Machine tool sector: Some evidence from Italian manufacturing

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ABSTRACT

In the last few decades, the increasing specialization in multi-technologies and multi-products firms has made production a complex task. In particular, it is more and more difficult to transfer the knowledge from one firm to another (Paoli, 2003). Scholars answered this problem by means of formulating the concept of modular architecture (Ulrich, 1995) and modular organization (Sanchez & Mahoney, 1996). However, high technological firms need to know more than just what they produce; in other words, the boundaries of the firms are, in terms of knowledge, wider than what such firms produce (Brusoni, Prencipe, & Pavitt, 2001).

Among the innovative and technological advanced firms there are the Italian machine tools firms. The aim of this paper is to investigate the technological know-how of some Italian machine tool builders and to understand the industrial organizational model of these firms between the machine tool builders and their main suppliers. In order to do it, there have been interviewed three representative firms of the sector.

The main result of this research is that the firms interviewed are losing their technological know-how in favour of their suppliers. The systems integration approach has been proposed as an emerging industrial organizational model to develop and increase the technological know-how of the Italian machine tool builders.

Keywords: Complex technologies, Modularity, Systems integration, Italian machine tool sector.

INTRODUCTION

In the last decades the machine tool sector has had important changes, first of all of technological nature, and also for the joining of new actors or the loss of others in the competitive world scenario. From the end of the ‘70s of the last century, Japan introduced the numerical control technology inside the machine tools. This technological change permitted the machine tools to do operations with such a high speed and precision, that many scholars talked about a new industrial and technological revolution (Carlsson, 1984; Mazzoleni, 1999). The other important change is the joining of new international competitors, such as China, Taiwan, and South Korea. China is the nation with the highest productive power, able to have a big competition with the traditional leaders, such as Japan, Germany, and Italy. Nowadays, the Chinese production of machine tools is aimed to satisfy the internal demand, but what will happen when the domestic market will be full and the Chinese machines will be commercialized in the external markets with lower prices than those of the competitors, and with a better technology?

The present article, starting from the references above, underlines the technological knowledge in-house possessed by the three relevant firm cases from the Italian machine tool sector. Particularly, the present research faces two research questions related between them.

- Which is the technological level possessed in-house by the firms which are object of the present study? In other words, who is the real possessor of the technological know-how necessary for the machine tool production in the case of the object of the present study?
- How the supply relations, and particularly the externalization of the relevant components of the machine tool sector, are influencing the development of the new technologies necessary for the knowledge and production of machine tools? Moreover, which is the most appropriate industrial organization model to develop the necessary knowledge for the machine tool builders, since nowadays the project and organizational modularity is the most utilized model by the Italian machine tool builders?

The theoretical origin of the present article is based on the literature concerning the division of innovative labour among the firms. Such debate focussed mainly on two concepts: that of modularity (Arora, Gambardella, & Rullani, 1997; Brusoni & Prencipe, 2001; Sanchez & Mahoney, 1996; Ulrich, 1995) and that of Systems Integration (Prencipe, Davies, & Hobday, 2003). The management scholars, and the industrial economy ones, and also the engineers, discussed about the implications of such models to facilitate the division of labour both at inter-firm and intra-firm levels.

With regard to the empirical part of the present research, it is necessary to underline that recently, many theoretical scholars tried to make easier the nature of the firm competitive advantage, through the formulation of concepts such as strategic asset, or that of capabilities. The empirical analysis present in the literature tried to individuate these aspects with regard to the firms and the sector. Nevertheless, most of these studies mainly focussed on the research of mass goods production, leaving those sectors with high-tech content and based on business to business markets, such as, for example, the field of machine tool production. The case of machine tools represents a relevant example for two reasons. Firstly, even if until today, the machine tools have been studied by the scholars, these contributions did not investigate the technological implications within the sector's dynamics.

Secondly, the machine tool sector represented since ever a strategic sector for the industrial development of every nation, and specifically for Italy, since this sector is one of the few parts of the Italian industry which has a positive commercial. Therefore, the aim of the present research is to give an initial contribution to the analysis and interpretation of the technological dynamics of the machine tool sector in Italy.

