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and Networking
Evidence on Complementarities
for a Local Economic System**

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SME Performance, Innovation and Networking

Evidence on Complementarities for a Local Economic System

Summary

The paper addresses the relevancy of networking activities and R&D as main drivers of productivity performance and output innovation, for small and medium enterprises (SME) playing in a local economic system. Given the intangible nature of many technological organisational innovation and networking strategies, original recent survey data for manufacturing and services are exploited. The aim is to provide new evidence on the complementarity relationships concerning different networking activities and R&D in a local SME oriented system in Northern Italy. We first introduce a methodological framework to empirically test complementarity among R&D and networking, in a discrete setting. Secondly, we consequently present empirical evidence on productivity drivers and on complementarity between R&D and networking strategies, with respect to firm productivity and process/product output innovation. R&D is a main driver of innovation and productivity, even without networking. This may signify, in association with the evidence on complementarity, that firm expenditures on R&D are a primary driver for performance. The complementarity with networking is a consequential step. Networking by itself cannot thus play a role in stimulating productivity and innovation. It can be a complementary factor in situations where cooperation and networking are needed to achieve economies of scale and/or to merge and integrate diverse skills, technologies and competencies. This is compatible with a framework where networking is the public good part of an impure public good wherein R&D plays the part of the private-led driving force towards structural break from the business as usual scenario. Managers and policy makers should be aware that in order to exploit asset complementarity, possibly transformed into competitive advantages, both R&D and networking are to be sustained and favoured. Our evidence suggests that R&D may be a single main driver of performance. Since R&D expenditures are associated with firm size, a policy sustain is to be directed towards firm enlargement. After a certain threshold firms have the force to increase expenditures. The size effect is nevertheless non monotonous. Then, but not least important, for the majority of firms still remaining under a critical size threshold, policy incentives should be directed to R&D in connection with networking, through which a virtuous circle may arise. It is worth noting that it is not networking as such the main engine. Networking elements are crucially linked to innovation dynamics; it is nevertheless innovation that explains and drives networking, and not the often claimed mere existence of local spillovers or of a civic associative culture in the territory. Such public good factors exist but are likely to evolve with and be sustained by firm innovative dynamics.

Keywords: Firm Competitiveness, Innovation, R&D, Networking, Complementarity, Local Economic System

JEL Classification: D21, L25, O3, O14, Z13

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0. Introduction

The recent interest of economic literature on the links among firms' networking innovation and R&D investments is part of a more general attitude of economic analysis, considering a larger spectrum of productive inputs, including both intangible forms of capital (such as organization, human resources, non technological innovation) and forms of capital external to the firm (as social capital, innovation networking). These extensions aim to improve the analysis on the relationships among firms' innovative strategies, investments in different capital forms, and performances.

The attention devoted to networking reflects different real-world situations where inter-firm cooperation is the primary and leading key to successful performance of both the single firms and the whole network. Without entering into the specific debate over taxonomy, we refer to these as either a "cluster" or a "district" of firms. What matters is that at some point firms need to join their efforts for achieving benefits which derive from and build on public-like forms of investments. This necessary joint effort to establish voluntary cooperative schemes, by which achieving goals specific to the network but appropriable by participants, characterises most forms of (i) voluntary agreements, (ii) inter-firms intra district cooperation, (iii) inter-firms inter-districts cooperation. The relevance of points (i)-(iii) as engines for innovation and growth at a regional level has increased over the last decades, following both the less prominent role of the state as "regulator" (top down approach), and the reshaping of governance and business strategies within the post-fordist society. Actually socio-economic changes occurring in the post fordist (post-industrial) era shift the focus of interest from man-made forms of capital to human, environmental and social capital assets.

Some recent works dealing with high performance practices, innovation, networking and spillovers occurring in local district systems, have paid great attention to the notion of complementarity. The question is whether the relationships of complementarity among different drivers of firms' productivity may themselves be considered as partially intangible factors of competitive advantages for firms, adding to, or substituting, the role of the other more usual productivity drivers. Anyway, it sometimes happens that some of the links existing among different productive factors do not necessarily turn out to be complementary relations.

The aim of the paper is to focus on the complementarity links between firms' internal R&D activities and networking activities. What we want to investigate is whether this relationship of complementarity may itself be considered a firm's productivity driver, and whether this relationship passes the test of complementarity both on theoretical and on empirical grounds, or in which specific circumstances this happens. To pursue the proposed aim, we first introduce a methodological framework useful to empirically test complementarity among R&D and networking, in a discrete setting. Secondly, we consequently present empirical evidence on complementarity between the two variables, with respect to firm productivity, exploiting detailed and specific survey-based data.

The paper is organized as follows. Section one introduces the analysis of networking activities and innovation dynamics, jointly with the issue of complementarity among productive factors. The recent research streams are briefly commented on. In section two, a methodological framework is presented, wherein the complementarity between R&D and networking is analysed through the supermodularity of

firms' productivity function; the database and the context are then presented. Section three comments on and presents the empirical framework and discusses some methodological issues, introducing the core empirical part, subdivided first in an analysis of productivity drivers and then of specific investigations of complementarity relationships. The last section concludes the paper by summarising results and offering insights for further research.

1. Innovation, networking and complementarity

Reasoning on firms networking helps to clarify a central issue for any theoretical and applied analysis on the determinants of innovation. A key point concerns the role of firm dimension (firm size) in achieving innovation intended as a breakout from established paradigms. The applied microeconomic literature which focuses on networks, social capital and spillovers in industrial districts deals with the issue by including both firm size and "social capital-network relationship" proxies as explanatory factors of innovation, in order to test which potential driving force is relevant (or more relevant). That is, in the words of Nooteboom (1999), who places his emphasis on different hypotheses developed by Schumpeter and on ambiguous results obtained by the recent empirical research: "the relevant variable is not firm size, but degree of integration and the strength of links" (Nooteboom, 1999, p.143). Depending on network linkages and on the organisational structure of the firm, both small and large organisations may be engines for innovation as "creative destruction".

Within this framework of analysis, another recent, crucial point of investigation revolves around the notion of complementarity.

In defining networking as an external source of innovation and productivity enhancement, it follows that network relations and high-performance oriented organizational strategies are indeed possibly linked by complementarity relationships, since they may represent external and internal ways of innovating the organizational firm structure.

The complementarity hypothesis recently received increasing attention stemming from the literature dealing with innovation, high performance practise, networking and spillovers occurring in local district systems. Complementarity has been addressed both from a theoretical and an empirical perspective over the past ten years, taking both main stream and heterodox approaches into account¹.

The relevancy of complementarity among drivers of performances has been underlined by various works, dealing with the relationship between innovation strategies and performances at firm level. Since the mid nineties, those contributions have highlighted the limited short-run effects of strategies biased towards organisational (cost) efficiency and the higher potential for increasing long-run performances of innovation-based management of firms (Huselid, 1995; Black, Lynch, 1996, 2001, 2004; Ichniowski, Shaw, Prennushi, 1997; Michie, Sheehan, 2003, 2005). The questions relevant to this approach and to the more circumscribed environment of complementarity are "by what mechanisms a high performance work system affects firm performance" and "how can these systems represent *a source of sustained value creation, rather than simply locus of cost control?*" (Becker, Huselid, 1998).

¹ Tab.1 sums up main recent empirical contributions on complementarity.

