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DEMAND PULL AND TECHNOLOGICAL FLOWS WITHIN INNOVATION SYSTEMS: THE INTRA-EUROPEAN EVIDENCE

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Demand pull and technological flows within innovation systems: the intra-European evidence

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Abstract

We investigate the demand pull effects on sector-level total factor productivity growth. Such effects stem from the knowledge interactions carried by the market transactions of intermediate inputs between competent customers and innovative suppliers. Both knowledge interactions and transactions are substantial ingredients in making the competent demand operate the positive impact on productivity growth of the entire economic system. The demand pull hypothesis is, thus, rejuvenated through the focus on the inter-sectoral linkages between competent users and innovative producers. In the empirical analysis based on a dynamic panel technique, we implement intermediate flows from input-output tables, qualified by productivity increases downstream, in order to investigate their joint influence on the upstream growth of productivity. The evidence Union of the derived demand-driven influence regarding the European (EU) over the period 1995-2007 is strong and positive, but varies between three EU innovation systems, EU core, East and South.

Keywords Derived demand · Productivity growth · Pecuniary knowledge externalities · Sectoral composition

JEL Classification L16 · O3 · O52

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1 Introduction

The paper explores the effects of the sectoral architecture of economic systems and sectoral interactions on the rate of upstream introduction of technological innovations. It relies on an analytical framework that uses the new understanding of economics of knowledge about the central role of external knowledge to qualify the demand pull hypothesis and applies it to input output methodology. More precisely, we focus on the role of knowledge interactions in the generation of technological knowledge and in the eventual introduction of technological innovations. Such knowledge interactions are crucially based on connections that are provided by the market transactions through which the creative users direct their derived demand towards innovative suppliers. The latter receive from the former not only the orders of goods, but also essential knowledge inputs that they use in responding to out-of-equilibrium market conditions as much as demand of innovative suppliers helps the former to generate new technological knowledge and fasten their rates of introduction of new technologies (Antonelli and Gehringer, 2012).

In our conceptual framework, thus, we refer to the demand-pulling hypothesis, according to which impulses generated by demand may stir economic system to grow thanks to productivity improvements on the supply side. Nevertheless, we provide a new meaning to the role of demand in the productivity-based growth process. Indeed, we recognize the crucial contribution offered by Nicolas Kaldor and of Jacob Schmookler in formulating the standard demand-pulling hypothesis. [2] Yet our articulation recognizes the crucial impact on growth not of the aggregate demand but of the derived demand, through which specialized customers acquire intermediate inputs from their upstream suppliers. In this context, the demand-pulling mechanism becomes effective under two conditions. First, the increase in demand is qualified through the positive rates of productivity increase by the users (Peters *et al.*, 2012). Building upon the recent advances of the literature on procurement, the demand pull hypothesis is enriched by a stronger emphasis on the role of the competence of the users (Edquist *et al.* 2000; Hommen and Rolfstam, 2009). Second and consistently, market-based demand flows are accompanied by knowledge interactions, thanks to which knowledge externalities come sufficiently into play (Scherer, 1964).

Applying the basic tools of input-output analysis, we identify - separately for Eastern, Southern and EU core country groups - the spectral architecture of economic systems that are most

[2] Kaldor (1966 and 1972) assigned the crucial role to the support of the aggregate demand through the growth-oriented public intervention. Schmookler (1966) refined such a hypothesis, by advocating the role of specific demand-enhancing investment in provoking further positive repercussion on the system's economic growth.

effective to support the rate of introduction of upstream innovations economy-wide. In this context, the notion of demand pull technological change finds new support and a new specification.

The empirical evidence confirms that the rate of technological change at the system level is, indeed, pulled by the growth of the derived demand, but only when the rate of technological change of each industry is accounted for (Antonelli and Gehringer, 2012). The main outcome of the paper consists in the identification of the types of sectoral architectures that support faster rates of introduction of innovations. Such sectoral architectures are able to activate – more than others – the intersectoral knowledge complementarities that take place by means of transactions-*cum*-knowledge interactions. Market transactions-*cum*-knowledge interactions are essential in channeling and valorizing knowledge externalities spilling from the creative customers. The latter direct their derived demand to innovative sectors and fasten their rates of introduction of innovations.

The rest of the paper is structured as it follows. Section 2 provides the foundations of the economics of knowledge and elaborates the basic hypotheses. Section 3 presents the empirical analysis based upon input-output tables for 15 European countries, belonging both to the old and the new EU members, in the years 1995-2007. The last section summarizes the main results and elaborates some policy implications.

2 Knowledge interactions within industrial structures

2.1 Knowledge interactions and knowledge externalities

Recent advances in the economics of knowledge stress the central role of external knowledge and knowledge interactions in the generation of new technological knowledge. More specifically, the new analysis on the generation of technological knowledge as a specific and dedicated activity appreciates the generation of technological knowledge as a process of recombination of existing units or items of knowledge. The larger is the number of knowledge items that can be included in the recombination, the larger are *ceteris paribus* the chances to actually generate new technological knowledge. This implies that technological knowledge is itself the primary input into the introduction of technological innovations and their adoption (Antonelli, 2008). In this context, however, no agent can command ‘intramoenia’ all the necessary knowledge items. A relevant part of the knowledge items that enter the recombination process are acquired and accessed from external sources. External knowledge is an indispensable and non-disposable input into the recombinant generation of new knowledge. Additionally, it follows that, because firms do not possess all the necessary knowledge within the borders of its organization, no of them can generate new knowledge in isolation. The access to existing knowledge that is being generated or has been generated by other firms is crucial to be able to generate new knowledge.

The second pillar of the new understanding of the knowledge generation process concerns the conditions and terms of accessing external knowledge. Because of the irreducible tacit content of technological knowledge that cannot be fully codified, the actual use of a large part of external knowledge can take place only by means of direct interactions between users and producers based on embodied and disembodied knowledge. Finally, the third pillar builds upon and is a consequence of the other two. Its central element is anchored in the existence of knowledge externalities that essentially drive productivity improvements, being the product of successful knowledge-based interactions.

In this context, thus, interactions among learning agents are crucial. Knowledge transactions are not sufficient to perform the actual transfer of knowledge from one party to another. The actual access to external knowledge requires dedicated knowledge interactions among parties that accompany and complete transactions among the same parties (Lundvall, 1985; Von Hippel, 1976, 1988, 1994, 1998, 2005). In turn, such transactions can be knowledge transactions – i.e. transactions such as the purchase of patents and licenses - or more often knowledge interactions that parallel and complement the transactions of goods that embody new knowledge items. In both cases, the direct assistance and participation of knowledge possessors is strictly necessary for users that try and enter the external knowledge into their own knowledge re-combinatory generation process.

Effective knowledge interactions make external knowledge available to the agents that are attempting to generate new technological knowledge. But crucial here is that knowledge interactions are not free or accidental. In the words often used in the past contributions, they do not fall from heaven like manna. Nor can knowledge externalities be considered as pure externalities that take place with no market exchanges. Consequently, knowledge externalities are pecuniary rather than pure. They occur through market-based knowledge interactions that are the result of deliberate attempts to try and build relations able to transfer technological knowledge (Gehringer, 2011a). As such, they bear a more or less substantial cost. When knowledge interactions are cheap and effective, agents can access external knowledge - the indispensable input into the generation of new knowledge - at costs that are below normal-good's equilibrium levels. This feature derives from the quasi-public good characteristics of knowledge that make it impossible to assign the market price of knowledge reflecting its true value. Hence, knowledge characteristics and knowledge interactions are the cause and the condition that make pecuniary knowledge externalities possible.

