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COMPETENCIES GROWTH IN MANUFACTURING FIRMS ENGAGED IN PRODUCT DEVELOPMENT– AN EMPIRICAL STUDY

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1 Introduction

If one tried to compare the design offices or the shop-floors in a manufacturing company from today with the same company some twenty years ago, it is fairly obvious that many things would appear radically different. Machinery has changed, with flexible and computer-based automation replacing manual machines or older forms of inflexible automation. New processes and materials have been introduced in products. Drawing boards and 2D CAD systems have been replaced with modern 3D modelling systems. Computers have become ubiquitous, and are nowadays integrated in complex IT (Information Technology) systems such as ERP (Enterprise Resource Planning) or PLM (Product Lifecycle Management), which nowadays incorporate most of the decision-making activities and information flows within the company. Inventories, once viewed as assets and now considered as costs, tend to shrink and the flow of goods now mostly occurs following just-in-time principles, with tight synchronization between process stages. Similarly, heaps of scrap parts are no longer to be seen, thanks to the diffusion of quality management and Design For Manufacturing practices. With all these visible differences, it is easy to overlook the most radical change, which has occurred in the generally invisible body of knowledge and competencies that are needed to operate the company and its physical assets.

While IT systems and computer-based equipment are generally viewed as the main determinants of change in modern manufacturing companies, literature has amply shown [1] that productivity growth induced by the adoption of new technology mainly occurs because of complementary organizational learning processes. Such learning includes both gaining the knowledge required to simply use the new tools and, even more important, in adapting organizational routines and management practices in order to fully exploit their productivity-enhancing potential. Organizational learning is not only relevant to the field of commercially-available technology, but can be viewed as a necessary condition for the effective transfer of results from design research into practice, be they related to new paper-based methods, computer-based systems, algorithms for supporting management decision-making, or else.

The way with which manufacturing companies manage their knowledge has been generally investigated as an instance of a more general problem of organizational learning [2], or with a specific focus on organizational change and training activities required in order to profitably adopt widespread best practice methods and advanced technology [3-6]. This paper adopts a different perspective, which consists in understanding the way with which manufacturing firms *practically* and *routinely* perceive the needs for competencies growth and manage the organizational learning process. In other words, the adoption of a technology, method or

management practice is not taken as a discrete and observable event impinging on the organization and requiring organizational innovation and change. Coherently with the concept of dynamic capabilities [7], adoption and change are taken as a stream of events that co-evolve with the firm. In this way the researchers' attention can focus on the higher-order practices and routines that companies enact in order to deal with a changing internal and external environment. Specifically, the research had the objective of providing a preliminary understanding of the role played by the three following determinants in shaping dynamic capabilities:

- **D1** – Company size. Large companies have a greater amount of organizational and financial resources that may be dedicated to understanding changes in the environment, to study potential innovations, and to make plans in order to adopt them. Such companies are therefore likely to have richer dynamic capabilities than smaller companies do. On the other side, it is likely for small companies to have a greater degree of flexibility and therefore be able to respond to change more quickly than the larger ones.
- **D2** – The relationship between ownership and management. It is likely that companies run by owners and not by professional managers will exhibit less dynamic capabilities both because of risk aversion and because the owner-manager may become a "bottleneck" in the process of competencies management. It is however possible for the opposite relationship to be true, due to the more direct control exerted by owner-managers on the organizations they run.
- **D3** – The importance of innovation. It is fairly easy to hypothesize that the more a company perceives innovation as a key competitive factor, the more it will be prone to internal change and will have created routines for dealing with it.

It should be remarked that this listing of potential determinants has not led to the setting and testing of formal hypothesis. This is due to the exploratory nature of the research and its mainly descriptive purpose. Moreover, the three determinants may influence dynamic capabilities in opposite ways and are very likely to be correlated among themselves, with large companies being managed by professionals and more innovation-oriented. This makes it difficult to come up with statistically sound results separating the contributions given by each. This more rigorous approach will eventually be pursued in a continuation of the research project.