The aim of the present work is to verify and highlight in which measure the Italian machine tool builders rely on the suppliers for the projecting, the development and production of the several component that constitute the machine tools. The present article is organized as follows: the first paragraph deals with the two theoretical traditions, the modularity and the system integration. The second paragraph highlights the main characteristics of the machine tools and the present situation of the sector. The third paragraph analyses the results of the research through the presentation of the three firm cases. The conclusions underline the theoretical implications, the limits, the future possibilities for the research and the improvement of the present work.

THE DIVISION OF INNOVATIVE LABOUR AMONG FIRMS

The concept of Modularity

During the last years, the debate on the division of innovative labour among firms has been focussed on the concept of modularity of the product, organization, and designing. The concept of modularity has origin in the work of Simon (1955; 1984). He studied the possibility of dividing the concept of knowledge-information in several parts, in order to obtain a better comprehension. According with this approach, the more the knowledge-information is complex, that is, not immediately interpretable by an agent, the more the process of composition-decomposition of knowledge-information will be effective for its interpretation and its transfer from one agent to the other.

Starting from this approach, some scholars (Arora, Gambardella, & Rullani, 1997; Sanchez & Mahoney, 1996; Ulrich, 1995) formulated the concept of modularity as an effective strategy for producing high-tech and multi-component products, through the use of modules. When a product, a project, or an organization is complexes, they can be divided in several modules. By means of doing it, the overall complexity is reduced, concerning the quantity of modules used. Every module can be improved without interfering on the specific of other modules (Ulrich, 1995).

When the firms adopt the modular producing strategy, they are able to solve technological and organizational problems, which would be difficult to solve otherwise. For this reason, the modularity of the product, of organization and of technologies is positively related. Therefore, if a technology can be separated in modules, also the necessary organization and the final product can be divided.

In order to divide a product in multiple modules, each module must have the minimum number of interactions among its main subsystems. Particularly, the less every variable of each module is linked to others modules' variable, the more its decomposition will be effective to interpret and analyse the problems of the good which has to be produced. This concept comes from the theory according to which the modularity of a product needs a "minor knowledge" of the project activity, because it is possible to specialize on a unique module which is not linked to the rest (Baldwin & Clark, 2001, 2004).

After the concept of modularity, there is that of the architecture of a product, according to which the tasks of a good can be linked to some physic components, in order to plan the product itself. The concept of architecture of the product concerns (Ulrich, 1995): the specification of the interfaces which unite the components, in terms of connections and interactions through contact or without it; the definition of several functional elements, that is, the structure of the single operations which contribute to the performance of the product; finally, the mapping of the element which are functional to the physical parts, that is, the identification of the tasks accomplished by the components. The architecture of a product can be modular or integral, depending on two properties: the mapping between the physical parts which form the product and the level of division of the components' interactions. In a modular architecture the components accomplish one or two tasks, and the interactions between them are well defined and divided. In addition, the modular architecture is effective when the firms stress the variety of products, the change and the standardization. A firm which uses a modular architecture can modify its products through the mere substitution of an only module or through the addition of new ones (Brusoni & Prencipe, 2001).

The concept of modularity can be applied also to organizations, particularly to the firms which deal with the development of new complex products (Prencipe, 2000a; Sanchez & Mahoney, 1996). According to the traditional designing approaches, a strong managerial coordination is required during the whole development process, since the products are characterized by integral architectures or are built from strongly united components. Rather, the modular architectures, by means of defining specifically the components' interfaces, the make the different moments of the development independent: all the components must conform to the characteristics of the interface. Therefore, the coordination of the new products development process is improved and widened. The continuous exercise of the managerial authority is reduced to the minimum, thanks to a precise and specific definition ex ante of the components interfaces. As stated by Sanchez and Mahoney (1996, p. 66):