We do not aim at surveying the mostly applied oriented literature on complementarities. Summing up, in recent works complementarity is analysed concerning diverse factors affecting firm performance such as technological innovation, R&D, organisational innovations, high performance practices, training. Networking is analysed both as a holistic factor and by differentiating cooperation with respect to other firms, universities, and suppliers. Various hypotheses of complementarity are explored, both with respect to their effects on firm performance (productivity, profits) and regarding innovation performances. We refer to Laursen, Foss (2003) and Laursen, Mahnke (2001) who focus on techno-organisational factors, organisational bundles and firm innovation performances. Bresnahan, Brynjolfsson, Hitt (2002), Brynjolfsson, Hitt, Yang (2002), Brynjolfsson, Hitt (1997, 2000, 2003) extensively analyse ICT and techno-organisational complementarities with respect to firm performance on the US environment. More recently, Aral, Weill (2005) focus on ICT innovations; Guidetti, Mancinelli, Mazzanti (2006) analyse formal and informal training links; Cassiman, Veugelers (2005), Belderbos et al (2004), Veugelers, Cassiman (2005) provide other evidence on the EU arena, focusing on large manufacturing firms, with a focus on heterogeneity in R&D cooperation strategies by firm typology and sector, networking between firms and universities, internal R&D and external knowledge acquisition.

Complementarity is also studied, along a different conceptual and empirical perspective, by more evolutionary, systemic-oriented and dynamic-focused streams of research. For example, complementarity in Teece (1996) emerges as associated with the joint asset specificity of some inputs and innovations, which may produce idiosyncratic not replicable organisational frameworks, leading to higher performance and rents. In other words, crucial complementarity links, such as the one regarding R&D and networking examined in this paper, may act as partially intangible factors of competitive advantages for firms, adding to or substituting the role of more usual drivers like size, R&D internal expenditures, etc..

An idea of co-specialisation between productive factors emerges (Teece, 1986). This asset specificity or co-specialisation between firms' tangible and intangible assets is a way of capturing and defending the rents of techno-organisational innovations, within a perspective which goes beyond the standard boundaries of the firm, and is potentially alternative to patenting activities (Gu, Tang, 2004).

Teece (1996) theoretically examines the extent to which innovative capacity is dependent on the formal and informal structures of the firm, as well as the network of external linkage that they possess. The complementarity between productive assets or firm modules in a broader sense emerges itself as an intangible asset. This asset is specific, non-transferable and non-modular (Langlois, 2002). We find a specific link to the main features of technological innovation, for example, in a nutshell: (i) technological interrelatedness (innovation is characterised by technological interrelatedness between various subsystems. Linkages to other technologies, to *complementary assets* and to users must be maintained if innovation is to be successful); (ii) inappropriability (accordingly, investment in innovative activity may not necessarily yield property which can be reserved for the exclusive use of the innovator).

Though the increasing empirical evidence on complementarity takes different directions, studies which focus on networking and innovation are quite rare, given, among other reasons, the paucity of reliable micro-data. Networking is, in fact, a typical non-market activity rarely elicited in official statistics, as well as

other intangible assets. Cainelli, Mancinelli, Mazzanti (2007) and Mancinelli, Mazzanti (2004) theoretically and empirically analyse the link between R&D and networking/ social capital. Within a theoretical framework that considers social capital as the public component of the impure public good² R&D, they show that the ‘civic culture’ of the district area in which a firm works is not a sufficient incentive to increase its investment in SC. Social capital/networking dynamics might positively and complementarily evolve only if the opportunity cost of investing in innovation is sufficiently low. Other recent relevant works are Fritsch, Franke (2004) and Belderbos, Carree, Lokshin (2004). The first work estimates a knowledge production function in order to verify the impact of R&D investments, cooperative R&D and knowledge spillovers on the adoption of patents and the number of registered patents. The second analyses the effect of various cooperative activities (with subcontractor, with other competitors, university, etc.) on innovation and productivity, finding weak evidence for the networking-productivity link and heterogeneous evidence, depending on the cooperative activity, for the link between networking R&D and output innovation. Mol (2005) instead focuses on innovation and outsourcing. He questions the ‘conventional’ wisdom which associates innovation with the advantages of vertical integration, and proposes as an alternative an innovation driving role of networking and outsourcing specifically. This is a ‘relational view’, (Mol, 2005, p. 575), which considers establishing connections with outside suppliers and is crucial in terms of networking and learning-by-interacting.

Following the reasoning described above, our aim is to focus on the complementary relation between firms’ internal R&D activities and networking activities.

Our paper is aimed at adding further empirical evidence on the following aspects. First, the literature has particularly focused on large firms belonging to manufacturing sectors. Our analysis, instead, exploits data for a local economic system composed of manufacturing and market service firms, where small medium enterprises³ (SME) are dominant, and synergies between R&D and networking are a crucial way for achieving (new) competitiveness, as a primary alternative to more usual economies of scale. With this respect it exists a role for public policies at regional level. Secondly, we primarily test complementarities taking as main elements R&D and networking, according to a theoretical framework which will be discussed below. Then, though the core analysis is between internal R&D and networking, defined by various agents’ relationships with firms and institutions, we extend the empirical assessment to a larger frame where other techno-organisational innovations (including outsourcing and ICT) are considered. With respect to the objective function, we test complementarity relationships primarily on productivity, but also on output innovation adoptions by firms. R&D and networking are main drivers of performance for SME dense areas. It is highly relevant to inform the management and the policy maker the extent to which complementarities is likely to play a virtuous role.

² In the micro-economic literature (Cornes, Sandler, 1984; 1986), an impure public good, or mixed-public good, is a good which jointly gives private and public benefits. A typical example is that of an individual who, by being inoculated against an infectious disease, confers both a private benefit on himself and a public benefit by reducing the risk of spreading the disease through the community. In this case inoculation is the impure public good.

³ SME based economic systems present the following features: (i) a high density of firms whose size is no more than medium; (ii) a considerable number of district firms, characterized by few but strong production specializations (Brusco, 1982).

It is worth noting that our aim is different from those works which concentrate their analysis on the knowledge spillovers on firms' innovation activity. Actually the concept of complementarity is different from that of positive spillover. Differently from spillover, hence, if a relationship of complementarity is found between two activities of a firm, this implies that if one of the two activities is increased, it will be more attractive for the firm to increase the other activity too, and system effects arise, with the whole being more than the sum of the parts. This has obvious implications on both firms' strategies and policy decisions. Actually, when two or more activities of a firm show complementary relations, firm and policy efforts should be targeted toward all the activities, since it is possible that improving only one of them would even worsen the firm's performance⁴.

2. Testing complementarity between R&D and networking

2.1 Concepts and methods

The aim of this section is to provide a methodological framework to support the empirical test on complementarity between firms's networking and R&D investments.

Since both R&D and networking are measured in our dataset as discrete choice variables, we study complementarity between these two activities, through the properties of supermodular functions.

Following Topkis (1995, 1998), Milgrom, Shannon (1994), Milgrom, Roberts (1990, 1995), we say that a set of variables $x \in X \subseteq \mathbf{R}^n$ is complementary if a real-valued function $F(x)$ on a *sublattice* $X \subseteq \mathbf{R}^n$ is supermodular in its arguments.

In our case, if R&D and networking are complements, a firm's objective function must be super modular in these two variables.