From the above discussion, the notion of knowledge transactions-*cum*-interactions becomes central. Transactions-*cum*-interactions can be identified within a continuum where at one extreme one can find pure transactions that take place with no knowledge interactions and at the other pure knowledge interactions that take place without transactions. Within these two extremes there are many possible combinations where transactions between customers and suppliers imply some levels of knowledge interactions. Pure interactions may take place occasionally and, indeed, may play a role. Their occurrence, however, seems unpredictable and cannot be integrated into an intentional strategy aimed at the generation of new knowledge. Pure transactions, at the other extreme, with no knowledge interactions, are also possible. Their occurrence seems likely to be dependent on the levels of knowledge intensity of both parties. The lower is the level of innovation activity in place the lower is the occurrence of knowledge interactions that accompany commercial transactions. The domain of transactions-*cum*-knowledge interactions takes place in the wide region comprised between the two extremes of pure transactions and pure interactions among innovative parties that are committed to the generation of technological knowledge. We articulate the hypothesis that the content of knowledge interactions that take place together with transactions is influenced by the intensity of innovative activity in place in either of the parties.

2.2 Knowledge interactions in the past literature

Much work has been done by the applied economics of knowledge to identify the structure of knowledge interactions among agents within regions and local innovation systems and their effects on the flows of knowledge. Network analysis has been applied successfully to identify the types of structures of knowledge interactions and the role of individual agents within it. The identification of the variety of network at work made it possible to better appreciate their effects on the actual amount of the flows of knowledge: some networks are better than others and some positions within each network yields more than the others in terms of the actual access to the knowledge flows (Ozman, 2009).

The remarkable achievements of the applications of network analysis to understanding the knowledge flows among individuals, within industries and regions, can be replicated when we focus on the architecture of the flows of goods that take place among industries and when we analyze it as a possible map for grasping the flows of knowledge interactions that are associated with market transactions.

Bearing in mind the results from the network analysis, the understanding of the strength and direction of such flows and of the effects that follow might be enhanced by grasping the implications of the life-cycle theory (Malerba et al., 2003). Concentrating on the demand-side dynamics, the important hypothesis from the life-cycle theory recognizes the presence and the operating of the network and bandwagon effects. Thanks to such effects, the users have the chance to concentrate their competences on the exploitation of a particular design. If the involvement of the customers in such a cognitive process arrives at the necessary threshold, the suppliers willing to survive will stick to the new prevailing design.

After the pathbreaking contributions of Terleckyj (1974 and 1980) and Scherer (1982b) to the investigation on the effects of inter-industrial flows of embodied technological change on the rate and direction of innovative activity, the more recent analysis has dedicated lesser attention to the effects of the sectoral architecture of economic systems and paid much more attention to other issues such as the relations between innovation on the industrial demography, the entry-exit dynamics of firms, their growth and internal development strategies (Geroski, 1994; Audretsch, 1995; Bottazzi *et al.*, 2002).

The analysis of national innovation systems has made it possible to bring back into the light cone of research the analysis of the links between innovation and industrial structure by re-discovering that industrial structures are a key component of innovation systems (Malerba, 2005).

Within the innovation system conceptual framework, however, issues that attracted much attention relate to the architecture of networks of agents (Hughes, 1984; Callon, 1992; Carlsson and Stankiewitz, 1995), the organization of research institutions and their relations with the business sector (Etzkowitz and Leydesdorff, 2000; Leydesdorff and Meyer, 2006, Boland *et al.*, 2012)[3], the regional distribution of innovative activities and the role of geographical clusters (Cook, 2001; Asheim and Isaksen, 2002), the mobility of skilled personnel among firms and between academic institutions and firms (Breschi and Lissoni, 2009). Instead, the new acquisitions of the economics of knowledge provide important opportunities to analyze the role of the industrial structure of an economic system from the viewpoint of the organization of the flows of transactions and, hence, knowledge interactions as well as the appreciation of the flows of knowledge among sectors.

2.3 The architecture of user-producer knowledge interactions and input-output analysis

In this context, input-output analysis provides the basic tools to identify the flows of transactions among industries. Complementary to this, the new understanding of the role of transactions-*cum*-interactions, i.e. knowledge interactions that take place along with business transactions, enables to

[3] Regarding the investigation of the relationship between the institutional and industry factors and their influence on innovation, authors refer to the so called Triple Helix Model. This model is distinct from the national systems of innovation approach (Freeman, 1987; Lundvall, 1988) because not the firms, but the university is supposed to play a role in enhancing innovation.

appreciate the structure of transactions that occur within an economic system. This provides a major clue to grasp the flows of knowledge interactions that accompany the exchanges of goods (Evenson and Johnson, 1997).

Based on such methodological tool, crucial in our approach is the recognition that industrial structures differ. The differences are both synchronic and diachronic. At each point in time, the comparative analysis of multiple industrial structures enables to note that both the flows of intermediary inputs and the centrality of some sectors are highly idiosyncratic. Each system exhibits characteristics and specificities that are not found in other systems (Gehringer, 2011b). Moreover, industrial structures are not static: they change over time. The historical development of industrial structures is marked by the succession of eras, within which different technologies play a dominating role (Malerba *et al.*, 2003).

Industrial structures are at the same time the cause and the consequence of technological change. Industrial structures are the cause of technological change, as some kinds of structures are more effective in organizing and channeling the flows of transactions-*cum*-knowledge interactions than others. As such, the rates of introduction of technological change are likely to be faster in more dynamic industrial structures. On the contrary, industrial structures are the consequence of technological change because the introduction of innovations, stemming from the effective flows of external knowledge, affects the composition of sectors, their differentiated rates of growth and modifies their degrees of centrality. This endogenous nature of the relation between the sectoral structure and technological change explains also the difficulty in empirically assessing their reciprocal roles.

This notwithstanding, the empirical investigation of the issue might be put in a framework, where the role played by technological change in influencing sectoral structure is considered from insight of the system. More precisely, changes in the sectoral structure derive from reciprocal relations between sectors interacting and/or performing transactions. In this context, the matrix of transactions between industrial sectors that participate to the delivery of intermediate and final products provides key information on the static architecture and dynamic properties of an economic system. Very much like network theory applications to the relations among individual agents, the matrix of transactions of intermediary inputs between industries enables to map the intensity of interactions among industries, the centrality of some industries with respect to the others.

The appreciation of the architecture of an economic system in terms of sectoral composition and strength of relations among sectors with varying levels of centrality is enriched by another aspect of technological change. In our approach, in fact, technological change matters with respect to two distinct and yet complementary dimensions: the rate of introduction of technological innovations and the rate of adoption of technological innovations. Too much attention has been paid to appreciating the determinants and the effects of the rates of introduction of technological changes and too little attention has been paid to appreciating the determinants and the effects determined by the rates and timing of adoption of technological innovations.