> thus, controlling the required output of component development processes by standardizing component interfaces permits effective coordination of development processes without the continual exercise of managerial authority. The specifications for standardized component interfaces provide, in effect, an information structure ....that coordinates the loosely coupled activities of component developers

The modularity represents a very important concept for those firms that deal with complex products, technologies, and organizations. These firms use the modularity as a planning strategy to improve their products during the "life" of the good, and to make their organizations more efficient. This is particularly relevant in the industrial sectors where the "life" of the product is longer than the life of its components. The modularity reduces the costs and times of production. A modular product, for instance, is more easily maintained. As a consequence of all this, the firms that can offer modular products use this method also for other business activities, such as marketing. Despite that, recently some authors (Paoli & Poledrini, 2007; Prencipe, 2000b; Prencipe, Davies, & Hobday, 2003) have highlighted the limits of the modular approach in the case of high-tech products. Concerning this problem, the systems integration gives the most effective response as an organizational interpretative model in the supply chain management between firms that deal with multi-technological products.

The Systems Integration

Systems Integration, in general, is the capacity of some firms, governmental agencies and other characters of the economic system, of define and combine together all the necessary inputs for the production of a complex systems. More specifically, systems integration is the organizational and cognitive process through which an agent produces a product which has the characteristics of the so called Complex Product and Systems (CoPS) (Acha, Davies, Hobday, & Salter, 2004; Hobday, Rush, & Tidd, 2000). Systems integrator has the general knowledge to put together different systems, subsystems and high-tech components, and also the specific skills concerning the integration of every system, subsystem and the relative components (Hobday, Davies, & Prencipe, 2005). Therefore, the bigger the complexity of the integration process and of the systems, the wider the distinction between the system integrator and a generic producer of goods and services. In order to have the role of system integrator, a firm must have technological, organizational and managerial skills, and these must be deeper than the ones concerning the production process of a single product. In fact, as Brusoni *et al.* (2001, pp. 613-614) pointed out:

> systems integrators (are) firms that lead and coordinate from a technological and organizational viewpoint the work of suppliers involved in the network. Systems integrator firms outsource detailed design and manufacturing to specialised suppliers while maintaining in-house concept design and systems integration capabilities to coordinate the work (R&D, design, and manufacturing) of suppliers. Systems integration appears, therefore, to be a particular type of coordination mechanism between markets and hierarchies.

In other words, in order to have the role of systems integrator, a firm must have more than the simple knowledge necessary to the single systems integration (Paoli, 2003; Prencipe, Davies, & Hobday, 2003).

The systems integration origins come form the Cold War, when the American government decided to invest a big sum of money for the basic science and for the technologies for the productive processes, in order to contrast the URSS military force. Nevertheless, the institutional system which dealt with the development of new military innovations was incapable of realize new technological levels which required the nuclear weapon, the ballistic missiles, the propulsion jet, since the production of such weapons required high scientific and technologic skills apparently not linked with each other (Sapolsky, 2003). The American Department of Defence started to coordinate different subjects, such as private firms, researchers and engineers, in order to gather as much as possible the scientific and technologic skills. During the past years, the military industry required a huge specialization to improve the productive processes and the development of new products; in the Cold War period, instead, multi-disciplinary and multi-technologic skills were required. For this reason, there was need to coordinate teams of scientists and engineers with different backgrounds, in order to improve the planning, development, and production of new weapons. As a consequence of this, the organizational structures for the development of several projects have been created, such as the so called project-based organizational structures, in which we can find the origins of systems integration (Sapolsky, 2003). The project-based organizations developed in two sides. First of all, the engineers who participated to the project were specialized on the techniques of system engineering. Secondly, the managers and the team leaders planned new tools, techniques and organizational routines to face the new problems concerning the complex products planning. The main idea was that, in order to realize the integration of more technological systems in an only one final product, for instance a propulsion aircraft, the system integrator was required to have more specific skills than those necessary to the integration of the different systems. In other words, as Hobday *et al.* (2005, p. 1118) pointed out:

> the idea was that an integrated system was a whole greater than the sums of its parts and that entire weapons systems, and their components had to be designed together concurrently (e.g. airframe, electronics, and armaments) so that the system could be integrated successfully.