Specifically, we consider a firm's average productivity function (AP_j) as the objective function and we focus on just two of the many decisions that can affect the firm's productivity function: R&D and networking:

$$(1) \quad AP_j = AP_j(R, N, \theta_j) \quad \forall j.$$

The problem of firm j is to choose a set of investment strategies for R&D (R) and networking (N), which maximizes its average productivity function. Complementarity between R&D and networking may be analysed by testing whether $AP_j(R, N, \theta_j)$ is supermodular in R and N . θ_j represents the firm's exogenous parameters. Actually, a firm operates in an environment which is characterized by exogenous parameters (such as product market) and one can be interested in how different values of the parameter θ may imply different instances of the firm's decision problem, and hence different optimal choices and average productivity of the firm. The maximization problem is the same for all the firms, but, since each firm

⁴ On this subject, it is worth quoting the example described in Milgrom, Roberts (1995, p. 194): "General Motors, once the most successful of mass producers, spent some \$80 billion during the 1980s on robotics and other capital equipment normally associated with the new methods. It did not, however, make any serious adjustments in its human resources policies, its decision systems, its product development processes, on even in its basic manufacturing procedures. Either it failed to see the importance of making these complementary changes or else, it was unable to make the changes that were required on these dimensions. The result was that those billion dollars were largely wasted."

is characterized by specific exogenous parameters (θ_j), the AP function may result as supermodular in R and N for some firms, but not for others.

Our aim is to derive a set of conditions that can be used in empirical tests, to verify whether complementarity between R&D and networking is confirmed by the data, or in which specific circumstances (firm-specific exogenous parameters) complementarity holds.

We can consider each of the two choices about R&D and networking as binary decision variables. So, if a firm chooses to invest neither in R&D, nor in networking, we have $R = 0, N = 0$; in this case the element of the choice set is $\{00\}$. If a firm chooses to invest both in R&D and in networking, we have $R = 1, N = 1$, and the element of the choice set is $\{11\}$. Including also the mixed cases, we have four elements in the choice set: $\{\{00\}, \{01\}, \{10\}, \{11\}\}$.

From the definition of complementarity through supermodularity, we can assert that R and N are complements and hence that the function AP_j is supermodular, if and only if:

$$(2) \quad AP_j(11, \theta_j) + AP_j(00, \theta_j) \geq AP_j(10, \theta_j) + AP_j(01, \theta_j),$$

clearly equivalent to:

$$(3) \quad AP_j(11, \theta_j) - AP_j(00, \theta_j) \geq [AP_j(10, \theta_j) - AP_j(00, \theta_j)] + [AP_j(01, \theta_j) - AP_j(00, \theta_j)],$$

that is, the changes in the firm's average productivity when both forms of investment are increased together are more than the changes resulting from the sum of the separate increases of the two forms of investment. Actually, the increases in AP due to an increase of both R&D and networking from $\{00\}$ to $\{11\}$ are more (or at least equal) than the sum of the increases in AP due to separate increases of R&D and networking from $\{00\}$ to $\{10\}$ ($\{01\}$).

Inequality (3) can also be written as:

$$(4) \quad AP_j(11, \theta_j) - AP_j(01, \theta_j) \geq AP_j(10, \theta_j) - AP_j(00, \theta_j).$$

Increasing one of the two forms of investment (for instance R&D) increases firm's average productivity in a wider way if the other form of investment also increases: increases in AP due to an increase of R from $\{00\}$ to $\{10\}$ are less (or at least equal) to the increases in AP due to increases of both R and N from $\{01\}$ to $\{11\}$.

Summing up, complementarity between the two forms of investment (R&D and networking) exists if the AP_j function is shown to be supermodular in these two variables and this happens when one of the above inequalities is satisfied:

2.2. Data and context

The applied analysis is based on a dataset stemming from a comprehensive study concerning a Province of the Emilia Romagna Region, in Northern Italy. Emilia Romagna (fig.1) is an area of Northern Italy

characterised by a high density of industrial districts, and shows a very high level of per capita GDP (around 27,000€ in 2003).

We support the perspective that micro-data at firm level are necessary for the kind of theoretical and applied analyses we deal with. Surveys are therefore the only way to pursue such a research direction.

Surveys have been conducted on industrial and market-service firms with at least 20 employees and which have establishments in the Province, thus excluding agriculture and public administration. We initially identified 436 firms, which were disaggregated by sectors (metalwork, market services and other industries: textile-wearing articles, food products, chemical products, engineering and energy) and size (20-49, 50-99 and more than 99 employees, corresponding to small, medium and “large size” firms). Building on those 436 firms (the universe), a random sample of 250 firms was selected (57% of the universe).

A first wave of data was collected during 2003 by direct interviews to managers of human resources at the central offices of the firms. We ended up with 243 filled questionnaires out of a total population of 436 firms in the Province. A second consequential survey, which is the root of this study, was carried out in May 2005, administering a shorter but focused questionnaire by telephone. This questionnaire elicited information on performance trends (productivity, profit, turnover, employment)⁵ over two periods (2000-2002 and 2003-2004), high-performance practices, outsourcing, training, R&D and technological innovation, and ICT dynamics. Within part of the questionnaire devoted to innovation, a specific part was dedicated to networking. We asked whether firms had voluntarily experienced networking activities concerning technological innovation development (broadly defined), with respect to clients/subcontractors, universities and research centres, other competitor firms. If networking occurred, it was specified whether it concerned both agents within the local area and outside, or only within/only outside. On this basis we may thus exploit different proxies of networking in a discrete framework: networking in general terms, networking with specific agents, geographical specificity.

Most of this data was elicited over 2000-2004, either as trends (i.e. adoption of some typology of innovations over the period) or as annual mean values (i.e. R&D and training expenses). We addressed the same 243 firms which joined the first survey: after dropping firms which closed down and others which refused to be interviewed, we ended up with 147 firms. This is the number of firms forming our integrated final dataset. Tab.2a-d show population and sample firms of 2003 and 2005 surveys. Tab.3a-d show descriptive analysis of the main variables of present relevancy (R&D, networking), presenting general figures and disaggregated figures by sector and size.

⁵ We chose to elicit and use performance trends as stated by managers, instead of official balance accounts data, since the latter are hardly available for all interviewed firms and moderately reliable, regarding SME, especially under the threshold of 100 employees. This is a critical point for applied research in SME contexts. Nevertheless, we note that recent works dealing with analyses concerning other areas of Emilia Romagna Region (Antonioli et al., 2004, 2007) interestingly show that the degree of statistical correlation between official balance accounts and survey information on firm performance are high, at around 0.7-0.8.

2.3 Empirical model and methodology

We may affirm that three methodologies exist for empirically assessing the complementarity hypothesis. The first analyses complementarity by studying the correlation of two or more variables, controlling for other factors. A usual way of carrying out such a test is by setting a bivariate or multivariate probit model, where complementarity arises if the null hypothesis of no correlation between the residuals of the two or more probit regression is rejected. In this case the variables under scrutiny are the dependent elements of the empirical model (Galia, Legros, 2004b; Laursen, Mahnke, 2001).

The second approach is defined as a reduced form approach (Arora, 1996): the analysis of complementarity is carried out by focusing on the effects of two factors, and on their correlation. It is typically implemented by setting interaction terms. The limit is the focus on only two elements (Athey, Stern, 1998).

