome the temporal sequence that normally characterises the decision process in the two models. The RBV faces at first the issue of the individuation of the internal firm's strengths, and then the choice of the market position. Porter's model, instead, takes as point of departure the analysis of the industry structure (and the choice of the market), while the issue of the detection of the resources necessary to enter the market follows only afterwards. Foss and Knudsen (2000) nicely refer to the *"chicken-and-egg"* [8] issue when they talk (following Porter, 1991) about the nature of the problem of finding out a temporal priority of firms versus industry determinants of competitive advantage.

	MODELS OF STRATEGY	
INTANGIBLE ASSETS	**Emphasizing efficiency (RBV)**	**Emphasizing the exploitation of market power (Porter, 1980)**
Nature	Firm-specific assets	Industry-specific assets
Scope	Enabling intangible investment	Intangible investment in technology
Measure	Four learning factors	Technology groups
	- COMPETITIVE ADVANTAGE -	

Tab. 2: Intangible assets: nature, scope and measure. A comparative/operative framework that shows differences between RBV and industry-based analysis.

The framework proposed in Tab. 2 pushes to have a circular and not sequential view of the decision process, as it is shown in Fig. 2.

[8] Foss and Knudsen (2000): p.2

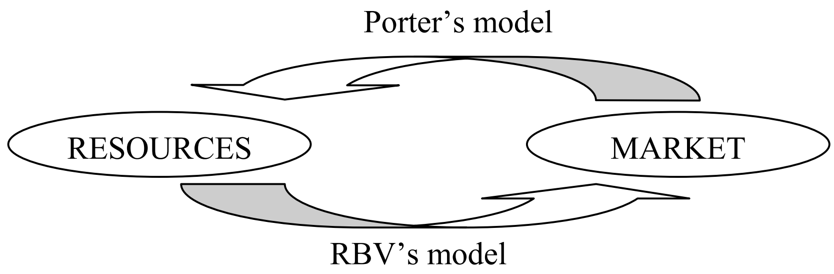

Fig. 2: The circularity of the decision process

In the following sections the hypotheses here formulated have been tested using data on Denmark workforce, results and conclusions will close the paper.

3. Data description

Secondary data are used for the study, coming from two Danish databases: IDA (Integrated Database for Labour Market Research) and F-IDA, both belonging to Statistics Denmark.

IDA database contains all-inclusive, longitudinal and integrated data on establishments and employees. It provides data on:

- dynamics of establishments (birth, death and growth);
- flows of workers (turnover, transition between labour market states);
- interactions between characteristics and flows of establishments and workers.

Since the database keeps track of the year of birth of establishments, and of the year in which a worker was hired, variables such as establishment age and worker tenure can be derived. The distinctive feature of the database is that it enables you to connect persons with companies. It is thus possible to characterize persons on the basis of information about the companies, in which they are employed and correspondingly you can describe companies on the basis of information about the employees. There are more than 200 variables in the database, including a vast number of background variables related to the population. Moreover, both persons and companies can be monitored over time.

The database contains information about the entire Danish population and all companies with employees and is updated annually starting at 1980, at present covering the period 1980-2000.

F-IDA database is linked to IDA and provide specific information about firms (such as type of ownership, total annual exports, total value added, and other structural indicators). Data in F-IDA cover the period 1995-1999.

IDA and F-IDA are two relational databases, and can be used complementary (through key-connecting-codes) for assembling information concerning firms with information concerning people.

Population and sampling procedure

The purpose of the work is to put in relation the main features of the Danish workforce (in IDA) with performance indicators of firms (in FIDA). The analysis is conducted using a sample from the whole Danish population. In the following a description of the population and of the sampling procedure can be found.

The idea undergoing this work is to produce, at first, the latest imagine available related to the condition of the Danish workforce. For this reason, I have taken in account for the study data related to the year 1999 both in IDA and in F-IDA dataset.

The sample is drawn from a multi-stage sampling (non probability one at the first stage and probability at the second stage) to fit at the best the research questions here addressed and for obtaining the representativity needed for generalize the results to the population.