The definitive step of the systems engineering-integration approach towards the concept of system integration happened during the ‘80s of the past century, when some big firms which operated in the military and civil sector, transferred their skills of big weapons systems' planning and production to the "civil" sectors of manufacturing industry. In this passage, systems integration became the internal organizational form, also between the firms which operate in the production of Complex Products and Systems (CoPS), which are formed by several systems and technologies. Nowadays, the system integrator does not only have the highest technological skills, but it also has a know-how concerning how to deal with the main supply relations and with the secondary supply relations inside its productive chain. It is necessary to make a distinction between the role of the assembler and that of system integrator. The first is the one who assembles the components, while he takes their components along the productive chain, in order to produce the final product, but he does not have in-house technological and scientific skills about systems, subsystems and the components which he assembled.

Differently, the systems integrator has the technologic and organizational skills to integrate, change, and develop the systems which form the final product. In other words, the systems integrator, in order to be as described above, does not only have to know how to integrate each system that form a product, but its cognitive level must reach knowledge capable of designing and develop the systems themselves. Therefore, the difference between an assembler and a system integrator is not about the components produced and integrated inside, but it concerns the in-house level of knowledge which refers to the single systems. As Paoli (2003, p. 162) states:

> we contend that systems integration is a meta-super-cognitive-negotiative-dynamic process among individuals distributed throughout the contexts of several firms that are made up of specific physical attributes, combined also with the knowledge of the agents themselves, their linguistic interactions, their organizational rules, incentives, power distribution, beliefs, myths, and culture. Because of these agents it is possible, at the same time, to construct the system integration process of a multi-technology artefact (process or product) and, as a consequence, its evolutionary path.

In such a context, the systems integration is a cognitive process through which all the technological and organizational problems of all the systems, subsystems and components are solved. The relations between the system integrator and the agents belonging to the whole productive process, cannot be reduced to the mere "problem" of designing, because the knowledge of the several planning and integration processes is not simply the information which has to be transferred from an agent to another. It has to be developed and possessed by the systems integrator (Brusoni, Prencipe, & Pavitt, 2001; Paoli, 2003).

THE ITALIAN MACHINE TOOL SECTOR

Machine tools are industrial machines which can transform the form, dimension or surface of a piece of row metal such as a bar, a tube, or an ingot. The term "tool" comes from the fact that these machines use tools to do their operations (Saba, 1954). Although in the past, the term machine tool indicated also the industrial machines which worked on other materials apart from metals, such as wood or stones, nowadays almost of the authors (Cilona & Trona, 1993; Ferrari *et al.* 2001; Rolfo, 1998; Wengel & Shapira, 2004), indicate with such a term the industrial machines for metalwork. Also the association of Italian machines tool builders (UCIMU) and the new classification ATECO 2007 of economic activities made from ISTAT (C 28. 41. 00) define machines tool as machines for the metalwork. From the industrial revolution until today, the machines tool sector has become even more relevant for the economic and industrial development of the nations (Carlsson, 1984; Wengel & Shapira, 2004). Such strategic relevance comes from three main factors (Carlsson, 1989). First of all, machines tools are often useful for the realization of new products in the manufacture sector of metal components production, such as the case of the automobile sector, or that of home appliance. Inside the manufacture sector, new machines for the realization of a product with metal components are required. These machines are machine tools. This is an example of what happened during the ‘50s of the past century, when some researchers from Massachusetts Institute of Technology (MIT), were planning a new prototype of aircraft for the American army. They found out that they needed industrial machines that were able to cut the metals with a high precision to realize such a project. In other words, they needed new machine tools to realize this new aircraft typology. In this occasion, machine tools with numerical control technology have been created; thanks to a high precision capacity, this technology helped to realize what the new aircrafts needed (Mazzoleni, 1997, 1999).