The timely adoption of technological innovations exerts a strong influence on the increase in the general efficiency of firms and, hence, of the whole economic system. Once again, the appreciation of the links among sectors and, consequently, the investigation of the effective, efficiency-driven flows of intermediary inputs between sectors enables to grasp the positive effects generated by the customers of the derived demand on innovative sectors. Such flows of intermediary inputs between innovative suppliers and creative users provide an effective proxy for the amount of embodied technological knowledge that flows among sectors and is actually transferred together with the purchase of innovative inputs, be they intermediary inputs or capital goods. The flows of knowledge embodied in new products that take place between users and producers complement the flows of disembodied knowledge: the diffusion of innovation supported by their creative adoption and the access to external knowledge are two components of the same general process of recombinant generation of new technological knowledge.

An important implication from the above discussion is that the users involved in the system experience productivity increases that are directly related to the innovative activity of the rest of the system. The contribution of the system to the actual levels of technological advance of each agent consists in the spillovers of pecuniary knowledge externalities entering the recombinant generation of technological knowledge and enabling the introduction of technological innovations. Such spillovers take place both in the provision of innovative inputs introduced by innovative –upstream- producers that are creatively adopted by –downstream- customers, and in the provision of knowledge inputs or knowledge impulses by sophisticated –downstream- users to their upstream producers.

Users cannot be any longer regarded as passive customers and, specifically, as passive adopters of innovations introduced upstream. Learning by using in fact is a powerful process of accumulation of competence that enables the adoption technological innovations and is at the origin of many innovations introduced by users to adapt the new capital good or intermediary input to their own needs. Creative adopters are able to accumulate specific competence by means of learn-by-use processes that make it possible to upgrade the inputs provided by upstream suppliers with the introduction of new technological knowledge and to transfer the knowledge acquired to the producers. The systematic user-producer interactions that parallel the flow of goods favor the knowledge feedbacks from users and adopters to the original supplies of the innovation.

The new appreciation of the powerful effects of learning by using in the adoption process complements the well known effect of learning by doing and makes it possible to appreciate both the upstream and the downstream linkages as important vectors of pecuniary knowledge externalities. Indeed, both effects are relevant carriers of knowledge spillovers that make more attractive because cheaper the recombinant generation of new knowledge, both in upstream producers and downstream users.

The twin appreciation of the effects of both elements leads directly to using total factor productivity measures as an effective proxy for grasping the full spectrum of external effects that affect the general efficiency of firms and systems at large. Such output-based measures of innovativeness, although subject to critique for some justifiable reasons, are supposed to grasp productivity improvements effectively occurring, even those not covered by the patent protection.[4]

Under the application of total factor productivity, the timely adoption of technological innovations will be the more creative and the faster the stronger are the links between customers and innovative suppliers. Perspective adopters involved in either low levels of transactions with highly innovative suppliers, or high levels of transactions with poor innovators will have lower chances to adopt timely existing technological innovations. Similarly, the larger the demand directed to innovative sectors from creative users, the larger the chances for suppliers to timely generate technological innovations.[5] But transactions alone do not determine the final outcome of the induced innovative activity. Indeed, to invigorate pecuniary knowledge externalities, complementary to transactions, a great role will be played by interactions between creative users and producers. Moreover, the final efficiency outcome of such transactions-*cum*-interactions does not necessarily depend on the (actual) degree of innovativeness of users and producers (Gehringer, 2012). Even apparently less innovative producers (users), through intensive and efficient knowledge-based interactions, are able to put in motion beneficial pecuniary knowledge

[4] Total factor productivity, being constructed as a residual, is often criticized by representing more a "measure of ignorance" than a rigorous measure of productivity. This notwithstanding, on the conceptual basis, given our aim to disentangle the contemporaneous reciprocal productivity influences, we consider TFP measures as more adequate than patent-based measures or R&D expenditures that are supposed to take longer until some measurable effects are to be observed. Moreover, given the lack of a more reliable alternative and given its extensive use in the past empirical investigations characterized by conceptually coherent conclusions (for instance, Eberhardt and Teal, 2012), we adopt a TFP indicator in the present analysis as well.

[5] In such a demand-driven technological change, the central role has been assigned to the profit incentive: thanks to the profits, the creative user will invest and thus increase the derived demand towards their suppliers (Andersen, 2007).

externalities. As a consequence, the rates of increase of total factor productivity of respective units will be the higher the more intensive is the joint effect of the strength of the links with the counterpart.

The joint appreciation of the introduction and the creative adoption of innovations makes better clear their intrinsic complementarity from a dynamic viewpoint. Introduction and adoption are not only complementary with respect to the actual definition of the bottom line efficiency of customers. They are complementary from a second and most important viewpoint. From the viewpoint of suppliers, in fact, the larger is the demand for their products and the larger will be the opportunity and the incentive to introduce technological innovations by the anxious customers, eager to purchase the new products, the stronger will be the incentive for the supplier to respond to these demand pulling impulses with the introduction of upstream innovations.[6]

Again here, recalling the concept of the matrix of intermediate transactions previously anticipated, it becomes evident that the input-output methodology provides the powerful tool to measure the amount of transactions that take place among the industries that are part of an economic system. Within this methodology, Leontief coefficients become particularly relevant as they measure the relative demand – direct and indirect – of intermediate inputs that each sector j demands from sector i in order to produce 1 unit of output going to the final demand. Complementary to this, the total factor productivity measures provide a reliable proxy of the amount of technological change that has been introduced by each sector. As such, considering our focus on inter-sectoral transactions-*cum*-interactions, weighted by efficiency-improving effects, we can articulate our central hypothesis. The sectors experiencing higher total factor productivity increases are likely to qualify their internal efficiency improvements thanks to transactions with other sectors that use their innovative output - accompanied by appropriate levels of knowledge interactions and, thus, knowledge externalities – to generate subsequent waves of derived innovations.

The analysis of user-producer interactions plays a central role in this context. Such interactions take place and accompany the transactions of all the other goods. Suppliers are supposed to help users to better exploit the goods that are being delivered. Such help is all the more

[6] The complementarity argument raised here is strictly related to the motivation discussed in Mohnen and Röller (2005) who investigate complementarities in innovation policy in Europe. They confirm the existence of such complementarity between different innovation policy measures that, nevertheless, depends on the stage of the innovation process. Moreover, the forces determining such effects might derive from the characteristics of the process of introduction and adoption of knowledge, but also from the reciprocal technical characteristics or subjective abilities of producers and users involved in interactions.

intensive, the faster the rate of introduction of innovations and hence the degree of novelty of the goods that are being purchased. High levels of upstream total factor productivity growth, consequently, are expected to generate an impact on high levels of total factor productivity growth in downstream sectors. Such a relationship is expected to be the stronger, the larger are the Leontief coefficients that account for the flows of derived demand of downstream sectors to innovative upstream ones. At the same time, however, the analysis of user-producer interaction makes possible to appreciate the central role of the derived demand expressed by advanced customers on the innovative capabilities of upstream producers. Here the complementarity in the innovation process works the other way around. Downstream sophisticated users with high levels of total factor productivity help their suppliers to learn about their superior production processes and higher product requirements and guide with the provision of knowledge interactions their own effort to introduce technological innovations that make it possible –for them- to cope with the higher quality of their customers.