In the first stage a non-probability sample from the 1995-year IDA data set as been selected. The selection criterion is driven by the purpose to keep tracks only of people that all have a known place of employment (that is: individuals with fictive place of employment are excluded from the cohort) AND are employers OR employees (with known place of employment) in 1991 AND in 1999. In brief, all the employees or employers in 1995 that are employees or employers also in 1991 and 1999 are included in the sample at the first stage. This choice is motivated by the prospective of doing further analyses comparing the work-status of employers or employees in different years, looking at workers mobility between firms and sectors as a proxy of knowledge transfer and learning at the boundaries (Sedita, 2003).

In the second stage, a 10% random sample of individuals is drawn from the sample selected in the first stage. Finally, only workers employed in manufacturing industry[9] entered in the following analysis.

4. Methodology and results

For detecting and evaluating the impact of skills and technology on firm's performance, two types of statistical analysis have been performed. Firstly, thanks to a factor analysis, human resources and firm's features have been summarized in four firm's learning drivers. Secondly, two regression models have been examined, to understand role and explanatory capability of skills and technology in the determination of firm's competitive advantage (superior returns).

Factor analysis addresses the problem of analysing the underlying structure of the interrelationship among a number of variables, by defining a set of common underlying dimensions, known as factors.

It plays than a unique role in the application of other multivariate techniques. In this case, the factor loadings derived from the factor analysis will be used as variate in a regression analysis on performance dependent variable.

Variable	Description
SIZE	Firm size (full time equivalents)
EDU	Employees average years of schooling
EXP	Employees average years of work experience
EAGE	Employees average age
TEN	Employees average seniority (job tenure)
HCRATIO	Human capital ratio (Human capital employees/# employees)
PLANTS	Number of plants
FAGE	Firm age

Tab. 3: Variables selection for factor analysis

The set of variables entered in the factor analysis are shown in Tab. 3.

Human capital ratio includes individual incomes in the analysis, it is defined, in fact, as human capital to employment. Assuming that human capital is the result of the interaction of two factors: difficulty to replace and value added, in the formulation given by Stewart (1997) and discuss above, we can infer that, as well as any scarce

[9] Danish companies are classified by NACE codes (Version 4 Rev.1 1993); manufacturing industry includes firms with NACE codes from 151110 to 372000.

resource, firms tend to pay more for it. Nevertheless, some distinctions have to be done, because it is not to be taken for granted that competencies (in terms of work experience and formal education) that can be relevant for an activity are relevant also for another one.

That is why we have to take in account that different status in employment[10] (Tab. 4) drives to different interpretation about what can be considered human capital, because different are the competencies required.

Status in employment
employer
top managers
employees, higher level
employees, medium level
employees, basic level
other employees

Tab. 4: Status in employment, Denmark Statistics classification

Concerning the individuation of what kind of workers can be considered human capital I empirically proceeded as follow:

a. Preliminary assumption: best-paid workers form human capital, being the most valuable part of the workforce, and the group of people that firms consider not easy to substitute. After all, you usually pay more for a scarce resource. This consideration takes in account both the definition of human capital given by Stewart (1997) and the well known remarks on the topic from Drucker (1973).

b. Thus individuation of the human capital for each status in employment as people with an annual gross income up to the average.

There are different criteria for the number of factors to extract. I applied the three most common used ones, which are:

- Eigenvalues greater than 1: only the factors having latent roots or eigenvalues greater than 1 are considered significant.

[10] Status in employment refers to the relationship of a person doing a job to the means of production, and, for an employee, to his or her position in the hierarchical structure of the workplace.

- Percentage of variance criterion: approach based on achieving a specified cumulative percentage of total variance extracted by successive factors. [Threshold: 60% of the total variance, commonly used in social sciences (Hair et al., 1998)].
- Scree test criterion: identification of the optimum number of factors that can be extracted before the amount of unique variance begins to dominate the common variance structure. The cut-off point is given by the shape of the curve.