The second relevant aspect developed by the machine tools builders during the industrial revolution, is the important role of to be a diffuser of new technologies among the manufacture firms (Rosenberg, 1963). It means that, since they have been used in several productive processes in the manufacture sector, the machine tools can transfer the technologic change from an industrial sector to the others. If we look at the previous example about the numerical control technology, we can see that it developed inside the aeronautical sector and other sectors; later, it spread in other industrial sectors, so that today almost all the industrial machines are built with the numerical control technology. Thirdly, it is important to underline that in the planning and development process of new machines tool, the relation between producer and user is fundamental (Rolfo, 2000). Such importance comes from the fact that the machines tool must often be designed in collaboration with the users and according to their needs. As it has been shown elsewhere, the geographic proximity between producers and users is a decisive factor for the technological development of machines tools (Poledrini, 2006). For instance, in Italy, Lombardy and Piedmont, such as Baden Wurttembergin in Germany, are the regions where there are both the main users and producers of machine tool.

In the last decades, the machine tool sector has changed world-wide. There have been two reversals. Firstly, the world leadership has switched from the USA to Japan. In 2006 the USA were at the seventh place in the world list of the sector producers (6% out of the total amount), while Japan reached the 23% of the world production.

The second change, more recent, is about the switching of the main production and consumes area from the Euro-American to the Asian one, particularly to Japan, South Korea, China, and Taiwan. In 1999, the 67% of the world quote consumes were concentrated in the USA and the countries of CECIMO, against the 25% of Asian area (Japan, South Korea, Taiwan, China). During 2010 the situation exchanged. The latter countries “consumed” around the 50% against approximately the 40% of the Euro-American area. Therefore, during 12 years the main Asian countries raised their consumers until the 245, while the “old” world leaders reached the 26%. Despite that this leadership switching has been influenced by the Chinese economic growth, also other countries showed a higher performance. In 2010, among the first seven countries which used machine tool there were Japan, with the 13% of the world quote, China with the 23%, South Korea with 9%, and Taiwan with 4%. The other nations were the USA, with 11%, Germany, with 9%, and Italy, with 7%.

Also with regard to the world production quotes, there has been an inversion from the Euro-American area to the Asian one. For example, in 1999 the former constituted the 62% of the world production, against the 34% of the Asian area, while in 2010 the latter developed and reached the 48%, the same quantity of the USA and the CECIMO countries. Specifically, if we observe the productive growth of the sector in the single nations from 1999 to 2010, we can notice that China, with 219% of growth, South Korea, with 211%, Taiwan, with 195%, and Japan, with 52%, have been the countries with the highest growth rate. On the other side, the main European countries' growth was inferior: Italy with 29%, Switzerland with 14% and Germany with 14% and Spain with 9%. The USA has been the only country with a negative growth of 27% among the first ten productive world countries.

These numbers show the fact that, despite Italy still has a world leadership role, as fourth producer and third exporting country, the growth trend of the Asian countries is superior and capable of filling the gap with Italy in few years. Moreover, China passed Italy in productive volumes since 2005.

SOME EVIDENCE FROM THE ITALIAN MACHINE TOOL SECTOR

For this research three firms belonging to the Italian machine tool sector have been interviewed and analysed. These firms will be called Alfa, Beta, and Gamma for privacy reasons; they have been chosen according to two criteria. The first one has a dimensional firm orientation, that is, it gathered the sector's firms in three groups, according to the number of workers: little, between 50 and 100; medium, between 101 and 250, and big, with more than 250 workers. The firms with a number of workers inferior to 50 have been excluded from the present research, since they have been considered not relevant from the technological point of view. The total number of the population, divided as described, consists of 87 firms over a total population of 450, 19 of which belong to the "big" group, 22 to the "medium", and 46 to the little group. For every group there have been chosen the three "best" firms from the technological know-how point of view possessed in-house, these firms have been identified in collaboration with the technical bureau of association of UCIMU category. Then, a questionnaire has been sent to each of the nine selected firms, in order to choose one of them for every dimensional area, according to the availability to provide the requested data, and to the relevance of the firm with the object of the present research.