It becomes now clear that, within the inter-industrial flows of goods, two specific and distinct knowledge complementarities –may- take place: A) downward complementarities take place when downstream sectors benefit from the purchase of intermediary inputs that embody superior technologies and stir the introduction of incremental innovations to adapt the new technologies to their own production process; B) upward complementarities take place when upstream sectors benefit from the derived demand coming from the other –downstream- sectors. In this case, the sophisticated demand of advanced users stirs producers to try and cope with higher standards of the downstream users and innovate in turn. This last hypothesis constitutes the core of our empirical investigation.[7]

3. Economics of knowledge and the new demand pull hypothesis

These arguments, concerning both the rates of introduction of technological innovations and their rates of adoption, enable to elaborate a new approach to the demand pull hypothesis. The demand pull hypothesis can be effectively rejuvenated by the combination of the classical demand pull hypothesis ala Kaldor (1966) and Schmookler (1966) with the new advances of the economics of knowledge (Antonelli and Gehringer, 2012).

The demand pull hypothesis has a new scope of application. It does not apply any longer to any undifferentiated increase of demand, as in the Kaldorian tradition. Nor is it limited to the

[7] This notwithstanding, we do not ignore the opposite, upstream-to-downstream influence. Consequently, in the empirical exercise that follows, we include a control variable that measures an average effect of innovative suppliers on productivity improvements downstream.

demand for capital goods, as in the tradition that elaborates upon Schmookler's analysis. In our approach, the demand pull hypothesis applies to the derived demand of goods at large, but simultaneously taking into account the sector-level rates of technological change, as proxied by the rates of increase of total factor productivity growth. This new, re-defined, scope of application of the classical demand pull hypothesis stems directly from the appreciation of the role of knowledge interactions as carriers of pecuniary knowledge externalities that make external knowledge available at costs that are lower than equilibrium levels.

The capability of a system to introduce and adopt timely technological innovations is influenced not only by the internal efforts to generate new technological knowledge, but also and most effectively, by the amount of external knowledge that flows between the sectors of the system, taking into account the strength of their links as measured by the Leontief coefficients.

For given levels of R&D activities, a system can be able to generate more technological knowledge and, hence, introduce and adopt faster technological innovations, according to the sectoral architecture of the system. The sectoral architecture of an economic system has major implication with respect to two specific and quite distinct mechanisms. A top-down mechanism by means of which knowledge spills from upstream suppliers to downstream users and a bottom-up mechanism where knowledge spills from downstream users to upstream producers. A system endowed with innovative sectors that have high levels of centrality can support the innovative performance of all the system with two specific dynamic mechanisms based upon the dissemination of knowledge and the activation of learning processes by means of knowledge interactions that accompany their commercial transactions: A) they can provide innovative inputs to many other sectors and B) they can demand innovative inputs from their suppliers, stimulating further innovations of the latter with demand-side knowledge impulses.

Sectoral architectures characterized by the centrality of such innovative sectors able to activate both downstream and upstream knowledge interactions will display higher levels of innovative performances than other systems where innovative sectors are either weak or poorly connected to the others. The composition of the system in terms of distribution of industrial sectors and the architecture of the links play a crucial role in assessing the innovative output of an economic system. The notion of structural complementarity in innovative performances at the system – as well as the agent level - acquires a clear economic content (Mohnen and Röller, 2005).[8]

[8] This complementarity argument that we advocate here relates to the contribution by Jacobs (1969) who recognizes the role played by the contribution of diverse and yet complementary pieces of knowledge in assuring increasing returns in economic activity.

The appreciation of the sectoral architecture of a system and the identification of the structural complementarities enable to grasp the pervasive role of technological congruence. Technological congruence is defined by the matching between the output elasticity of the inputs and their relative price in factor markets. High levels of technological congruence make it possible to increase the general efficiency of the production process. With a given budget, the output is larger the higher is the output elasticity of a given input and the lower its relative price. The sectoral architecture of an economic system contributes the levels of technological congruence. A sectoral architecture is 'good' when it is able to provide the rest of the system with a large and cheap supply of inputs that enter the production functions of other products with large output elasticities (Antonelli, 2012).

Building upon these arguments we explore in the rest of the paper the relevance and magnitude of the downstream-to-upstream linkages i.e. we analyze the effects of the demand expressed by downstream users, according to their own levels of technological advance upon the innovative performances of their upstream suppliers. We expect that the larger is the derived demand that is directed by advanced users, the larger are the opportunities and the incentives to introduce technological innovations in upstream sectors.

We can fully articulate our hypothesis according to which the rate of introduction and adoption of technological innovations, as proxied by the rate of increase of total factor productivity of a system, are larger: a) the higher the downstream Leontief coefficients that link each sector to the others, i.e. to extent to which each sector receives its derived demand from all the others that are part of the economic system, taking into account b) the downstream rates of introduction and adoption of technological innovations.

Economic analysis, so far, has paid more attention to the top-down mechanism of knowledge dissemination. The new analysis of the demand pull hypothesis carried out in this article enables to focus the necessary attention to the important role of the bottom-up mechanisms of knowledge dissemination and stimulation.

From this viewpoint the evidence confirming the role of the bottom-up mechanism within the demand-pulling hypothesis is not scarce. Numerous contributions engaged in investigating the link between demand forces and upstream innovativeness. Those studies differ, most importantly in three dimensions regarding the choice of the method to measure innovativeness, the choice of the aggregation level and the choice of the empirical method. More precisely, to measure innovativeness, different indicators have been implemented: dedicated patents (Scherer, 1982), R&D expenditures (Jaffe, 1988; Kleinknecht and Verspagen, 1990), total factor productivity (Jaffe, 1988) and labor productivity (Crespi and Pianta, 2008). Moreover, the aggregation levels have been chosen between the sector-level and firm-level (Brouwer and Kleinknecht, 1999; Piva and

Vivarelli, 2007). Finally, the choice of the empirical strategies was based on the case-study analysis as in Walsh (1984), Nemet (2009) and Guerzoni (2010), or on econometric estimation methods, like in Antonelli and Gehringer (2012). A major contribution to re-assessing the demand pull hypothesis within the framework of the economics of knowledge has been made by the literature on procurement and specifically by the pathbreaking contribution of Clarles Edquist and colleagues at Lund Univerity (Edquist *et al.*, 2000; Mommen and Rolfstam, 2009) who have shown how important is the role of sophisticated users in guiding upstream suppliers towards the generation of new technological knowledge and the eventual introduction of technological innovations. Their contribution has revealed that the traditional demand pull mechanism can be fruitfully enriched by the appreciation of the central role of the bottom-up flows of knowledge 'spilling' upstream from customers to suppliers,

Consequently, our empirical analysis implements the two-digit sector-level data in a dynamic model setting, dedicated to grasping the new demand-pull hypothesis that focuses not only the bottom up mechanisms of knowledge dissemination but also the subsequent innovation inducement.[9]

4. Estimation strategy

The scope to grasp the effects of the inter-industrial flows of transactions-*cum*-knowledge interactions requires the design of the empirical model able to account for the simultaneous role of both transactions *and* interactions. In what follows, we first derive the main estimation framework. Then we describe the data and their source. Finally, we present the estimation procedure and discuss the main results.