The paper draws from the empirical research activities carried out during 2004 within the VINCO project, which has been part of the EU-funded EQUAL program [8-9]. The project had the purpose of understanding the dynamics of competencies management in the case of indirect workers operating in the metalworking industry. The population of firms being studied is located in the province of Turin, in Northwestern Italy, where the concentration of such firms is very high and is based on a long tradition in the field, serving the automotive, machine tools and aerospace industries. The category of indirect workers includes managers in general, together with employees engaged in new product development, production (with the exclusion of machine operators, but including process planners, quality assurance, production planning, maintenance, etc.), sales and marketing, and finance. In this kind of industry, the majority of such workers nonetheless belongs to the technically-oriented functions of product development and production. Besides, this choice also allows to draw interesting comparisons with the non-technical workforce. The choice to focus on indirect workers is due to the fact that – due to their skills and roles – this group of employees is likely to incorporate most of their organizations' competencies and are therefore particularly affected by firms' dynamic capabilities. The choice of focusing on indirect workers was also welcomed by the funding

body because of its practical relevance. Indirect workers have in fact been somewhat neglected in the past, since most research and government funding for training has traditionally been directed to direct workers.

The above mentioned research activities have been carried out in three steps. The first phase dealt with defining industry boundaries and structure, and in studying its performance through statistical analysis on financial statements over a five-year time period. In the second phase, field research was performed through twelve matched-pairs case studies, conducted through multiple in-depth interviews to top-level and middle managers in each company. Finally, the third phase consisted in survey research and statistical analysis on a dataset developed through the replies to a survey by a representative sample of about 100 firms. The main findings of the latter two steps of the research project are summarized in the following sections and cover the organizational choices in setting up the indirect workforce, the approaches used to manage its competencies and, finally, the kind of training provided when adopting best practice methods and IT-based tools for supporting product development and manufacturing.

2 The indirect workforce

Table 1 shows the main figures describing the indirect workforce in the companies surveyed. From a descriptive point of view one can notice the relatively young age in the population and a strong gender-related distortion (females are nearly non-existent in product development and production, but make up most of the workforce in finance). Moreover, it is important to focus on the average level of education attained by the workforce. The datum is important from both a static point of view, since it provides an indicator of the skills operating within the company, as well as from a dynamic point of view, since it is an indicator of the absorptive capacity of the company [10] with respect to new knowledge. Absorptive capacity is becoming increasingly important not only because of rapid technological change, but also because reform in welfare systems is currently leading towards increasingly high ages of retirement. This implies that exploiting age-related turnover will not be enough to effectively manage the renewal of corporate competencies, as was the norm in the past. Firms will have to continuously train their workforce until a later age, but in order to do so, they will need employees capable of sustaining such continuous learning. The sample exhibits a very low figure for educational level, especially in the more technical functions of product development and production. The datum is to be lower than the average of the employed population in the same region (which is 11.5 % and 31 % with secondary and tertiary education respectively).

Table 1. Composition of indirect workforce in sample

	Production		**Prod. Dev.**		**Sales**		**Finance**		**Total**	
	Ave	**Median**	**Ave**	**Median**	**Ave**	**Median**	**Ave**	**Median**	**Ave**	**Median**
N. of employees	43	10	48	5	15	3	11	4	119	25
% of employees with higher education degree	4	0	16	1	19	8	6	0	9.16	6.67
% of employees with secondary education degree	39	38	69	75	66	75	72	78	55.05	54.29
% of women employees	15	6	5	0	37	33	73	75	24.76	21.58
Average age	38	39	37	37	39	38	39	39	38.31	37.56
Average tenure	12	10	11	10	10	10	13	12	12.10	11.49

This finding is quite worrying since it is related to the group of employees which – at least in theory – should be more highly qualified and are at the core of the firms' competitiveness. The evidence shows the failure of the manufacturing industry to appeal to highly educated individuals or, differently put, the unwillingness of firms in the industry to dedicate the financial resources required to pay the expectedly higher wages required by such people. The result can of course be generalized only for the region being surveyed, but it should be mentioned that similar reasons for concern have been voiced in other areas of the world as well [11].

It may also be interesting to study the correlation of the workforce's education level with the three determinants listed in the introduction to the paper, and the main findings are shown in Table 2. The fact that company size does not appear to be correlated with education level hints that the choice of recruiting university graduates depends on cultural – rather than financial – reasons.