Variable	N	Mean	Std. Dev.	Minimum	Maximum
SIZE	4547	51.70	148.09	0	4083
EDU	4547	12.13	2.42	0	20
EXP	4547	14.24	4.25	0	20
EAGE	4547	41.88	9.19	14	88
TEN	4547	6.02	5.02	0	19
HCRATIO	4547	0.59	0.41	0	1
PLANTS	4547	1.74	1.84	1	9
FAGE	4547	13.47	6.34	0	19

Tab. 5: Simple statistics

Considering that, as with other aspects of multivariate models, parsimony is important, four factors qualify (the most representative - 69% of the total variance - and parsimonious set of factors).

The unrotated factor solution doesn't provide a meaningful pattern of variable loading. Therefore a rotational method will be applied, to improve the interpretation by reducing some of the ambiguities that accompany the initial unrotated factor solution. An orthogonal rotation method is preferred because it keeps the factors uncorrelated. The uncorrelation of factors turns to be useful in the following regression analysis, where these factors are used as independent variables (collinearity problems are avoided; see the VIF and Tolerance values in Tab. 11,

Tab. 12, Tab. 13, Tab. 14). Among the orthogonal methods, the VARIMAX criterion is chosen, which seems to give clearer separation of the factors.

After having identified the highest loading for each variable (Tab. 6), we are ready for the interpretation, and so to label the factors, giving a meaning to the pattern of factor loading (Tab. 7).

Variable	Factor			
	Factor 1	Factor 2	Factor 3	Factor 4
SIZE	0.21435	-0.12594	0.04858	**0.78195**
EDU	-0.00267	-0.23093	**0.78334**	-0.13975
EXP	0.04858	**0.79010**	0.20595	0.09402
EAGE	0.19842	**0.77792**	-0.20664	-0.06889
TEN	**0.79520**	0.33555	-0.01692	-0.07212
HCRATIO	-0.04113	0.27662	**0.73824**	0.15154
PLANTS	-0.24414	0.16345	-0.04608	**0.72413**
FAGE	**0.87293**	-0.01535	-0.02818	0.04513

Tab. 6: Rotated factor loadings (Rotation: VARIMAX)

Factor	**Label**
Factor 1 = F1	Collective learning
Factor 2 = F2	Informal – Non formal learning
Factor 3 = F3	Formal learning
Factor 4 = F4	Firm size

Tab. 7: Final learning drivers detected

The first factor derives from the observation that the story of the firm and the worker's tenure are good indicators of the potentialities of firms to operate as knowledge integrators between organizational and individual knowledge.

The identification of the learning factors F2 and F3 is driven by the 2001 Communication from the Commission of the European Communities[11], where, while describing different types of learning, three main categories are defined as follow:

- Formal learning: *"Learning typically provided by an education or training institution, structured (in terms of learning objectives, learning time or learning support) and leading to certification. Formal learning is intentional from the learner's perspective."*
- Non-formal learning: *"Learning that is not provided by an education or training institution and typically does not lead to certification. It is, however, structured (in terms of learning objectives...). Non formal learning is intentional from the learner's perspective."*

[11] "Making a European Area of Lifelong Learning a Reality", Communication from the Commission of the European Communities, Brussels, 21.11.01

- Informal learning: *"Learning resulting from daily life activities related to work, family or leisure. It is not structured (in terms of learning objectives, learning time or learning support) and typically does not lead certification. Informal learning may be intentional but in most cases it is non-intentional (or "incidental"/random)."*

The fourth factor is identified after having considered that the size of firm is due both to the number of full time equivalents and to the number of plants. Besides, for larger firms this factor can be seen as a proxy of degree of internal division of labour.

Regression analysis is applied to explain the contribution of the set of four factors extracted in the previous factor analysis (rotation=VARIMAX) to the determination of firms performance. In other words, given the level of collective learning, formal, non formal-informal learning, internal division of labour, I want to explore its relationship with firm performance, measured in terms of both labour productivity and profitability. Furthermore, I want to assess the explanatory contribution of the firm technology level into the determination of the performance.
A description of the variables entered in the models will follow.

Dependent variables:

- Labour productivity is measured as the ratio of value added to employment.

  LP=VA/SIZE

  Where:

  LP=labour productivity;
  VA= value added (Euro);
  SIZE=number of annual full time equivalents.