4.1 The empirical model

The analysis of the input-output context permits to appreciate it as a crucial source of valuable information on inter-sectoral flows of intermediate goods. However, as it has been discussed in the previous section, the transactions alone do not deliver insights on productivity influence stemming from them. For that reason, we construct a framework, in which we extrapolate from the entire

[9] The debate on the validity of the demand-pulling hypothesis and on the empirical strategies for its verification was attracting a lot of attention especially in the 1980s. There are prominent contributions (Mowery and Rosenberg, 1979; Dosi, 1982; Geroski and Walters, 1995; Di Stefaon et al., 2012) which succeeded in discussing some important methodological issues referred to the demand-pulling empirical evidence. For an overview, see Antonelli and Gehringer (2012).

spectrum of intermediate transactions those that originate from dynamically efficient users and result in productivity improvements of dynamically efficient producers.

Input-output framework and knowledge-based inter-sectoral transactions

Given input-output tables for country g and time t, let's define matrix $\mathbf{A}_{g,t}$ as the matrix of technical coefficients:

$$\mathbf{A}_{g,t} = \mathbf{C}_{g,t}\left(\widehat{\mathbf{X}}_{g,t}\right)^{-1} \qquad \text{or also} \qquad \mathbf{A}_{g,t}x_{g,t} = c_{g,t} \tag{1}$$

where $c_{g,t}$ is the vector of total intermediate inputs supplied by each row sector and $\left(\widehat{\mathbf{X}}_{g,t}\right)^{-1}$ is the diagonal matrix of total sectoral output represented in a column vector $x_{g,t}$. Each element of matrix $\mathbf{A}_{g,t}$, given by $a_{ij,g,t}$, expresses direct requirements of intermediate goods that sector j demands from sector i in the production of one unit of output of j (i, j=1, …, N).[10]

From the input-output model - describing for each row sector the distribution of its total output between the intermediate and final uses - we have:

$$c_{g,t} + y_{g,t} = x_{g,t} \tag{2}$$

with $y_{\mathrm{g,t}}$ being the vector of final demand. Substituting for $c_{g,t}$ an adequate expression from equation (1), we have

$$\mathbf{A}_{g,t}x_{g,t} + y_{g,t} = x_{g,t} \tag{3}$$

that, after simple matrix algebra, gives

$$\mathbf{B}_{g,t}y_{g,t} = x_{g,t}. \tag{4}$$

Matrix $\mathbf{B}_{g,t}$ is called Leontief's inverse matrix, in which each single element, $b_{ij,g,t}$, describes direct and indirect requirements that industry j demands from industry i in order to produce one additional unit of goods in industry j going to final demand. This matrix, thus, describes the full spectrum of market-based bi-directional relative transactions between using and producing sectors. Among such transactions, we focus on those going from each producer to the respective users. Moreover, we are interested in transactions that are accompanied by the productivity improvements. For that reason, for each row sector from the input-output tables, we construct a vector $r_{i,g,t}$ in the following way

[10] We apply standard notation, according to which matrices are in bold and with capital letters, whereas scalar and vector variables are in italics and lower-cases letters. Moreover, matrix and vector components are in lower-cases italic letters.

$$r_{i,g,t} = b_{i,g,t} p_{g,t} \quad (5)$$

where $b_{i,g,t}$ is a transpose vector of the i-th row vector from matrix $\mathbf{B}_{g,t}$ and $p_{g,t}$ is a vector of sectoral productivity growth rates.[11] Each element of vector $r_{i,g,t}$ expresses direct and indirect relative intermediate demand for inputs offered by i to all the sectors in the national system, qualified, however, by the productivity increases experienced by the using sectors. This vector will be subsequently included in the estimating equation.

Finally, along the entire empirical procedure, as a measure of sector-level productivity growth we use the logarithmic growth rate of TFP. With this measure, which adopts the standard growth accounting framework based on a constant returns Cobb-Douglas production function, we follow Jorgenson and Griliches (1967) and Jorgenson et al. (1987). The functional form of the TFP growth rate is given by

$$\Delta \ln \mathrm{TFP}_{i,g,t} = \Delta \ln x_{i,g,t} - \bar{\alpha}^{k}_{i,g,t} \Delta \ln k_{i,g,t} - \bar{\alpha}^{l}_{i,g,t} \Delta \ln l_{i,g,t} - \bar{\alpha}^{c}_{i,g,t} \Delta \ln c_{i,g,t} \quad (6)$$

where $x_{i,g,t}$ is total output of sector i in country g at time t, $k_{i,g,t}$ is sectoral capital stock, $l_{i,g,t}$ is labour force measured in terms of total employment and $c_{i,g,t}$ expresses intermediate inputs. Moreover, $\bar{\alpha}^{f}_{i,g,t}$ where $f = (k, l, c)$ denotes the two-period average share of factor f over the nominal output defined as follows:

$$\bar{\alpha}^{f}_{i,g,t} = \left(\alpha^{f}_{i,g,(t-1)} + \alpha^{f}_{i,g,t}\right) / 2 \quad (7)$$

whereas

$$\alpha^{l}_{i,g,t} = l_{i,g,t} / x_{i,g,t} \; ; \quad \alpha^{c}_{i,g,t} = c_{i,g,t} / x_{i,g,t} \text{ and } \quad \alpha^{k}_{i,g,t} = 1 - \alpha^{l}_{i,g,t} - \alpha^{c}_{i,g,t} \, . \quad (8)$$

The model

Given such knowledge-based inter-sectoral transactions-*cum*-interactions and their influence on productivity growth upstream, the dynamic panel model to estimate assumes the following form:

$$\Delta \ln \mathrm{TFP}_{i,g,t} = \beta_1 + \beta_2 \Delta \ln \mathrm{TFP}_{i,g,t-1} + \beta'_3 r_{i,g,t} + \beta'_4 z_{i,g,t} + \gamma_g + \delta_i + \mu_t + \varepsilon_{i,g,t} \quad (9)$$

where β_1 is a constant, $\Delta \ln \mathrm{TFP}_{i,g,t-1}$ is the lagged dependent variable referring to sector i, country g and time t, γ_g, δ_i and μ_t are the country, sector and time specific effects, respectively, and $\varepsilon_{i,g,t}$ is

[11] Expressed as a row vectors, we have $b'_{i,g,t} = [b_{i1,g,t} \; \cdots \; b_{ij,g,t} \; \cdots \; b_{iN,g,t}]$ and $p'_{g,t} = [\Delta ln\mathrm{TFP}_{1,g,t} \; \cdots \; \Delta ln\mathrm{TFP}_{j,g,t} \; \cdots \; \Delta ln\mathrm{TFP}_{N,g,t}]$.

the idiosyncratic error term. Vector $r_{i,g,t}$ includes explanatory variables measuring the productivity-enhanced demand-side influence. In particular, each of the 19 variables in vector $r_{i,g,t}$ refers to each pair ij, where j referes to single manufacturing and service sector, going from "food" to "real estate", and is constructed as a product between the corresponding Leontief coefficient $b_{ij,g,t}$ (expressing the relative demand – direct and indirect – of intermediate inputs that sector j demands from sector i in order to produce 1 unit of final demand) and the growth rate of TFP of the corresponding sector j.[12] Finally, vector $z_{i,g,t}$ includes three control variables, namely, a variable measuring an average supply-side influence on the productivity growth of sector i deriving from all linkages that this sector maintains with its suppliers by means of intermediate inputs transactions, in addition to sectoral unit wages, sector-level final demand and sector-level R&D expenditures in % of sectoral output.[13] Regarding the variable expressing the average influence coming from the supply-side, its inclusion is motivated by the necessity to account for both the demand- and supply-side effects in a unique framework. This hypothesis we have already discussed in the previous section. Moreover, it has been confirmed in the past empirical investigations for instance by Mowery and Rosenberg (1979) and more recently by Arthur (2007). Finally, the inclusion of sectoral unit wages, of sector-specific final demand and of the R&D variable should separate their possible influence on the TFP growth from the demand-pulling effect, on which we focus.