Table 2. Degrees of association of workforce education with determinants

Association with	**% of workforce with higher education degree**
Company size (log of total employees)	Pearson correlation = 0.146 (not significant)
Professional management (boolean variable)	Mann-Whitney significant with $p < 0.03$ Kolmogorov-Smirnov significant with $p < 0.087$
Innovation as key competitive factor (booelan variable)	Mann-Whitney significant with $p < 0.01$ Kolmogorov-Smirnov significant with $p < 0.029$

As a support to this finding, one common remark made in owner-managed firms during the case study interviews was that "jobs can be learned" and "degrees don't matter much". This is probably due to an implicit assumption that the owner of the firm is the originator of all jobs and competencies operating in the company, and employees are in some way "delegated" and "empowered" by him/her to perform what is required of them. As an extreme but probably effective example, one of the interviewed owners stated "when I set up the company I was my own secretary. Be sure I know how to teach a girl to be an efficient secretary". This stance has been found to be even more common when dealing with product development activities, since most owner-founders interviewed actually started their company as designers at the drawing board, and still operate as heads of the design office, personally making most of the technical decisions. By contrast, firms run by professional managers seemed to have a clearer view of each individual's contribution within the organization and are thus able to attach greater value to degrees.

3 Approaches used to managing competencies

In traditional organizations, competencies management used to be a fairly easy task. Learning was mostly experiential (i.e., "learning by doing"), while there was a limited but probably adequate absorption of external knowledge through the younger employees that entered the workforce because of turnover. A sort of osmosis would occur, with young employees bringing elements of generic formal knowledge acquired through technical education, while the older employees would contribute with the company-specific knowledge on products and processes developed through experience (figure 1).

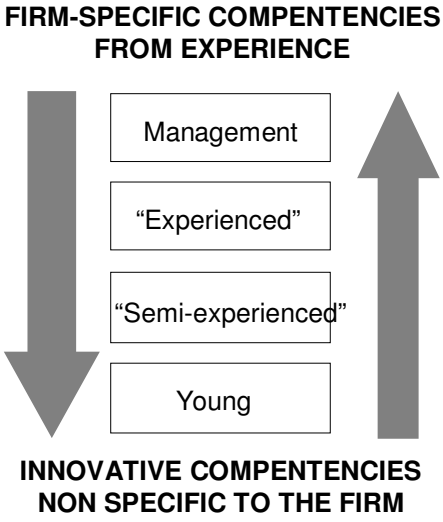

Figure 1. The traditional approach to competencies management

During field research it became quite apparent that this traditional mechanism was not operating properly any longer, and that firms required new approaches to deal with change. The companies interviewed were unanimous that the problem was due to discontinuities, and especially the introduction of computer-based tools for product development (especially 3D CAD and systems for managing technical information such as EDM/PDM/PLM) and non-traditional manufacturing technology. Elder workers have not been culturally capable or willing to effectively absorb the knowledge being brought in the firms by young employees and that would have enabled them to use the new methods and tools. Even worse, the prospect of job insecurity and the fear that the young hires could easily become more productive than they were once they gained some of the firm-specific know-how, led the elders to entrench themselves and to avoid "teaching the job" to the younger individuals. The perceived reasons behind such behaviour are reported in Table 3, which shows that only 18 % of firms declared the problem not to be significant, while the absence of incentives (often stated by literature to be a powerful way to induce knowledge sharing) is not really considered to be a major cause.

Table 3. Hindrances to knowledge transfer between employees with different age and tenure.

Problem	**% of firms that perceive the problem**
Not a real problem	18.2 %
Resistance to change	48.5 %
Cultural gaps	41.4 %
Fear for job insecurity	30.3 %
Jealousy and character problems	21.2 %
Rivalry in the career path	19.2 %
No real incentive to share knowledge	11.1 %

In face of this "breakdown" in the traditional knowledge sharing process, firms have progressively learned to adopt a richer portfolio of approaches for managing competencies, as shown in Table 4, which summarizes qualitative findings from case studies and reports "frequency of use" data from the survey.