The third approach is the one which allows greater flexibility and it is currently the most widespread. We may call it the productivity approach: it can deal with two or more factors on which the hypothesis is tested, and it is based on the estimation of an objective function, either a production function or an innovation function. Within it, two ways can be highlighted. The most common one is assessing the hypothesis by testing the significance of interaction variables, which capture the complementarity effect (Laursen, Foss, 2003, Brynjolfsson, Hitt, Yang, 2002 among the others). The most recent and highly flexible way is to analyse complementarity within a discrete framework where, given two or more factors, the hypothesis is tested by evaluating the effects of all possible states of the world, associated with complementarity or substitutability. We use (average) labour productivity (value added/employment) trends (as elicited from firm managers) for 2003-2004 as the main dependent variable, a variable ranging from 0 to 1⁶.

The empirical model is a reduced form for productivity, of the form:

$$PROD_{i,t} = \beta_0 + \beta_{1,t}(\text{structural firm features: size and sector as main controls}) + \beta_{2,t/t-1}(\text{R\&D variables}) + \beta_{3,t}(\text{Networking variables}) + \beta_{4,t}(\text{other innovation variables: ICT, organisational innovations, outsourcing}) + e_i$$

Where *PROD* represents the performance of firm *i*, and *e_i* the error term with usual properties. β_0 is the constant term, β_{1-4} the set of coefficients associated with groups of explanatory variables, where (*t*) stands for a variable whose trend is ascertained over 2004-2003 and (*t-1*) over 2004-2000. Tab.4 presents descriptive statistics for main dependent and independent variables.

It is worth speaking briefly about the discrete based regression analysis of complementarities. We specify regressions entering the four dummies associated with the potential states of the world: 00 (no networking, no innovation⁷), 10 (only networking, no innovation), 01 (no networking, only innovation), 11

⁶ In addition, in the analyses of sections 3.1.1 and 3.2.2, output innovation-related dependent variables are also exploited, being primarily productivity and also output innovation (product and process) the two objectives of R&D and networking efforts. A sort of 'knowledge production function' is adopted as reference (Griliches, 1979).

⁷ See tab. 6b for a description of the complete vector of innovation and networking discrete (dummy) proxies used here and tested by couples (i.e. networking and R&D, networking with universities and R&D, networking with universities and innovation output, etc..).

(both networking, and innovation), where *one*, as said, means presence and *zero* the absence of the productivity input in a specific firm.

From a statistical perspective, each state of the world, is included in the productivity regression as a sort of dummy.

Going directly to the definition, we may recall from section 2.1 that complementarity holds if and only if $[b_1+b_2-b_3-b_4 \geq 0]$. Empirically speaking, b_1 and b_2 are the estimated parameter linked to “complementarities states” (i.e. (00), (11)), while b_3 and b_4 are associated with the other states ((10), (01)). The reasoning surrounding couples of input drivers (bivariate analysis) leads to a statistical framework where the complementarity hypothesis is the one expressed above. A *one sided t test* is thus applicable for the present investigation in order to assess the degree of complementarity. The null hypothesis is the complementarity state under a non-strict inequality (≥ 0); we thus test complementarity in a non strict framework. Only if a negative value is observed below the defined threshold (e.g. 5%, 1%) we may conclude and reject the null at the specified significance level.

The next sections present and comment on empirical outcomes drawn from regression analysis.

3. Empirical evidence

3.1 Preliminary analysis: main productivity drivers

As far as structural firm features are concerned, a clear size effect emerges. Size is a crucial and confirmed explanatory factor. Then, productivity is also correlated with metalwork manufacturing firms, although statistically less significant across specifications, but not to market service firms, also confirming an expected result.

Focusing on main productivity drivers, expenditures per employee in R&D and informal training emerge both as significant factors, impacting on productivity with the expected positive effect. This is in line with other evidence on Sweden and France: R&D and training exert significant effects on productivity which may be partially country-specific; nevertheless, no evidence is found in favour of positive interactions between these two forms of capital (Ballot, Fakhfakh, Taymaz, 2001). Furthermore, the training coverage variable, when included separately, is associated with a positive significant coefficient.

To conclude with the analysis of drivers, we add evidence on further explanatory factors of productivity.

Other significant factors impacting on productivity trends, included incrementally in other specifications, are: (i) the dummy capturing whether or not firms have adopted product/process technological innovations over 2000-2005, (ii) the index of networking activities in the realm of innovation activities⁸; and, interestingly, (iii) the dummies associated with the outsourcing of accessory and core activities show, respectively, a positive and a negative plausible sign of coefficients.

Instead, ICT dynamics, high performance practices, like TQM, QC, JIT, and synthetic indexes of organisational innovations do not *directly* exert significant impact on 2003-2004 productivity trend (see tab.5 for a summary of main regression outcomes). R&D, training, networking, technological innovation and

⁸ Networking is defined with respect to cooperation activities regarding other firms (clients, suppliers, competitors) and institutions (university). The index varies between 0 and 1 and captures the intensity of networking activities by firms.

outsourcing arise, to a greater or lesser extent, as forces behind the productivity trend. The consequential analysis of next sections will focus on complementarities based on such premises.

We then now focus on the specific relationship of R&D with networking dynamics, first testing interactions, and secondly assessing R&D/networking relationships in a discrete setting as described above.

3.2 Testing complementarity between R&D and networking activities in a discrete setting

A full assessment of complementarity is performed by creating four states of the world for each analysed couple of drivers. All drivers should be discrete or made discrete. Regressions are estimated inserting those states, and the usual control variables (firm structural features). The test is implemented as a t test on the estimated coefficients for the 4 state variables.

Overall, then, 66 tests are carried out. The factors on which complementarity is analysed are R&D and networking discrete indexes. R&D is made discrete both by using a dummy taking value one if $R\&D > 0$ and a dummy taking value one if R&D expenditures of the firm are higher than the average figure. Networking is analysed by means of six discrete proxies: general presence of networking (58% of firms), networking with Research institutions and Universities, networking with clients and suppliers, networking with other competing firms, networking with firms within the boundaries of the local area (province), networking in the form of outsourcing activities.

Summing up, twelve combinations of R&D/networking are scrutinised. Such combinations are tested for four different objective variables: productivity, as above, as the main factor. Then, the index of technological innovation adoption and two dummies for process and product innovation adoption are also used. Those mentioned examined links account for 48 tests on complementarity. The remaining 18 tests are carried out using productivity and the index of technological innovation adoption as objectives (see Mohnen and Roller, 2005, for an analysis on technological innovation and complementarities). R&D, networking (general dummy proxy) and ICT/organisational innovations are selected as drivers, in order to further test whether networking, R&D and also 'organisational innovation inputs' are complements, with respect to firm performances.

We summarise empirical evidence distinguishing between the analysis which refer to (1) productivity, (2) innovation output, (3) process and product innovation separately taken⁹.

First, we observe that with regard to productivity (21 tests overall) strict complementarity (t ratio higher than 1.645, a 5% probability mass in the right tail) is never found. We find three cases where the test would pass at the lower 1.245 statistical threshold (a 10% probability mass in the right tale): R&D/networking with clients and suppliers, R&D/networking with non-local firms (both cases with $R\&D=1$ if higher than average)¹⁰, ICT/networking. Nevertheless, in no case would the test lead to a negative and statistically significant value (though some negative values are observed), thus rejecting even non strict complementarity.

⁹ Tab. 6b presents a synthetic sketch of results. Regressions are not presented for brevity and because instrumental to the complementarity tests.