4.2 Data source and description

The estimation of the general model presented in equation (9) refers to an unbalanced panel of 19 manufacturing and service sectors in 15 EU countries, observed over the period 1995-2007. In particular, limitedly to the data availability, we include both the old and the new EU member states. Given that we are interested in differences in the relative importance of single sectors within the EU, we estimated equation (9) separately for three groups of countries. More precisely, we split our sample of 15 countries into core EU, East and South.[14] This distinction is reasonable based on the observation of differences in the TFP dynamics between these country groups, as discussed below.

[12] For a full list of sectors taken under analysis, see Appendix A.1.

[13] The method used to construct the variable expressing an average supply-side influence has been described in Appendix A.2.

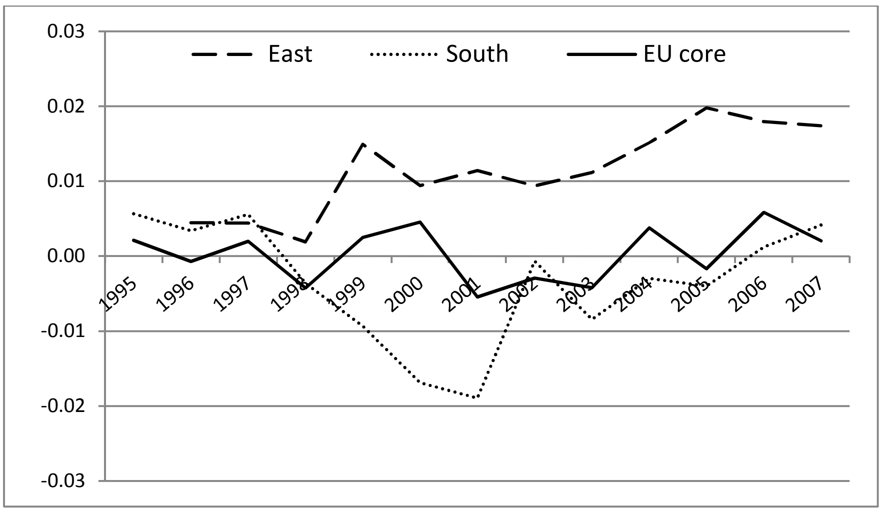
[14] The core EU is composed by Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Sweden and the UK. South refers to the three Mediterranean economies, i.e. Italy, Portugal and Spain. Finally, due to the data limitations, to the group of East belong only three countries, namely, the Czech Republic, Hungary and Slovakia. It can be argued that within the group of the core EU might be further

Annual input-output tables, used to calculate the inverse Leontief matrices, have been taken from World Input-Output Database (WIOD). The rest of the data necessary to calculate the logarithmic growth rate of TFP as well as the sector-specific unit wage come from OECD STAN database.

Regarding the calculation of TFP growth rates, the time series of capital were missing in some countries. In such a case, we calculated the time serieses of capital implementing data on sectoral investment and using the perpetual inventory method.

Summarizing the outcomes of the calculation of TFP, by considering the averages for three country groups, a rather clear picture emerges. In Figure 1 we plot the annual growth rates of aggregated TFP for East, South and EU core in the entire analysed period 1995-2007. A clearly and distinguishing positive development could be observed for East, especially after 1998, thus, after the impact from the post-transition recession broadly expired. Even if there were periods of lower TFP growth rates, they were showing an increasing tendency over the whole analysed time span.

Both the EU core and South were performing worse than East, with periods of positive and negative TFP growth rates. Nevertheless, it seems that at least since 1998, thus, corresponding to the eve of the Eurozone, the developments in those groups of countries were remarkably diverging, with the core EU reaching positive TFP growth rates in some years, whereas South was reporting negative growth rates at least between 1998 and 2006. This short analysis should justify our choice to take the within-EU heterogeneity into account and to treat the three groups of countries separately, in order to compare their respective industrial pictures.



distinguished between Northern EU countries and the rest core. We tried also this combination, but the estimation results did not change considerably.

Figure 1 TFP annual growth rates in the EU country groupings, averaged over the manufacturing and service sectors.

Source: Own calculations based on OECD STAN database.

Finally, Table 1 offers summary statistics of the variables included in the estimations. The statistics for TFP growth rates are comparable between country groups. However, the average growth rate of TFP for South reports a negative sign, broadly in line with the tendencies seen in Figure 1. A similar observation regards the remaining sectoral variables.

Table 1 Descriptive statistics

	EU core			East			South		
	Obs.	Mean	St. dev.	Obs.	Mean	St. dev.	Obs.	Mean	St. dev.
tfp	2887	0.0003	0.035	850	0.0118	0.048	783	-0.005	0.046
food	2900	0.0001	0.004	850	0.0003	0.012	800	-0.0001	0.010
textiles	2900	0.0001	0.004	850	0.00002	0.006	800	0.0001	0.009
wood	2900	-0.0011	0.006	850	0.0015	0.012	800	-0.003	0.011
paper	2900	0.00004	0.006	850	0.0008	0.008	800	-0.0001	0.007
chemicals	2900	0.0003	0.014	850	-0.0004	0.010	800	-0.0011	0.017
rubber & plastic	2900	0.0003	0.008	850	0.0013	0.009	800	-0.0001	0.008
other non met.	2900	0.0001	0.005	850	0.0011	0.008	800	0.0001	0.008
basic met.	2900	0.0002	0.006	850	0.0008	0.008	800	-0.0011	0.019
mach. &equip.	2900	0.0003	0.006	850	0.0008	0.008	800	0.0001	0.009
electr. equip.	2900	0.0003	0.012	850	0.0016	0.011	800	0.0001	0.011
trans. equip.	2900	0.0001	0.014	850	0.0012	0.009	800	0.0002	0.020
manuf nec	2900	-0.0001	0.006	850	0.0009	0.009	800	-0.0001	0.007
electr, gas & wat.	2900	0.0003	0.008	850	-0.0001	0.013	775	-0.0004	0.009
construction	2900	-0.0004	0.005	850	0.0002	0.012	775	-0.0006	0.014
wholesale	2900	0.0003	0.005	850	0.0018	0.009	775	-0.0005	0.004
hotels & restaur.	2900	-0.0007	0.009	850	-0.0013	0.013	775	-0.0006	0.004
transport	2900	0.0004	0.006	850	0.0010	0.008	775	-0.0003	0.006
finance	2900	0.0005	0.010	850	0.0010	0.015	775	-0.0002	0.010
real esate	2900	0.0003	0.005	850	0.0014	0.010	775	0.0006	0.007

4.3 Estimation strategy and the results

Our empirical strategy consists in two steps. In the first step, we consider the model in equation (9) and apply standard econometric techniques on it. In the second step, we use the results obtained in the first step and transform them into ratios expressing the relative importance of each sector in a given context. We repeat the same procedure for three distinct groups of countries, the core EU, East and South.