- Profitability is calculated as the ratio of gross profits to sales[12].

  PRO=GP/S=(VA-W)/S

  Where:

  PRO=profitability;
  GP=gross profits (Euro);
  S=total annual sales (Euro);
  VA=total annual value added (Euro);

[12] Firms with negative value of profitability have been excluded by the analysis.

W=total wages paid by firm (Euro);

Independent variables:

Variable	Description
F1	Collective learning*
F2	Non formal – informal learning*
F3	Formal learning*
F4	Firm size *
MHTE	Medium-high technology**
MLTE	Medium-low technology**
LTE	Low technology**

Tab. 8: Independent variables description
Note: * denotes factors from principal component analysis; ** denote classification of manufacturing industries based on technology (OECD, 2001), see appendix for details.

Incorporating nonmetric data (such as the technology groups) in the regression arises the need to introduce dummy variables which represent the categories of the nonmetric variable. The nonmetric variable has K=4 categories, which can be represented by K-1=3 dummies. I chose "High technology" as reference category (or baseline).

Technology groups	Dummies		
	LTE	MLTE	MHTE
Low tech	1	0	0
Medium-low tech	0	1	0
Medium-high tech	0	0	1
High tech	0	0	0

Tab. 9: Dummy variable coding patterns for the four-category nonmetric variable "technology groups".

Variable	N	Mean	Std. Dev.	Minimum	Maximum
F1	3992	0.03	0.98	-2.79	5.92
F2	3992	0	1	-4.31	2.87
F3	3992	0	0.99	-5.36	2.05
F4	3992	0.01	1.01	-1.09	20.58
LTE	3992	0.14	0.34	0	1
MLTE	3992	0.45	0.50	0	1
MHTE	3992	0.33	0.47	0	1
LP	3992	280080	1334592	4172	31281131
PRO	3992	0.21	0.11	0	0.74

Tab. 10: Simple statistics

As it is presented above, two dependent variables entered in the regression models in turns. The first dependent variable to be used is the labour productivity (LP). Because of linearity issues, LP has been transformed in its logarithm and one of the independent variables (F4) in its square root.

Transformation of the dependent: LLP= [ln (LP)]

Transformation of an independent (F4): $rF4=\begin{cases} \sqrt{F4} & \text{if } F4\geq 0 \\ -\sqrt{abs(F4)} & \text{if } F4<0 \end{cases}$

The following model (1) includes as independent variables the four learning factors previously identified, it has been estimated with a OLS analysis, the parameters estimated are presented in Tab. 11.

Model: $LLP=a+b_1F_1+b_2F_2+ b_3F_3+ b_4rF_4+\varepsilon_1$ (1)

Variable	Estimate	t-value	Std. Est.	VIF	Tolerance
INTERCEPT	11.458***	928.87	0	0	.
F1	-0.269***	-22.09	-0.252	1.00	0.99533
F2	0.155***	12.95	0.147	1.00	0.99627
F3	0.034***	2.82	0.032	1.00	0.99943
RF4	0.874***	53.14	0.607	1.01	0.99141
N	3992				
F	937.49***				
R^2	0.48				
Adj R^2	0.48				

Tab. 11: Regression results explaining firm performance in manufacturing by means of the four learning factors. Parameter Estimates, model (1)

Note: ***/** denote 1 and 5 percent levels of significance (one-tailed test)

VIF (Variance Inflation Factor) in excess of 20, or a Tolerance (1/VIF) of 0.05 or less may be worthy of further investigation for multicollinearity.

Learning drivers are all statistical significant, they are able to explain the 48% of the variability of the dependent variable. Collective learning seems to affect negatively firm's performance. This behaviour can be justified by the "side effect" of an isolation mechanism. When workers are hired for a long time from the same organization and the firm is old, they both are affected by path-dependency, which leads to inflexibility and scarce propensity towards changes.

Non formal, informal types of learning are more valuable than formal ones in the building advantage process, revealing the power of the tacit component of knowledge and the role of social complexity.

The last observation concerns the fourth factor: there is a clear size-effect in the distribution of productivity; basically larger dimensions drive to higher performances.