¹⁰ Though we cannot conclude that overall the dummy $R\&D=1$ higher than average structurally changes test results with respect to $R\&D=1$ if $R\&D > 0$.

Secondly, when using the index of output innovation as the objective, we instead find two cases where the null $b_1+b_2-b_3-b_4 \leq 0$ would be rejected (substitutability situations)¹¹ and one case where strict complementarity arises at 10% (networking/ICT). All other 18 cases refer to *non strict complementarity* as defined here¹².

Finally, as far as product and process innovations are concerned, we highlight six cases (out of 12) where complementarity is rejected by our data when focusing on process innovation, and one case of strict complementarity (R&D/networking with non local agents) when testing complementarity with respect to the adoption of product innovation. Overall, complementarity seems to play a role with regard to product innovations, which are, for the sectors studied here, more involved by innovation radicalness (Dahlin, Behrens, 2005)¹³. Regarding process innovation, instead, complementary relationships appear to characterise R&D and networking dynamics to a lesser extent. Firms rely either on internal R&D or on networking, if they adopt process innovation (the 54% of firms).

To sum up, with respect to productivity, complementarity holds, with some signals of “strictness” in the examined empirical link¹⁴. From the analysis on innovation outputs, some signals of possible non-complementarities arise, confirming the outcome of section 3.2. Looking more specifically at diverse adoption of process and product innovations, heterogeneous results arise. This highlights the need to investigate complementarity in detail with respect to the firm performances of interest. Along the innovative and value chain “innovation input \rightarrow firm performances: innovation output \rightarrow productivity”, non-homogenous relationships of complementarity could characterise different levels/steps of the chains and/or different assets/productive inputs. The picture, as it arises here, is possibly patchy. Within a general evidence of complementarity links holding for SME performance drivers, some links of complementarity in its strictest sense here defined, and also some elements of substitutability links emerge. On this more detailed basis, we may then assess with more specificity where, on average (for the average firm), potential negative criticalities and potential positive dynamics are.

4. Conclusions

The picture we draw out of our data analysis is the following. At a more conceptual level, complementarity in its strictest sense rarely arises from the data, though it is present in some cases. Some “ice stones” of strict complementarity evidence in fact arise with respect to R&D/general networking and R&D with some specific

¹¹ R&D/networking with non local agents; R&D_{av}/ORGdummy.

¹² Those include R&D and outsourcing, which present complementarity in all tested regressions, in line with the analysis of Mol (2005), who underlines a relational perspective when studying outsourcing in R&D intensive industries, showing that firms in R&D intensive industries may have increasingly started to rely on partnership relations with outside suppliers.

¹³ Conceptually, we mean that in terms of radicalness intensity, product innovation is deemed relatively more radical than process innovations by many authors (Langlois and Robertson, 1992, Teece, 1986), insofar product innovations characterise more the embryonic phase of innovation development while process innovation the mature stages of development. Both can in any case share radical and incremental features.

¹⁴ Complementarities may also be aimed at maintaining the current innovation dynamics and thus performance. This is to be considered a successful outcome as well (Carlaw e Lipsey, 2002). We may affirm that strict complementarity relationships can be certainly associated with increasing returns to scale, generating extra rents and externalities with respect to the BAU scenario, but it is consistent also with constant returns to scale, where the market opportunity cost is merely replicated, and real externalities are not emerging.

networking activities. Overall, R&D and all networking specifications we use are characterised by a non-strict complementarity nexus which, by analogy, may be associated with constant returns to scale. Process innovation is instead the realm where effective non-complementarity is more frequent. Compared to other studies more focused on large firms, the weaker, though present, evidence on complementarities among productive inputs, could be related to the average size of firms in SME environments. That is why the analysis of networking as an alternative way to achieve scale economies plays a crucial role, and the evidence between networking and innovation should be taken as key information for management and policy making.

Our observed local economic system is characterised by low average figures on innovation and networking. Even observing a local economic system which is located in a rich European region like Emilia Romagna and which is representative of the average system with respect to Italian economic dynamics, 60% of firms declare not to invest their own money in R&D, and 42% say that they do not collaborate with either firms or research centres. A limited number of firms drive the whole system by high innovative dynamics and performances. The picture is thus quite heterogeneous, in line with most local systems where small firms are predominant. As shown, networking and R&D weaknesses are more visible in small firms.

First, R&D is a main driver of innovation and productivity, even without networking. This may signify, in association with the evidence on complementarity, that firm expenditure on R&D is a crucial driver for performance. The complementarity with networking is a consequential step: according to the conceptual framework depicted in this and other quoted works, networking is an external asset which is, totally or partially, a public good (not protected by formal appropriable agreements), or the public element of an impure public good, where R&D is the private factor. Thus networking by itself cannot play a role in stimulating productivity and innovation. It can be a complement factor in situations where cooperation and networking are needed to achieve economies of scale and/or to merge and integrate diverse skills, technologies and competencies.

Networking, as a partial public good, nevertheless probably emerges if stimulated by a *sufficient amount* of the “private” R&D element (internal source, explicitly excluding public funds). This is probably the reason why we observe a stronger overall evidence in favour of complementarity when analysing links in a discrete setting, which by definition distinguish and separate out different firms as “0” (below a threshold) and “1” (over a threshold).

This theoretical reasoning, associated with our and other empirical evidence, is plausible with the lack of investments in R&D and networking by firms in local economic systems in the current economic scenario. As a consequence, networking is in itself probably not a source of innovation. Networking cannot exist without R&D acting as primary engine. We reject theories asserting that networking stems from a territorial atmosphere that produces networking and innovation as by products or more or less spontaneous outcomes. The territorial atmosphere rich in spillovers, externalities and voluntary networking is favourable to competitiveness because it is intense in innovation. R&D and other innovation oriented investments create the pillars of innovation, networking and performance in local economic systems where SEM prevails. The virtuous circle, we believe, starts from innovation investments, favoured by market (opportunity costs) and public (subsidies, regulations) driving forces. The metaphors of civic virtue and favourable socio economic atmospheres characterising local

areas are representing a concrete phenomenon, but observed from an incorrect angle, or at least not useful for providing information on how increasing competitiveness in this currently fragile local systems.

On the basis of the mentioned average lack of investments in R&D and networking, complementarities are shown with respect to those drivers but are, to a greater extent, not exploited, given insufficient investments in R&D and, consequentially, a very limited development of networking. With R&D as main driver, relatively larger firms are probably self sufficient in local economic system, though networking is still relevant for them at the level of interrelationships with other large firms operating in other national and non national areas. The majority of SME is instead lacking both of R&D and networking. Large firms' development is not sufficient to structurally change the dynamic of local system needing new competitive advantages. This is the current challenge for many European local systems where SME prevail. Though networking is certainly crucial for SME, the first step is likely to be R&D, which then favours and stimulates virtuous dynamics. This is consistent with a theoretical framework where R&D and networking are linked by an impure public good structure: the lack of networking and the lack of R&D are two sides of the same coin; networking is necessary, potentially generating crucial innovation exchanges, but probably not sufficient for a full upturn in terms of competitive advantages of single agents and of local economic systems.