We estimate the model presented in equation (9) according to the system GMM method elaborated by Arellano and Bover (1995) and Blundell and Bond (1998). This method appears to be particularly attractive in our context, in which we are focusing on the contemporaneous external effects between sectors, yet major endogeneity concerns exist. Their methodology is based on a system of two equations. The first one is a difference equation, in which variables expressed as first-differences are instrumented with theirs lagged levels. The second one is the equation with variables in levels instrumented with their own lagged first-differences. To be valid, the following assumptions need to hold:

$$E\left[d\left(\mathrm{TFP}_{i,g,1}\right)\varepsilon_{i,g,t}\right]=E\left[r_{\mathbf{i1}}^{n}\varepsilon_{i,g,t}\right]=E\left[z_{\mathbf{1t}}^{m}\varepsilon_{i,g,t}\right]=0,\ \forall\ m,n \text{ and t= 2, …, T}$$
$$E\left[\Delta d\left(\mathrm{TFP}_{i,g,2}\right)\left(\gamma_g+\delta_i\right)\right]=E\left[\Delta r_{i2}^{n}\left(\gamma_g+\delta_i\right)\right]=E\left[\Delta z_{\mathbf{2t}}^{m}\left(\gamma_g+\delta_i\right)\right]=0, \forall\ m,n\ and\ t=\ 2, \ldots, \mathrm{T}$$

where $n \in \{1 \ldots N\}$ is the number of variables in vector $r_{i,g,t}$ and $m \in \{1 \ldots M\}$ is the number of control variables in vector **Z**.

The results from the estimations regarding our three country groups signal the relevant role played in the sector-level productivity growth of the system as a whole by the demand-driven influence coming from the intermediate users. Indeed, highly significant coefficients in all three columns in Table 2 express the positive impact of sectors, seen in their quality of intermediate customers, on the productivity growth of their upstream suppliers. This confirms our considerations concerning the new formulation of the demand pull hypothesis. Indeed, according to our results, the positive influence on the system's dynamic efficiency crucially depends on the availability of knowledge interactions - as carriers of pecuniary knowledge externalities - associated with the flows of transactions that relate each upstream supplier to the demand received from sophisticated downstream users. Such externalities take place when downstream sophisticated customers transmit their creative ideas to upstream suppliers and stimulate in that way suppliers' innovative activity. The capability of a system to introduce and adopt timely technological innovations is influenced not only by the internal efforts to generate new technological knowledge, but also and most effectively, by the amount of external knowledge that flows between the sectors of the system, taking into account the strength of their links as measured by the Leontief coefficients.[15]

[15] For brevity, we do not include the results showing the influence of the internal R&D activities on the sector's productivity dynamics. Those results were rather unsatisfactory, showing the lack of the clear link between R&D expenditures and TFP growth.

Table 2 Estimation results according to system GMM method, entire period 1995-2007.

	EU core	East	South
l.tfp	-0.072	-0.147	-0.067
	(0.041)*	-0.148	-0.044
food	0.703	0.131	0.668
	(0.077)***	-0.251	(0.196)**
textiles	0.924	0.856	0.711
	(0.032)***	(0.119)***	(0.085)***
wood	0.815	0.723	0.669
	(0.068)***	(0.082)***	(0.073)***
paper	0.794	0.583	0.687
	(0.060)***	(0.119)***	(0.065)***
chemicals	0.804	0.669	0.741
	(0.084)***	(0.119)***	(0.136)***
rubber & plastic	0.967	0.746	0.687
	(0.053)***	(0.093)***	(0.065)***
other non metallic min	0.802	0.758	0.776
	(0.087)***	(0.118)***	(0.059)***
basic metals	0.617	0.485	0.451
	(0.082)***	(0.120)***	(0.093)***
machinery & equip	0.928	0.715	0.554
	(0.040)***	(0.093)***	(0.115)***
electr equip	0.793	0.722	0.606
	(0.081)***	(0.130)***	(0.096)***
transp equip	0.810	0.524	0.628
	(0.106)***	(0.233)**	(0.180)**
manuf nec	0.874	0.734	0.499
	(0.041)***	(0.113)***	(0.192)***
electr, gas & water sup	0.693	0.522	0.680
	(0.053)***	(0.113)***	(0.119)***
contruction	0.620	0.432	0.294
	(0.170)***	(0.188)**	(0.437)
wholesale	0.725	0.527	0.477
	(0.111)***	(0.193)**	(0.337)
hotels & restaur	0.648	0.945	0.481
	(0.149)***	(0.097)***	(0.408)
transport & comm	0.558	0.136	0.623
	(0.119)***	(0.316)	(0.194)***
finance	0.600	0.719	0.738
	(0.101)***	(0.083)***	(0.096)***
real estate	0.341	0.259	0.435
	-0.278	(0.367)	(0.451)
Sargan	0.763	0.999	0.998
Arellano-Bond	0.243	0.361	0.447

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parenthesis.

These results are also in line with the life cycle theory in its version stressing the role played by the demand-side dynamics (Malerba *et al.*, 2003). According to this hypothesis, the bulk of network and bandwagon effects on the demand side make the users concentrate on a particular design and develop a minimum threshold to motivate the suppliers to stick to it as well in order to remain on the market.

But the demand-side life cycle theory is even more insightful for our purposes, as it focuses on heterogeneity conditions intrinsic in every industrial structure and resulting in dynamics regarding the relative importance of sectors both over time and across industrial structures. Within a certain industrial context, a sector that in a given period of time acquired dominating importance in shaping sectoral design and the speed of transformation could be able to maintain its position in the next era as well, but it could also fail to do this if the demand intensity and dynamics related to some other sector successfully enters the picture. Similarly, the differences existing across industrial systems in the same era derive from different relative strength that each sector is able to establish, based on customers' internal characteristics and market mechanisms put on their disposition. From this viewpoint, our results confirm and generalize at the same time the microeconomic evidence of high tech industries such as semiconductors (Fontana and Malerba, 2010).

This is confirmed in the results shown in Table 3 and illustrated in Figure 2. These ratios have been obtained based on the estimation coefficients seen in Table 1, by taking as reference for each country group the highest coefficient and calculating for the remaining sectors the ratios between their respective estimation coefficients and the coefficient of the reference sector. In that way, we obtained a relative classification of sectors, where the highest the ratio, the strongest the demand-side influence of the sector on the productivity dynamics of the rest of the system. This procedure permits us to go beyond the sole confirmation of the substantial role played by demand-side influence in spurring productivity dynamics of the system, as seen in Table 2. Indeed, here we are able to observe and comment on the 'quality' of the sectoral architectures of the different systems so as to appreciate whether certain industrial structures with sectors connected with more or less remarkable inter-sectoral linkages are able to experience higher levels of technological congruence and exert larger positive effects on the general increase of total factor productivity at the system level.