The following model (2) includes as independent variables the four learning factors previously identified, plus the R&D intensity (expressed by the status of belonging or not to one of the technology groups described in Tab. 8). It has been estimated with a OLS analysis, the parameters estimated are presented in Tab. 12.

Full model: $LLP = a + b_1F_1 + b_2F_2 + b_3F_3 + b_4rF_4 + b_5 MHTE + b_6 MLTE + b_7LTE + \varepsilon_2$ (2)

Variable	Estimate	t-value	Std. Est.	VIF	Tolerance
INTERCEPT	11.577***	284.84	0	0	.
F1	-0.268***	-22.02	-0.25	1.01	0.99452
F2	0.154***	12.89	0.146	1.01	0.99500
F3	0.027**	2.23	0.026	1.04	0.96249
rF4	0.867***	52.38	0.601	1.02	0.97614
MHTE	-0.133***	-2.89	-0.059	3.26	0.30694
MLTE	-0.101**	-2.27	-0.048	3.46	0.28925
LTE	-0.232***	-4.42	-0.076	2.31	0.43358
N	3992				
F	541.36***				
R^2	0.49				
Adj R^2	0.49				

Tab. 12: Parameter Estimates, model (2)
Note: ***/** denote 1 and 5 percent levels of significance (one-tailed test)
VIF (Variance Inflation Factor) in excess of 20, or a Tolerance (1/VIF) of 0.05 or less may be worthy of further investigation for multicollinearity.

The predicting power of the model is improved by the information about R&D intensity (R-square 0.4866). Firms that operate in high technology industries have the highest performance, but, for example, medium-high tech and medium-low tech have the same performance level (according to a F-test on the parameters). The introduction of innovative intensity improves the estimation, but performance is not increasing monotonically at the pace with the R&D investment.

The second dependent variable to be used is the profitability (PRO). Because of linearity issues, PRO has been transformed in its logarithm, as well as one of the independent variables (F4).

Transformation of the dependent: LPRO=ln (PRO+1)[13]

Transformation of an independent (F4): ln (F4+1) if F4>0; ln(abs(F4+1)) if F4<0

The following model (3) includes as independent variables the four learning factors previously identified, it has been estimated with a OLS analysis, the parameters estimated are presented in Tab. 13.

Model: $LPRO= a+b_1F_1+b_2F_2+ b_3F_3+ b_4lF_4+\varepsilon_3$ (3)

Variable	Estimate	t-value	Std. Est.	VIF	Tolerance
INTERCEPT	0.178***	78.09	0	0	.
F1	-0.008***	-5.29	-0.083	1.00	0.99905
F2	-0.004***	-2.88	-0.045	1.00	0.99712
F3	-0.004***	-2.65	-0.042	1.00	0.99890
lF4	0.018***	3.92	0.062	1.00	0.99543
N	3992				
F	14.94***				
R^2	0.01				
Adj R^2	0.01				

Tab. 13: Parameter Estimates, model (3)
Note: *** denote 1 percent level of significance (one-tailed test)
VIF (Variance Inflation Factor) in excess of 20, or a Tolerance (1/VIF) of 0.05 or less may be worthy of further investigation for multicollinearity.

Learning drivers are still all significant, but the direction of their effect on firm's performance is generally opposite to the model previous predicted (1). This is understandable because investment in human resources and on learning capacity is a cost for the firm. Hiring highly qualified employees, both in terms of experience and formal training, while enhancing productivity, tends to affect negatively profitability, especially in the short run. Returns on investments in human capital, in fact, can be detected only in the long run, and, as well as other intangibles, are definable as "non-physical sources of value (claims to future benefits)"[14]. Predicting power is less intense than in the other models where LP was the dependent (R-square: 0.0148), profitability is more influenced by external environment. Anyway the model still makes sense because of the analysed sample is very large.

[13] +1 is added because the variable PRO assumes values close to zero, where the logarithm is not defined.
[14] Baruch (2001) : p. 7.