R&D is the key that is likely to stimulate a virtuous circle of investments in R&D and networking. This means that, given the current typical small firm environment of the Italian local economic system, a few number of large and medium firms (3% of firms employ more than 50 workers) is self sufficient in terms of R&D investments (and even networking, within and outside the local system). The remaining bulk of agents has to increase investments both in formal R&D and networking, in order to create innovation by formal and informal instruments, and, more importantly, to generate non-appropriable asset specificity involving internal R&D and external networking dynamics. The menu of institutional alternatives is large, and both internal firm resources and networks, of which there are several kinds, can be successful, growth-promoting adaptations to the competitive environment (Robertson, Langlois, 1995).

From a policy perspective, we may provide two suggestions. Our evidence suggests that R&D may be a single main driver of performance. Since R&D expenditures are associated with firm size, a specific policy sustain, under the general umbrella of R&D subsidy intervention justified by market failures, is to be directed towards firm enlargement. After a certain threshold firms have the necessary strength to increase R&D expenditures, that may act as an autonomous performance driver for firms. The size effect is nevertheless non linear: if it is true that in absolute levels R&D is increasing with size we may also find inverted U-shapes when examining the correlation between R&D per employee and size. In any case, a critical threshold, say 100 employees, is necessary for experiencing a sufficient base of R&D as driver of innovation and performance.

Finally, but not least important, for the majority of firms still remaining under a critical size threshold, policy incentives should be directed to R&D in connection with networking, through which a virtuous circle may arise. It is worth noting that it is not networking as such the main engine. In our framework and evidence, we argue that networking is necessary to achieve economies of scale for SME enterprises. Nevertheless, incentives should still target R&D, since it is R&D that stimulates the public component of networking, then providing the necessary basis for a co-causation effect. It is thus important to stimulate initial efforts on R&D for small

firms, that, given it is unlikely that they possess internally by themselves all the innovative capacities and competencies, will join other agents in cooperative efforts where complementarities relationships emerge.

Managers and policy makers should be aware that in order to exploit asset complementarity, possibly transformed in competitive advantages, both R&D and networking are to be sustained and favoured. Nevertheless, R&D should probably be the first target, by means of regional/local policies, if positive externalities are deemed to exist, and the process of size enlargement, even possibly stimulated by fiscal instruments and subsidies. As recently noted by Blanes, Busom (2004) for Spain, it is necessary to identify those R&D projects where the gap between private and public returns is the highest. Being networking a relevant “public part” of our model of reference, that generates additional social returns in a R&D-networking interplay, one criterion for selecting R&D subsidy may be the intensity of networking associated with R&D expenditures. This may be a way to attract new smaller firms since, as found by the cited authors, size seems still to represent a barrier, even for participating in R&D programs even at a policy level, a transparent correlation between R&D and networking when funding innovation could help virtuous dynamics to emerge in local systems.

Networking elements are crucially linked to innovation dynamics; it is innovation that explains and drives networking, and not the often claimed mere existence of local spillovers or of a civic associative culture in the territory. Such public good factors exist but are likely to evolve with and sustained by firm innovative dynamics. According to the theoretical reasoning, we should give a primary role to R&D, which then drives networking for R&D effort which needs, to go beyond BAU scenarios, a networking of competencies, innovation efforts, and skills. R&D and networking are thus complementary under this framework.

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Tab.1 – Main recent empirical contributions dealing with complementarity

| Paper | Performance | Innovation activities on which complementarity is tested | Data/country |
|--|--------------------------------|--|---------------------------|
| Caroli, van Reenen (2001) | PRODUCTIVITY | Skill, organisational innovation/change | Panel/UK |
| Bresnahan, Brynjolfsson, Hitt (2002); Brynjolfsson, Hitt, Yang (2002); Brynjolfsson, Hitt (1997, 2000, 2003) | PRODUCTIVITY | HRM, organisational innovation/change, skill, ICT | Panel/US |
| Laursen, Mahnke (2001) | * | High performance practices, HRM | Cross section/Denmark |
| Laursen, Foss (2003) | Product and process innovation | Organisational innovation/change, HRM | Cross section/Denmark |
| Lokshin, Carree, Belderbos (2004) | PRODUCTIVITY | Techno-organisational innovation/change; R&D networking | Cross section/Netherlands |
| Galia, Legros (2004a) | Product and process innovation | Team work, training, HRM, organisational innovation/change | Cross section/France |
| Galia, Legros (2004b) | * | Innovation obstacles | Cross section/France |
| Guidetti, Mancinelli, Mazzanti (2006) | PRODUCTIVITY | General and specific training | Cross section/Italy |
| Cristini, Gaj, Leoni (2004) | PRODUCTIVITY | Organisational innovation/change, ICT | Cross section/Italy |
| Astebro, Colombo, Seri (2005) | PRODUCTIVITY | Automotive technological technologies | Cross section/US |
| Mohnen, Roller (2005) | Innovation | Innovation obstacles | Cross section/ EU |
| Aral, Weill (2005) | PRODUCTIVITY | HRM, organisational innovation/change, skill, ICT | Panel/US |

*the analysis sees hypothesised complementary variables as dependant variables in the model, not drivers of firm performance.

Tab.2a: Reference Population (number of firms): *Survey 2003*

| Sector | Size | | | Total |
|---------------------|-------|---------|-------|-------|
| | (<50) | (50-99) | (>99) | |
| Machinery/Metalwork | 87 | 23 | 20 | 130 |
| Other industries | 83 | 22 | 26 | 131 |
| Market services | 87 | 35 | 53 | 175 |
| <i>Total</i> | 257 | 80 | 99 | 436 |

Tab.2b: Population (%)

| Sector | size | | | Total |
|---------------------|-------|---------|-------|--------|
| | (<50) | (50-99) | (>99) | |
| Machinery/Metalwork | 19,95 | 5,28 | 4,59 | 29,82 |
| Other industries | 19,04 | 5,05 | 5,96 | 30,05 |
| Market services | 19,95 | 8,03 | 12,16 | 40,14 |
| <i>Total</i> | 58,94 | 18,35 | 22,71 | 100,00 |

Tab.2c: Interviewed firms (sample): *survey 2005*

| Sector | size | | | Total |
|---------------------|-------|---------|-------|-------|
| | (<50) | (50-99) | (>99) | |
| Machinery/Metalwork | 28 | 10 | 7 | 45 |
| Other industries | 21 | 8 | 11 | 40 |
| Market services | 31 | 20 | 11 | 62 |
| <i>Total</i> | 80 | 38 | 29 | 147 |

Tab.2d: Interviewed firms (sample) (%)

| Sector | size | | | Total |
|---------------------|-------|---------|-------|--------|
| | (<50) | (50-99) | (>99) | |
| Machinery/Metalwork | 19,05 | 6,80 | 4,76 | 30,61 |
| Other industries | 14,29 | 5,44 | 7,48 | 27,21 |
| Market services | 21,09 | 13,61 | 7,48 | 42,18 |
| <i>Total</i> | 54,42 | 25,85 | 19,73 | 100,00 |

Tab.2e: Interviewed firms (sample) (%), detailed sectors

| sectors | size | | | Total |
|--------------------------------|-------|---------|-------|--------|
| | (<50) | (50-99) | (>99) | |
| Other industries | | | | |
| Other manufacturing industries | 1,36 | 0,00 | 0,68 | 2,04 |
| Textile | 8,16 | 0,00 | 0,68 | 8,84 |
| Food & beverages | 1,36 | 1,36 | 0,68 | 3,40 |
| Chemical | 3,40 | 3,40 | 2,72 | 9,52 |
| Construction/ Energy | 0,00 | 0,68 | 2,72 | 3,40 |
| Machinery/Metalwork | 19,05 | 6,80 | 4,76 | 30,61 |
| Market services | | | | |
| Commerce | 8,16 | 4,76 | 1,36 | 14,29 |
| Banking | 0,68 | 0,00 | 0,68 | 1,36 |
| Other market services | 12,24 | 8,84 | 5,44 | 26,53 |
| <i>Total</i> | 54,42 | 25,85 | 19,73 | 100,00 |