Table 4. Approaches used for managing competencies

Approach	Owner-managed firms	Firms run by professional managers	% of firms using the approach in each function			
			Prod.	Sales	Prod. Dev.	Finance
Hiring young people	Mostly with secondary education degrees High attention paid to references from network of acquaintances	With both secondary and higher education degrees Attention paid to knowledge and skills	43.4%	9.1%	14.1%	12.1%
Hiring experienced personnel and external managers	Uncommon choice, since the hires have a different organizational culture	Frequent choice for both workers and managers Promoting cultural diversity is often an explicit choice	39.4%	32.3%	45.4%	36.4%
Training	Choice made in reaction to events (e.g., new legislation, new equipment)	Both reactive and proactive training programmes Formal training plans exist at corporate and individual level	53.5%	30.3%	52.5%	38.4%
Consultancy	Used for non-core processes	Used on all processes as a first approach to deal with new topics	6.1%	12.1%	22.2%	32.3%
Outsourcing	Used for non-core processes	Used for non-core processes. Used for core processes if the firm operates within a group	13.1%	3.0%	7.1%	5.1%
On the job training	The most common approach	Common, but used together with other approaches	n.a.	n.a.	n.a.	n.a.
Internal mobility between functions	Seldom used	Frequently used for promoting process orientation in the workforce Helps find the best matching between individual attitudes and job requirements	19.2%	11.1%	12.1%	8.1%

It is noteworthy that the frequency of use of these approaches is generally higher for the product development function. This can be explained by the fact that firms recognize this process to be particularly knowledge-intensive and in need of having greater attention paid to it. Field research has also shown substantial differences in the way with which owner-managed and management-run companies use the approaches described in Table 4. Owner-managed companies tend to be more conservative and self-referencing, and broadly tend to use in-house training of young recruits in order to manage the workforce's competencies. Again, it may be hypothesized that this is due to an implicit axiom by which the company is considered as the result of a progressive outgrowth of the founder's original competencies, so that new competencies "must" originate in a similar and highly path-dependent way. Conversely, management run companies seem to view themselves as a "collection of competencies" for which a market is available, both internally and externally. This opens them to consider a broader set of alternatives for acquiring such competencies when a need is felt for them.

From the perspective of statistical analysis, the breadth and number of measures used, among the ones listed in table 4, may be considered to be a proxy of the richness of corporate dynamic capabilities. The analysis performed has shown that attention to innovation as a competitive factor does not appear to be correlated to the variety of approaches used for managing competencies. Correlation exists with company size and type of management, but due to

collinearity between the two variates it is difficult to extricate the contribution of the two. Correlation analysis shows a higher value of r^2 between company size (given by the log of the number of employees) and variety of approaches (expressed by the count of approaches used in the different functions) for management-run companies than for owner-run companies. In the former case Pearson $r^2 = 0.301$, while in the latter case Pearson $r^2 = 0.174$. Though this result is quite weak, it does suggest that management structure has a mediating effect on the expected result that larger companies exhibit a greater richness of dynamic capabilities, with management-run companies behaving in a more predictable (and possibly more rational) way than owner-managed ones.

4 Training

Training is, as it may easily be expected, the main approach used for managing and increasing competencies in firms, and has been studied in depth during the research project. The amount of training provided by firms to their workforce is in any case fairly low, as shown in table 5. Few companies reach beyond a figure of 30 hours of training per capita (which is less than about 2% of yearly working hours available). It should be noticed that personnel engaged in product development tend to benefit from a greater amount of training effort, if compared to other members of the indirect workforce. Degrees of association with determinants only show a slight relationship with company size. Table 6 details the objectives of training programs, with the somewhat "reactive" objective of "learning to use new tools" being cited by most companies (and especially owner-managed ones). The more "proactive" purpose of broadening professional skills also is often mentioned, but in strong association with large, innovation-oriented and management-driven firms.

Table 5. Amount of training provided by firms to indirect employees

Yearly hours of training per employee	**Prod.**	**Sales**	**Prod. Dev.**	**Finance**
<15	41.3%	46.7%	29.1%	57.0%
15 – 30	27.5%	24.0%	27.8%	17.7%
30 – 45	16.3%	13.3%	22.8%	6.3%
45 – 60	6.3%	6.7%	13.9%	6.3%
>60	8.8%	9.3%	6.3%	12.7%
Significance of association with determinants				
Company size	n.s.	p<0.005	p<0.08	n.s.
Professional management	p<0.039	n.s.	n.s.	n.s.
Innovation as key competitive factor	n.s.	n.s.	n.s.	n.s.

Table 6. Objectives of training programs

Reason for training	**Total**	**Degrees of association with determinants**	**Company size**	**Prof. mgmt**	**Innovation**
Providing new skills to workers with obsolete competencies	14.9 %		p<0.05	n.s.	n.s.
Usage of new tools and updating on legislation	74.5 %		n.s.	p<0.08 (neg.)	n.s.
Broadening of professional skills	61.7 %		p<0.045	p<0.1	p<0.05
Changing organizational culture	20.2 %		p<0.073	n.s.	n.s.
Training provided to workers being downsized	0 %		n.a.	n.a	n.a.