The following model (4) includes as independent variables the four learning factors previously identified, plus the R&D intensity (expressed by the status of belonging or not to one of the technology groups described in Tab. 8). It has been estimated with a OLS analysis, the parameters estimated are presented in Tab. 14.

Full model: $LPRO=a+b_1F_1+b_2F_2+b_3F_3+b_4\,lF_4+b_5\,MHTE+b_6\,MLTE+b_7LTE+\varepsilon_4$ (4)

Variable	Estimate	t-value	Std. Est.	VIF	Tolerance
INTERCEPT	0.204***	39.41	0	0	.
F1	-0.007***	-5.11	-0.080	1.00	0.99784
F2	-0.004***	-3.19	-0.050	1.00	0.99582
F3	-0.004***	-2.79	-0.044	1.04	0.96216
lF4	0.015***	3.29	0.051	1.01	0.98937
MHTE	-0.035***	-6.58	-0.184	3.23	0.30994
MLTE	-0.017***	-3.21	-0.092	3.43	0.29169
LTE	-0.038***	-6.25	-0.147	2.29	0.43710
N	3992				
F	19.08***				
R^2	0.03				
Adj R^2	0.03				

Tab. 14: Parameter Estimates, model (4)
Note: *** denote 1 percent level of significance (one-tailed test)
VIF (Variance Inflation Factor) in excess of 20, or a Tolerance (1/VIF) of 0.05 or less may be worthy of further investigation for multicollinearity.

Also in this case the inclusion of technology intensity produces an improvement in the predicting value of the model (R-square: 0.0307).

Assumptions for regression analysis are been checked with the analysis of the residuals for each model shown above. No violations occurred.

For evaluating the generalization of the models here presented, a split-sample validation has been conducted. Data have been randomly splitted into two sub-sets, each of them including 50% of the observations. Models have been estimated on one of them, and the estimated parameters have been used to calculate the values of the dependent variable in the other one. A measure of distance between the real and estimated value is applied. The model with LP (labour productivity) as dependent variable ends up to be robust. Results related to models (1) and (2) are generalizable to other samples.

5. Conclusion and further research

In a world dominated by high degree of uncertainty, given by the growing global competition an by the need of changing the actual organisation system in order to front the new challenges of an enlarged market, the process of creation and transfer of knowledge has a strategic role.

The key factor of the new knowledge-based paradigm is the power of generating knowledge by knowledge. Inputs of productive process are technology and knowledge, and outputs are technology and knowledge as well, deriving by learning capacity of the agents of the value chain. The virtuous cycle created by the interplaying action of these inputs/outputs allows swelling firms (as well as regions, clusters, networks) production. Knowledge and technology, in fact, are both the fruit of their daily processing, building a cumulative feedback loop between innovation and the use of innovations, manufacturing and services, tacit (not codified or/and not-transferable) and explicit (codified or/and transferable) knowledge (look at the SECI[15] process in Nonaka and Takeuchi, 1995).

This work is an attempt to give some empirical evidence, and some methodological tools, to face the issue of learning in organizations, as a process of combining internal resources for achieving a superior competitive advantage.

The four learning drivers individuated by the factor analysis (collective, non formal-informal and formal learning, firm's size), can be used as valid indicator for predicting firm's performance (especially when it is measured in terms of labour productivity) in the manufacturing industry. The first hypothesis formulated in section 2 is verified. As it is claimed in the RBV, human resources are a crucial factor in the determination of firm's performance. Furthermore, when the R&D intensity is included as predictor for performance, the predicting power of the model slightly increases and this leads to accept the assumption made in the second hypothesis. Industry-analysis framework has to be taken in account, because the structure of the industry, in the specific the innovative intensity, influences the performance variables.

The RBV of the firm seems to be a good approach to untangle the complex issue of firms competitiveness. The analysis produced in this work partially covers the lack of empirical validation of the RBV core propositions. In the specific, looking at human

[15] SECI = Socialisation, Externalisation, Combination, Internalisation.

resources as one of the most important drivers for knowledge creation, application and diffusion, we are able to build a model that clearly shows their explanatory capability in the study of the sources of firm's competitive advantage.