Tab.3a: Networking activities aimed at innovation: descriptive statistics

| Networking activity | firms | % firms with networking over 2004-2000 | With agents in the Province (%) | With agents outside the Province (%) |
|--|-------------------|--|---------------------------------|--------------------------------------|
| University | 28 | 19,05 | 14,97 | 6,80 |
| Research centres | 15 | 10,20 | 4,08 | 7,48 |
| Clients | 33 | 22,45 | 8,84 | 18,37 |
| Suppliers | 42 | 28,57 | 11,56 | 24,49 |
| Other competing firms | 29 | 19,73 | 9,52 | 15,65 |
| Other agents | 13 | 8,84 | - | - |
| No networking | 62 | 42,18 | - | - |
| Networking index (0-1, averaging the presence of networking activities) | Average: 0,181 | - | - | - |

Tab.3b: Networking activities aimed at innovation: descriptive statistics by size and sectors

| Networking index (0-1) | size | | | |
|------------------------|-------|---------|-------|-------|
| | (<50) | (50-99) | (>99) | Total |
| Sector | | | | |
| Machinery/Metalwork | 0,14 | 0,23 | 0,33 | 0,19 |
| Other industries | 0,09 | 0,27 | 0,24 | 0,17 |
| Market services | 0,16 | 0,24 | 0,14 | 0,18 |
| Total | 0,14 | 0,25 | 0,22 | 0,18 |

Tab.3c: Firms which has invested own resources in R&D (*excluding public funds*) in R&D over 2000-2004, by size and sectors

| % firms with R&D >0 | size | | | |
|---------------------|-------|---------|-------|-------|
| | (<50) | (50-99) | (>99) | Total |
| Sector | | | | |
| Machinery/Metalwork | 0,46 | 0,80 | 0,86 | 0,60 |
| Other industries | 0,14 | 0,88 | 0,40 | 0,36 |
| Market services | 0,19 | 0,50 | 0,27 | 0,31 |
| Total | 0,28 | 0,66 | 0,46 | 0,41 |

Tab.3d: Technological innovation adopted since 2000 by elicited typology

| <i>Technological innovations</i> | % of firms |
|---|--------------------------|
| 1. Product radical innovation | 12,93 |
| 2. Process radical innovation | 16,33 |
| 3. Product incremental innovation | 31,29 |
| 4. Process incremental innovation | 44,90 |
| 5. Radical innovations | 23,81 |
| 6. Incremental innovations | 54,42 |
| 7. Product innovation | 38,78 |
| 8. Process innovation | 54,42 |
| 10. No relevant innovation adopted | 34,01 |
| <i>Technological innovation index (0-1)</i> | <i>Average:</i> 0,265 |

Table 4- Descriptive statistics of variables: dependent and independent variables

| Variable | Typology and value range | Acronym | Mean value | Minimum and maximum values | Period of observation |
|---|--|--------------------|---------------|----------------------------|-------------------------|
| Average labour productivity 2003-2004 trend | Continuous index (0-1); 0,5 value means a stable average productivity; lower than 0,5 a decreased, higher than 0,5 an increase | PROD | 0,58 | 0,1 | 2003-2004 |
| Controls | | | | | |
| Sectors: Services, manufacturing/metalwork, benchmark base: other industry | 2 dummies | SERV, MANUF | 0,42; 0,30 | | Elicited in 2005 survey |
| Share of revenue on international markets | Continuous index (0-1) | NAT-REV | 0,14 | 0,1 | Elicited in 2005 survey |
| Share of revenue from acting as subcontractor | Continuous index (0-1) | SUBCONTR | 0,67 | 0,1 | Elicited in 2005 survey |
| Firm size | 2 dummies (50-99 employees, >100 employees) or alternatively number of employees | Size1, Size2, Size | 110 employees | 20; 2207 employees | 2004 employment level |
| Innovation and training variables | | | | | |
| R&D expenditures per employee | Continuous | R&D-EXP | 479€ | 0, 10000€ | 2000-2004 |
| R&D positive expenditures | Dummy | R&D | 0,41 | 0,1 | 2000-2004 |
| R&D positive expenditures (taking value 1 if R&D is higher than average) | dummy | R&D-1 | 0,21 | 0,1 | 2000-2004 |
| Index of technological output innovations (radical and incremental, process and product) | Continuous index (0-1) | INNOTECH | 0,55 | 0,1 | 2000-2004 |
| Adoption of process innovation | Dummy | PROC | 0,38 | 0,1 | 2000-2004 |
| Adoption of product innovation | Dummy | PROD | 0,54 | 0,1 | 2000-2004 |
| Formal training coverage (share of employees involved) | Continuous index (0-1) | COVER | 0,39 | 0,1 | 2002-2004 |
| Formal training expenditures per employee | Continuous | TRAIN-EXP | 160€ | 0, 1458€ | 2002-2004 |
| Presence of any formal training expenditures using internal firm sources (excluding public funding) | Dummy | TRAIN | 0,63 | 0,1 | 2002-2004 |
| Networking | | | | | |
| Networking index (summarising cooperative behaviour with private and public agents within and outside the local area) | Continuous index (0-1) | NETW | 0,18 | 0; 0,83 | 2000-2004 |
| Networking (any) | dummy | NET | 0,58 | 0,1 | 2000-2004 |
| University/ Research centres | Dummy | NET-RIC | 0,25 | 0,1 | 2000-2004 |
| Clients/Suppliers | Dummy | NET-CL | 0,40 | 0,1 | 2000-2004 |
| Other firms | Dummy | NET-OTH | 0,20 | 0,1 | 2000-2004 |
| Non local firms | Dummy | NET-OUT | 0,15 | 0,1 | 2000-2004 |
| outsourcing | Dummy | OUT | 0,46 | 0,1 | 2000-2004 |
| Other organisational variables | | | | | |
| High performance practices (TQM, Just in time, Quality circle, Team working) index | Continuous index (0-1) | HPP | 0,38 | 0,1 | 2000-2004 |
| High performance practices (taking value 1 if index is higher than average) | dummy | INNOORG | 0,33 | 0,1 | 2000-2004 |
| Labour related innovation index (on ten HRM practices; i.e. task rotation, formal evaluation) | Continuous index (0-1) | LAB-INNO | 0,32 | 0,1 | 2000-2004 |
| ICT index of adopted ICT-related innovations | Continuous index (0-1) | ICT | 0,28 | 0; 0,76 | 2000-2004 |
| ICT (taking value 1 if index is higher than average, core web ICT activities) | dummy | ICT1 | 0,50 | 0,1 | 2000-2004 |
| ICT (taking value 1 if index is higher than average, extensive ICT activities related to production) | dummy | ICT2 | 0,32 | 0,1 | 2000-2004 |
| Consultation with trade unions regarding innovation adoptions | Dummy | INDREL | 0,26 | 0,1 | 2000-2004 |

Table shows the all set of variables used in econometric exercises. Acronyms are shown for all variables entering final specifications.