The Alfa case

The firm Alfa s.p.a. is one of the main Italian firms of the sector with regard to the technical know-how possessed in-house, as indicated in table 1 (Appendix). Nevertheless, the relation between the value added and the turnover (around the 40%) is inferior to the value of the high-tech sectors, of 50% (Ferrari *et al.* 2004). The organizational model of the firm is similar to that of modularity, but, during the years, Alfa has been able to introduce in the market several radical innovations, such as the machine tools with laser technology. Although the modular approach leads the organizational aspects, with regard to the innovative processes, Alfa has developed necessary technological know-how to the production of machine tools technologically advanced.

The Beta Case

The medium production value (value added / turnover) of the firm Beta corresponds to the 36%, referring to the period 2005-1999, as indicated in table 2 (Appendix). The organization of innovative processes inside the firm is structured in a modular way and the innovations of the firm are incremental. Particularly, the Beta' products have built on modules which can be modified according to the specific requests of the clients.

The Gamma Case

The Gamma case is strongly oriented towards a policy of customization of the machine tools produced. Although it has a standard number of products through the modularity process of various components and of the organization necessary to assemble the parts, it can build machines according to the clients' needs. With regard to the innovation processes developed in the firm, which do not have people who work to the R&S function, they can be related to innovations linked to the mechanical components of the several machine tools produced. For this reason, we cannot talk about innovations, rather of little improvements, related to the mechanical components of the machines produced, as indicated in table 3 (Appendix).

CONCLUSIONS

From the interviews it emerged that in the last years the technological outsourcing has increased from the machine tools producers for their suppliers. The tendency towards the increasing use of collaborative relations, along the value chain, between machine tools producers and their suppliers, is bringing, nevertheless, to a moving of the value chain of the technological skills which concern the machine tools production. The machine tools producers who have been interviewed have the necessary in-house skills to the production, and, specifically, to the customization of the machine tools, but the technological know-how of the various systems, subsystems and the principal technological components are no more held internally by the builders. In other words, the outsourcing of the systems for the construction of the machines also means a technological outsourcing. The source of such technological loss is the organizational model of modularity, which has been adopted by the machine tools producers, according to which it is possible to decompose and compose the planning, organizational, and technological phases that constitute the various systems of machine tools, in order to obtain a more efficient production. In other words, the machine tools producers are loosing the technological know-how of their products. The role of these producers is becoming even more similar to that of the assembler, with the loss of technological knowledge and skills.

In the last decade, after the new competitors such as China, Taiwan and South Korea joined the world market, the international concurrence has increased. It is reasonable to sustain that there will be a need of machine tools with high-tech characteristics to contrast the future competition of such nations by the Italian producers. These technologies, which are necessary for the sector development, and which have been lost by the producers themselves, could be restored through the change of the organizational model both at the inter-firm level and intra-firm level. The eventual development of the system integrator inside the sector suggests the occasion for the restoration of the lost technologies. The system integrator, differently from what happens with the assembler, has the organizational and technological knowledge to change and develop the several systems that compose the final product. In other words, the system integrator does not have the only skills to integrate the various systems, which compose a product; its cognitive level has also the capacity to plan and develop the systems themselves within. The distinction between an assembler, that is, the present producers of the machine tools, and a system integrator, is not the reference to the components produced or internally integrated, it is rather the level of the in-house knowledge, with regard to the single systems.

Nevertheless, it is necessary to underline that the interviewed which have been carried out, do not permit to have strong generalizations at sector level. The study cases used had the aim to study in depth some subjects, essential for the present research, but the questions made to the firms, and the information that has been searched, have not permitted a major number of firm cases, because of the sensibility to the requested data. Between the strength of the statistic analysis and the depth of the quantitative analysis, the latter has been chosen, because it is more correspondents to the scope of the present research.

REFERENCES

Acha, V., Davies, A., Hobday, M., & Salter, A. (2004). Exploring the capital goods economy: complex product systems in the UK. *Industrial and Corporate Change, 13* (3), 505-529.