Nevertheless the technology factor, measured as industry investments in R&D, that is not really analysed in the works of authors that refer to this school, is instead important and it has to be included in the formulation of firm's strategy.

Finally, the importance of intangible investments as key determinants of competitiveness, growth and productivity is clearly shown. The typical classification of intangible investments, in fact, fits the elements studied in this work, according to the synthetic definition given by OECD (1992), as it emerges from Tab. 1.

Findings provided in the present analysis partially support the RBV approach to the firm; productivity is positively affected by investments in learning strategy in general and in human resources in particular. Struggling results derive from the analysis of the impact of learning factors on profitability. Their negative effect can be explained by the lack of a time-horizon that allows the returns on investments to emerge. Further researches should be conducted on the long run effects of learning investments on profitability, which will say something more about the capability of the firm to translate those costs in benefits.

At the same time, and both in the analysis of productivity and profitability, industry-effects emerge, especially when considering industry-specific intangible assets as investments in technology.

An integrated vision of a strategy that integrates RBV and industry-based analysis is suggested. Furthermore, future analysis on the incidence of the four learning factors on performance variable for each technology group will be highly informative to establish differences on role and effect of different types of learning.

Finally, a technique that allows to estimate simultaneously the effect of learning factors on productivity and profitability would give deeper insights, given that productivity and profitability can be mutually dependent.

APPENDIX: About the classification of industries based on technology

Being interested to the analysis of the manufacturing industry, I adopt the NACE classification (Rev.1) for individuating activities belonging to this industry. For having a detailed picture of the industry, without loosing significance, I like to adopt a further classification, which allows to create manufacturing sub-groups.

Doing that I'm particularly concerned about the target of the analysis. Constrained by the absence of statistics on the Danish amount of investments in R&D for each firm, we catch this information by adopting the classification of manufacturing industries based on technology (OECD, 2001). This classification (as it is shown in the table below) proposes to distinguish four technology groups:

- High technology industries;
- Medium-high-technology industries;
- Medium-low-technology industries;
- Low-technology industries.

The cut off point are cut according to two indicators of technology intensity:

- R&D expenditure divided by value added;
- R&D expenditure divided by production.

The division of manufacturing industries into technology groups is determined after ranking industries according to their average over 1991 to 1997 of aggregate OECD R&D intensities.

Other classifications are actually available (among the others: Pavitt, 1984; Evangelista, 1999), but they present some limitation to an extended application into different countries an into different periods, because of their nation and time specificity (respectively: UK, 1945-1979; Italy, 1992). The OECD classification has the advantage, although is less detailed, to be valid in all the OECD countries, and to be constantly up to dated. A new classification (same classes, more detailed "knowledge intensity" indicators), in fact, is expected in the next future.