Tab.5- Productivity Regressions: main drivers

| | | | | |
|--------------------|---------------|---------------|---------------|---------------|
| SIZE1 | 2,669*** | 1,960* | 2,076** | 2,546** |
| SIZE2 | 2,330** | 2,970*** | 2,799*** | 2,515** |
| SERV | 0,783 | 0,679 | 0,708 | 0,909 |
| MANUF | 1,483 | 1,626 | 1,847* | 1,708* |
| R&D-EXP | 2,416** | ... | ... | 2,508** |
| TRAIN-EXP | 3,261*** | 3,255*** | 3,247*** | ... |
| INNOTECH | ... | 2,081** | ... | ... |
| NETW | ... | ... | 2,031** | ... |
| COVER | ... | ... | ... | 3,539*** |
| F test (prob) | 3,34 (0,0006) | 3,28 (0,0008) | 3,23 (0,0009) | 4,04 (0,0001) |
| Adj-R ² | 0,138 | 0,135 | 0,132 | 0,172 |
| N | 147 | 147 | 147 | 147 |

Notes: Dependant variable is productivity trend 2003-2004; (PROD); OLS corrected for heteroskedasticity is used as estimation tool; the four states of the world are used in place of the constant term (not shown). We recall coefficients should not to be interpreted as elasticities; the table shows t ratios and emphasises statistical significance of coefficients at 10%, 5% and 1% (*, **, ***) levels. Besides size and sector dummies, only significant controls are presented in this table. The variable SIZE when included in place of size dummies is significant at ***: overall fit is unaffected.

Tab.6a Complementarities and drivers interactions: econometric outputs

| <i>Dependant variable</i> | <i>Variables on which complementarity is tested</i> | <i>comment</i> |
|---------------------------|---|--|
| PRODUC | R&D-EXP, NET | Interaction with positive sign but not significant, net dummy significant (+) |
| PRODUC | R&D-EXP, NETW | Interaction with positive sign but not significant, networking significant (+) |
| PRODUC | R&D-EXP, NET-CL | Interaction with positive sign but not significant, net dummy significant (+) |
| PRODUC | R&D-EXP, NET-RIC | Interaction with positive sign but not significant, net dummy not significant |
| PRODUC | R&D-EXP, NET-OTH | Interaction with positive sign but not significant, net dummy not significant |
| PRODUC | R&D-EXP, OUT | Interaction with positive sign but not significant, net dummy not significant |
| INNOTECH | R&D-EXP, NET | Interaction with negative sign and significant, net dummy significant |
| INNOTECH | R&D-EXP, NETW | Interaction with negative sign and significant, networking significant |
| INNOTECH | R&D-EXP, NET-CL | Interaction with negative sign and significant, net dummy significant |
| INNOTECH | R&D-EXP, NET-RIC | Interaction with negative sign not significant, net dummy significant |
| INNOTECH | R&D-EXP, NET-OTH | Interaction with negative sign but weakly significant, net dummy not significant |
| INNOTECH | R&D-EXP, OUT | Interaction with positive sign not significant, net dummy significant |

Tab. 6b complementarities (R&D, networking, organisational innovation) tests in a discrete setting: outputs from productivity and innovation functions

| <i>Dependant variable</i> | <i>Variables on which complementarity is tested</i> | <i>One sided T test (t ratio for the test)</i> |
|---------------------------|---|--|
| PRODUC | R&D, NET | 1,14 |
| PRODUC | R&D, NET-RIC | 0,93 |
| PRODUC | R&D, NET-OTH | -1,06 |
| PRODUC | R&D, NET-CL | 1,16 |
| PRODUC | R&D, NETOUT | 0,36 |
| PRODUC | R&D, OUT | 0,58 |
| PRODUC | R&D-1, NET | -0,35 |
| PRODUC | R&D-1, NET-RIC | 0,60 |
| PRODUC | R&D-1, NET-OTH | -0,06 |
| PRODUC | R&D-1, NET-CL | 1,48 |
| PRODUC | R&D-1, NETOUT | 1,39 |
| PRODUC | R&D-1, OUT | -0,22 |
| PRODUC | NET, INNOORG | 0,67 |
| PRODUC | NET, ICT1 | 1,63 |
| PRODUC | NET, ICT2 | 1,07 |
| PRODUC | R&D, INNOORG | -1,13 |
| PRODUC | R&D, ICT1 | -0,90 |
| PRODUC | R&D, ICT2 | -0,73 |
| PRODUC | R&D-1, INNOORG | -0,48 |
| PRODUC | R&D-1, ICT1 | -0,19 |
| PRODUC | R&D-1, ICT2 | -0,61 |
| INNOTECH | R&D, NET | 0,17 |
| INNOTECH | R&D, NET-RIC | 0,67 |
| INNOTECH | R&D, NET-OTH | -1,73 |
| INNOTECH | R&D, NET-CL | 0,26 |
| INNOTECH | R&D-NETOUT | 0,44 |
| INNOTECH | R&D, OUT | 0,26 |
| INNOTECH | R&D-1, NET | -0,36 |
| INNOTECH | R&D-1, NET-RIC | -0,73 |
| INNOTECH | R&D-1, NET-OTH | -1,17 |
| INNOTECH | R&D-1, NET-CL | -0,71 |
| INNOTECH | R&D-1, NETOUT | 0,17 |
| INNOTECH | R&D-1, OUT | 0,06 |
| INNOTECH | NET, INNOORG | 0,28 |
| INNOTECH | NET, ICT1 | -0,52 |
| INNOTECH | NET, ICT2 | 1,52 |
| INNOTECH | R&D, INNOORG | -0,50 |
| INNOTECH | R&D, ICT1 | 0,66 |
| INNOTECH | R&D, ICT2 | 0,32 |
| INNOTECH | R&D-1, INNOORG | -1,37 |
| INNOTECH | R&D-1, ICT1 | 0,10 |
| INNOTECH | R&D-1, ICT2 | 0,05 |
| PROC | R&D, NET | -1,73 |
| PROC | R&D, NET-RIC | -0,54 |
| PROC | R&D, NET-OTH | -2,25 |
| PROC | R&D, NET-CL | -1,38 |
| PROC | R&D-NETOUT | -1,97 |
| PROC | R&D, OUT | 0,28 |
| PROC | R&D-1, NET | -1,74 |
| PROC | R&D-1, NET-RIC | -1,02 |
| PROC | R&D-1, NET-OTH | -1,93 |
| PROC | R&D-1, NET-CL | -1,71 |
| PROC | R&D-1, NETOUT | -1,34 |
| PROC | R&D-1, OUT | 0,10 |
| PROD | R&D, NET | 0,15 |
| PROD | R&D, NET-RIC | 0,68 |
| PROD | R&D, NET-OTH | 0,61 |
| PROD | R&D, NET-CL | 0,41 |
| PROD | R&D-NETOUT | 1,98 |
| PROD | R&D, OUT | 0,40 |
| PROD | R&D-1, NET | 0,001 |
| PROD | R&D-1, NET-RIC | -0,35 |
| PROD | R&D-1, NET-OTH | 0,90 |
| PROD | R&D-1, NET-CL | -0,70 |
| PROD | R&D-1, NETOUT | 0,46 |
| PROD | R&D-1, OUT | -0,96 |

Fig.1 The Emilia Romagna Region, Northern Italy



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