Arora, A., Gambardella, A., & Rullani, E. (1997). Division of Labour and the Locus of Inventive Activity. *The Journal of Management and Governance, 1*, 123-140.

Baldwin, C. Y., & Clark, K. B. (2001). Modularity after the Crash: Harvard Business School Working Paper, May.

Baldwin, C. Y., & Clark, K. B. (2004). Modularity in the Design of Complex Engineering Systems: Harvard Business School Working Paper, January.

Brusoni, S., & Prencipe, A. (2001). Unpacking the Black Box of Modularity: Technologies, Products and Organizations. *Industrial and Corporate Change, 10* (1), 179-205.

Brusoni, S., Prencipe, A., & Pavitt, K. (2001). Knowledge specialization, organization coupling, and the boundaries of the firm: Why do firms know more than they make? *Administrative Science Quarterly, 46* (4), 597-621.

Carlsson, B. (1984). The development and use of machine tools in historical perspective. *Journal of Economic Behavior & Organization, 5* (1), 91-114.

Carlsson, B. (1989). Small-Scale Industry at a Crossroads: U.S. Machine Tools in Global Perspective. *Small Business Economics, 1*, 245-261.

Cilona, O., & Trona, M. (1993). L'industria delle macchine utensili negli anni novanta: mercati, innovazione e sistema delle imprese. *Economia e Politica Industriale, 77*.

Ferrari, S., Guerrieri, P., Malerba, F., Mariotti, S., & Palma, D. (Eds.). (2001). *L'Italia nella Competizione Tecnologica Internazionale. La Meccanica Strumentale*. Milano: FrancoAngeli.

Ferrari, S., Guerrieri, P., Malerba, F., Mariotti, S., & Palma, D. (Eds.). (2004). *L'Italia nella competizione tecnologica internazionale quarto rapporto*. Milano: Franco Angeli.

Hobday, M., Davies, A., & Prencipe, A. (2005). Systems integration: a core capability of the modern corporation. *Industrial and Corporate Change, 14* (6), 1109-1143.

Hobday, M., Rush, H., & Tidd, J. (2000). Innovation in complex products and system. *Research Policy, 29* (7-8), 793-804.

Mazzoleni, R. (1997). Learning and path-dependence in the diffusion of innovations: comparative evidence on numerically controlled machine tools. *Research Policy, 26* (4-5), 405-428.

Mazzoleni, R. (1999). Innovation in the Machine Tool Industry: a Historical Perspective on the Dynamics of Comparative Advantage. In D. C. Mowery & R. R. Nelson (Eds.), *Sources of Industrial Leadership. Studies of Seven Industries* (pp. 169-216). Cambridge: Cambridge University Press.

Paoli, M. (2003). The Cognitive Basis of Systems integration: Redundancy of Context-generating Knowledge. In A. Prencipe, A. Davies & M. Hobday (Eds.), *The Business of Systems Integration*. Oxford: Oxford University Press.

Paoli, M., & Poledrini, S. (2007). *The cognitive Basis of Systems Integration: the Eclipse of "core" and the Emergence of Redundancy.* Paper presented at the 10th International Conference SGBED: "Creativity & Innovation: Imperatives for Global Business and Development, Ryukoku University, Kyoto, Giappone, 8-11 agosto 2007.

Poledrini, S. (2006). *Sectoral and Regional Systems of Innovation: the Case of the Italian Machine Tool Industry.* MSc Dissertation, SPRU, University of Sussex, Brighton, UK.

Prencipe, A. (2000a). Breadth and depth of technological capabilities in CoPS: the case of the aircraft engine control system. *Research Policy, 29* (7-8), 895-911.