The reasons for not providing more training to employees are shown in table 7, with time and costs being the most frequently mentioned. One of the interviewed managers summarized this by quipping "of course training is limited. When business is going well we don't have time for it. When business is bad we don't have the money".

Table 7. Reasons that limit the amount of training provided

Reason	Total
Opportunity costs of having workforce spending time in training	49.5 %
Public grants for training are difficult to obtain	27.3 %
Lack of financial resources	23.2 %
The market for training does not offer what we need	22.2 %
It's difficult to monitor the impact of training	21.2 %
It's better to hire skilled personnel	17.2 %
Training is not considered to be important	14.1 %
Employees don't care enough	10.1 %
A skilled employee is more likely to leave the company	8.1 %
It's difficult to have knowledge on the programmes proposed	2.0 %

Concerning the subjects covered in training programs, a detailed breakdown is provided in table 8. In the table the "incidence of training" in the last column provides the ratio between the frequency with which each topic is applicable to the firm *and* training has been used, over the frequency with which the subject is relevant to the company. By looking at the subjects in the table it is easy to notice that firms tend to use training quite heavily when dealing with "objective" and "hard" subjects, while learning will tend to occur without the use of formal training programs when coping with "soft" ones.

5 Implications for research

The results described in this paper lead to some interesting implications for design research. Though preliminary and explorative, the research has shown that the introduction of innovations in manufacturing companies is perceived as a major discontinuity by firms. This makes it difficult to effectively adopt such innovations, because the development of a proactive and comprehensive set of dynamic capabilities (i.e., routines that allow the firm to manage and increase its competencies) is not yet well established, especially in companies that are smaller, owner-managed and less geared towards innovation.

The main implication for research is that the well-known and often-lamented difficulty to transfer innovative and theoretically effective tools into practice [12-13] should not be taken as an external factor for which nature should be blamed. Barriers to adoption have specific reasons and can be explained and possibly abated, though further research still needs to be carried out in order to achieve a greater insight on this topic. When taking barriers to adoption into account, evaluating the validity of an innovation requires to go beyond its purely technical merit. Innovative tools and practices ought in fact to be complemented with intellectual and operational tools that may help firms understand the potential of the innovation, together with the implications and requirements that could lead to a successful adoption process.

Another result of interest for researchers and, potentially, for policy makers, is the preliminary finding that the main hindrances to developing the dynamic capabilities that help the adoption of support methods and tools seems to be cultural and associated to management structure,

rather than financial and due to company size (which, on its own, does not imply much). As a final finding, it is possible to mention the evidence showing that firms tend to avoid formal training when dealing with topics that are perceived to be "soft", which makes it more difficult to design an effective process of technology transfer.

Table 8. Usage of formal training programs on main topics

Function	Topics	"Not applicable"	"Applicable, but no training was used"	"Applicable and training was used"	Incidence of training
Production	New machinery and processes	20.0%	13.3%	66.7%	83 %
	Methodologies for improving quality and operations (e.g., SPC. TPM, JIT)	20.7%	23.0%	56.3%	71 %
	Use of IT support tools (e.g., ERP)	23.3%	17.4%	59.3%	77 %
	New legislation (e.g., occupational safety standards)	4.4%	14.3%	81.3%	85 %
Sales	Foreign languages	14.9%	31.0%	54.0%	64 %
	IT support to sales	19.8%	44.2%	36.0%	45 %
	Sales techniques	32.1%	46.4%	21.4%	32 %
	New legislation	36.3%	38.8%	25.0%	39 %
Product development	CAD,CAM, CAE systems	11.4%	23.9%	64.8%	73 %
	IT support systems (e.g., PDM, PLM)	36.1%	27.7%	36.1%	57 %
	Design support methods, materials and components	27.1%	28.2%	44.7%	61 %
	Methods for managing the development process	38.3%	34.6%	27.2%	44 %
Finance	IT support to business processes	7.9%	32.6%	59.6%	65 %
	Legislation	7.1 %	38.8 %	54.1 %	58 %
	International trade	41.5%	43.9%	14.6%	25 %
General competencies	Human resources management	27.9%	40.7%	31.4%	44 %
	Teamworking	38.1%	41.7%	20.2%	33 %

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