Technology groups	NACE Rev.1	Total[2]	USA	CND	J	EU[2]	D	F	I	UK	E	S	DK	N	FIN	IRL[3]
		R&D intensity[1] for 13 OECD countries, 1991-97 average														
High-technology industries																
Aircraft and spacecraft	353	14,2	14,6	10,1	9,9	14,6	28,1	14,1	11,9	9,3	16,0	15,3	.. (4)	0,9	0,9	.. (4)
Pharmaceuticals	244	10,8	12,4	7,4	9,6	10,0	8,4	8,7	6,0	18,6	3,1	21,5	14,8	11,8	14,0	5,2
Office, accounting and computing machinery	300	9,3	14,7	6,8	7,5	4,3	7,5	5,6	7,2	2,0	2,6	12,0	5,4	7,8	3,1	0,6
Radio, television and communication equipment	32	8,0	8,6	12,7	6,0	10,2	13,0	10,3	11,7	5,2	6,3	17,8	7,7	25,7	11,4	8,6
Medical, precision and optical instruments	33	7,3	7,9	.. (5)	8,1	5,9	6,1	11,1	1,0	3,5	2,1	8,2	6,1	3,1	7,0	2,0
Medium-high-technology industries																
Electrical machinery and apparatus, n.e.c.	31	3,9	4,1	0,9	6,8	2,4	2,4	2,6	1,0	4,8	0,9	2,6	1,5	2,0	4,5	1,7
Motor vehicles, trailers and semi-trailers	34	3,5	4,5	0,2	3,1	3,6	4,6	3,2	3,3	2,9	0,8	6,1	.. (6)	1,8	1,8	1,2
Chemicals excluding pharmaceuticals	24 excl. 244	3,1	3,1	0,8	4,7	2,5	4,4	2,4	0,8	2,5	0,6	2,2	1,7	2,2	2,8	0,4
Railroad equipment and transport equipment, n.e.c.	352+354+355	2,4	.. (7)	0,2	2,6	2,6	5,5	2,6	1,2	1,5	1,2	2,5	0,3	0,8	9,4	0,0
Machinery and equipment, n.e.c.	29	1,9	1,8	1,2	2,2	1,8	2,3	2,0	0,5	2,1	1,0	4,0	3,2	2,6	2,4	1,1
Medium-low-technology industries																
Coke, refined petroleum products and nuclear fuel	23	1,0	1,3	0,6	0,7	0,9	0,3	0,9	0,3	2,9	0,4	0,4	.. (4)	0,8	0,8	.. (4)
Rubber and plastic products	25	0,9	1,0	0,4	.. (8)	0,8	0,9	1,6	0,5	0,4	0,5	1,5	0,8	0,7	1,7	0,8
Other non-metallic mineral products	26	0,9	0,8	0,2	2,2	0,5	0,7	0,8	0,1	0,5	0,2	0,9	0,4	0,5	1,4	0,9
Building and repairing of ships and boats	351	0,9	.. (7)	0,0	0,8	0,9	1,4	0,4	1,2	0,7	1,5	2,0	0,8	0,5	0,7	1,2
Basic metals	27	0,8	0,4	0,6	1,3	0,6	0,6	1,1	0,3	0,4	0,2	0,8	0,6	1,5	0,7	0,4
Fabricated metal products, except machinery and equipment	28	0,6	0,7	0,4	0,8	0,4	0,5	0,5	0,2	0,4	0,2	0,8	0,2	0,5	1,1	0,9
Low-technology industries																
Manufacturing, n.e.c. and recycling	36-37	0,4	0,6	.. (5)	0,4	0,3	0,5	0,4	0,1	0,2	0,2	0,3	2,3	0,4	0,7	0,4
Wood, pulp, paper, paper products, printing and publishing	20-22	0,3	0,5	0,2	0,4	0,2	0,1	0,1	0,0	0,1	0,1	0,7	0,1	0,3	0,5	0,2
Food products, beverages and tobacco	15-16	0,3	0,3	0,2	0,7	0,2	0,2	0,3	0,1	0,4	0,1	0,4	0,4	0,3	0,6	0,4
Textiles, textile products, leather and footwear	17-19	0,3	0,2	0,4	0,7	0,2	0,5	0,3	0,0	0,2	0,1	0,5	0,1	0,6	0,6	1,0
Total manufacturing	15-37	2,5	3,1	1,2	2,8	1,9	2,5	2,4	0,8	2,1	0,6	3,7	1,6	1,4	1,9	1,0

Classification of manufacturing industries based on technology

Source: **Adaptation from: OECD, ANBERD and STAN databases, May 2001.**

Note:

1. R&D intensity defined as direct R&D expenditures as a percentage of production (gross output).
2. Aggregate R&D intensities calculated after converting countries' R&D expenditures and production using 1995 GDP PPPs.
3. Production from industrial surveys.
4. NACE 23 and 353 not available for Denmark and Ireland.
5. NACE 36-37 production includes NACE 33 for Canada.
6. NACE 34 included in NACE 35 for Denmark.
7. R&D expenditures in "Shipbuilding" (351) is included in "Other Transport" (352+354+355) for the United States.
8. NACE 25 production does not include plastics for Japan.

Concerning Designations and abbreviations for the countries used:

USA	United States
CND	Canada
J	Japan
EU	Europe
D	Germany
F	France
I	Italy
UK	United Kingdom
E	Spain
S	Sweden
DK	Denmark
N	Norway
FIN	Finland
IRL	Ireland

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