Prencipe, A. (2000b). *Competenze tecnologiche, divisione del lavoro e confini d'impresa. Il caso della motoristica aeronautica*. Milano: FrancoAngeli.
Prencipe, A., Davies, A., & Hobday, M. (Eds.). (2003). *The Business of Systems Integration*. Oxford: Oxford University Press.
Rolfo, S. (1998). L'Industria Italiana della Meccanica Strumentale di Fronte alla Globalizzazione: Opportunità e Limiti. *L'Industria, 19* (4), 881-894.
Rolfo, S. (2000). The Italian machine Tool Industry towards product Development Networks. In U. Jurgens (Ed.), *New Product Development and Production Networks. Global Industries Experience*. Berlin: Springer.
Rosenberg, N. (1963). Technological Change in the Machine Tool Industry. *The Journal of Economic History, 23* (4), 414-443.
Saba, R. (1954). *Macchine utensili*. Torino: Boringhieri.
Sanchez, R., & Mahoney, J. T. (1996). Modularity, flexibility, and knowledge management in product and organization design. *Strategic Management Journal, 17 (Winter Special Issue)*, 63-76.
Sapolsky, H. M. (2003). Inventing systems integration. In A. Prencipe, A. Davies & M. Hobday (Eds.), *The Business of Systems Integration*. Oxford: Oxford University Press.
Simon, H. A. (1955). A behavioral model of rational choice. *Quarterly Journal of Economics, 69*(1), 99-118.
Simon, H. A. (1984). On the behavioral and rational foundations of economic dynamics. *Journal of Economic Behavior & Organization, 5*(1), 35-55.
Ulrich, K. (1995). The role of product architecture in the manufacturing firm. *Research Policy, 24* (3), 419-440.
Wengel, J., & Shapira, P. (2004). Machine tools: the remaking of a traditional sectoral innovation system. In F. Malerba (Ed.), *Sectoral systems of Innovation*. Cambridge: Cambridge University Press.

Author's Brief Biography

Simone Poledrini is Assistant Professor of Innovation Management (tenure-track position) at University of Perugia, Italy. In 2007 he got a MSc at SPRU at the University of Sussex in the UK and in 2008 he got his PhD at the University of Perugia in Italy. In 2007 he was awarded the second prize for his paper at the 4th PRIME PhD Conference at IKU Center in Budapest. His research interests range from social enterprises to cooperatives and from modular innovation to systems integration. He is author of several scientific articles published in national and international journals.

APPENDIX

Table 1
Principal Alfa firm indicators

Turnover		110.685
Employees		498
Of which		
	Directors/manager	36
	Employees	150
	Workers	236
	in R&D	76
Tot. graduated		199
Main outlet sector		41% EU market (except Italy)
main outlet sector		Automobile (60% of the turnover)
Export		80.835 (73% of the turnover)r
Most technologically advanced product		3D laser machine (61% of the turnover)
Technological innovation degree of the machine from 1 (low-tech) to 5 (high-tech)		5
Machine planning		Almost totally internal
Organization typology		Modular, but with high internal knowledge
Innovation capacity of the firms		Radical innovations

Source: our elaboration

Table 2
Principal Beta firm indicators

Turnover (thousands of €)		31.017
Employees		213
Of which		
	Directors/managers	7
	Employees	92
	workers	114
Tot. graduated		13
Tot employees in R&D		4
	Of which graduated	4
Main outlet sectors		55% EU market (except Italy)
main outlet sector		80% automotive
Export (thousands of €)		17.844
Most technologically advanced product		High speed grinding machines
Technologically innovation degree of the machine from 1 (low-tech) to 5 (high-tech)		5
Machine planning		Almost totally internal
Organization typology		Modular
Innovation capacity of the firm		**Incremental**

Source: our elaboration

Table 3
Principal Gamma firm indicators

Turnover (thousands of €)		10.800
Employees		60
Of which		
	Directors/manager	2
	Employees	4
	Workers	54
Tot. graduated		3
Tot employees in R&D		0
	Of which graduated	0
Main markets		50% EU (except Italy)
Main outlet sector		40% mechanical equipment
Export (thousands of €)		5.546
Most technologically advanced product		Grinding machines
Innovation degree of the machine from 1 (low-tech) to 5 (high-tech)		5
Machine planning		Almost totally internal
Organization typology		Modular type
Innovation capacity of the firm		Components innovation

Source: our elaboration