Regarding the sectoral architecture within each country group, in the EU core the dominating position in the analysed period has been taken by rubber and plastic products, followed by machinery and equipment; textile and textiles products, as well as all the remaining manufacturing sectors. These manufacturing sectors have been able to activate a sophisticated demand of intermediary inputs that pushed and helped upstream suppliers to introduce technological innovations. All the service sectors, instead, were playing relatively weaker influence in this system of demand-driven productivity growth.

Table 3 Relative importance of sectors in the transmission of demand-driven pecuniary knowledge externalities

	EU core	East	South
food	0.727	0.139	0.861
textiles	0.956	0.906	0.916
wood	0.843	0.765	0.862
paper	0.821	0.617	0.885
chemicals	0.831	0.708	0.955
rubber & plastic	**1.000**	0.789	0.885
other non metallic min	0.829	0.802	**1.000**
basic metals	0.638	0.513	0.581
machinery & equip	0.960	0.757	0.714
electr equip	0.820	0.764	0.781
transp equip	0.838	0.554	0.809
manuf nec	0.904	0.777	0.643
electr, gas & water sup	0.717	0.552	0.876
contruction	0.641	0.457	0.379
wholesale	0.750	0.558	0.615
hotels & restaur	0.670	**1.000**	0.620
transport & comm	0.577	0.144	0.803
finance	0.620	0.761	0.951
real estate	0.353	0.274	0.561

Note: The sector with the highest coefficient reported in Table 1 has been taken as the reference sector and its coefficient was equalized to 1. For the remaining sectors, the values express the ratio between their own estimation coefficients and the coefficient of the reference sector. Ratios in grey refer to sectors for which the estimation results were statistically insignificant.

Quite a different picture is found for South, where a relevant influence has been exercised by financial intermediation and transport and communication services. In the South the most effective manufacturing sector is the other non metallic mineral products.

Finally, the group of Eastern European EU members was characterized by the most incisive influence coming from hotels and restaurants services, closely followed by textiles and textile products. Distinguishing in this country group is the relatively weaker impact coming from the remaining manufacturing sectors than it was the case both in South and even more in the EU core.

From such a vertical comparison, it can be noted that manufacturing sectors were on average more effective than services in generating a positive demand side influence. The only exception from this rule among manufacturing sectors constitutes basic metal sector, as well as electricity, gas and water supply; hotels and restaurants and financial intermediation within services. Regarding the latter, this result is in line with theoretical contributions underlying the crucial role of finance (and of innovative financial instruments) in supporting the productivity-based economic growth (King and Levine, 1993; Galetovic, 1996; Blackburn and Hung, 1998; Morales, 2003; Acemoglu, Aghion, and Zilibotti, 2003).[16] Such theoretical findings were confirmed in the empirical investigations pointing on the crucial link between the improvements in the financial systems and technological development. This evidence might be found in historically distant events, as for instance in the case of the establishment of specialized investment banks and of improved accounting systems to deal with the financing of the construction of railroad infrastructure in 19th and 20th century (Baskin and Miranti, 1997). But also more recent investigations point on the considerable contribution of new financial products in mitigating agency concerns and informational asymmetries that typically impede the financing of the passage towards a new technological frontier (Allen and Gale, 1994; Tufano, 2003; Frame and White, 2004).[17]

The case of the energy sector has been also extensively discussed in the past literature. There is a well-established, even though almost implicit, convincement that energy-related innovations play a crucial role in economic growth. Indeed, most probably due to its abundance and at the same time low relative share of energy costs over the total production costs, the theoretical analyses around the endogenous growth do not include energy as an input of production. An exception here is the work by Stern and Kander (2012), who construct a simple extension of the Solow model of growth with the energy factor and, additionally, confirm that the expansion of energy services contributed to the explanation of long-run growth in Sweden.

Among manufacturing sectors that contributed a lot to the positive demand-side influence on productivity dynamics upstream, textiles and textile products assume an important role. This effect might be better understood in the light of the recent developments leading to the successful and efficiency-enhancing establishment of industrial districts covering the traditional EU manufacturing sectors, among which textile sector as well. The so called "district effect", combined with the

[16] Apart from contributions supporting the view of a great role played by financial innovation for economic growth, there are also other theoretical views arguing that this influence might be negative. In particular, Gennaioli *et al.* (2012) argue that in a context where investors neglect small risks, financial innovation might result in financial and economic instabilities. Moreover, Shleifer and Vishny (2010) find out that financial innovation accompanied with biased expectations of investors or excessive institutional constraints might be detrimental for economic development.

[17] Even if the process of financial liberalization doesn't entirely correspond to the process of financial productivity improvements, it is plausible to argue that the former might accurately proxy the latter. In a recent empirical investigation regarding the EU, Gehringer (2013) found the evidence confirming that the overall process of financial globalization contributed to the intensification of the aggregated TFP dynamics.

generation of innovative textile products, permitted to achieve a better diversification of production towards high value-added product lines (Nassimbeni, 2003; Dunford, 2006; Puig *et al.*, 2009).

The evidence regarding chemicals and also rubber and plastic products confirms the role of the sector as being continuously involved in the search for new feedstocks in the economic system at large.[18] An exemplary case of the change in the feedstocks is given by switching from coal to oil and gas in the production of synthetic fibers and plastic products in the US already before World War II.[19]

The horizontal comparison of the standardized results is quite interesting as well. Food has a strong effect in the EU core and the South while it does not provide strong effects in the East. Textiles exert a strong positive effect in the three blocks. The strong results of wood are homogeneous across the three blocks. Paper has stronger effects in the EU core and in the South than in the East. Chemicals exert very strong effects in the South and in the EU core, but to a lesser extent in the East. Rubber and plastic is the strongest sector in the EU core where it peaks, but is less effective in the South and in the East. Other-non-metallic minerals have a strong role in the South where it peaks, but quite a weaker one in the EU core and in the East. Basic metals effects are stronger in the EU core than in the South and the East. Machinery and equipment exert a very strong role in the EU core, but a weaker one in the South and in the East. Similarly, electrical machinery has a more powerful effect in the EU core than elsewhere. Transportation equipment has a pulling role in the EU core and in the South but much less so in the East. Manufacturing-not-elsewhere- classified has the expected strong role in the EU core, but a weaker one in the rest of Europe. Electricity-gas-water-supply has a strong role in the South, a slightly weaker in EU core and a weak one in the East. Construction is very effective in the EU core and very weak in the South. Wholesale is very effective in the EU core and much weaker in the rest of Europe. Hotels-and-restaurant has a surprising strong role in the East where it ranks first but exerts much lower pulling effects in the rest of Europe. Transportation and communication services have powerful effects in the South, but negligible effects in the East. Finally financial intermediation is very effective in the South and less effective both in the East and in the EU core.

[18] According to Davis Landes (1969:269), chemical industry is the most "miscellaneous of industries", encompassing synthetic fibers, plastics, agricultural pesticides and fertilizers, food additives, health and beauty aids, and many other products and production components.

[19] For a detailed description of the case and for an extensive discussion of the role of chemical innovation for economic growth, see Arora and Gambarella, 2010.

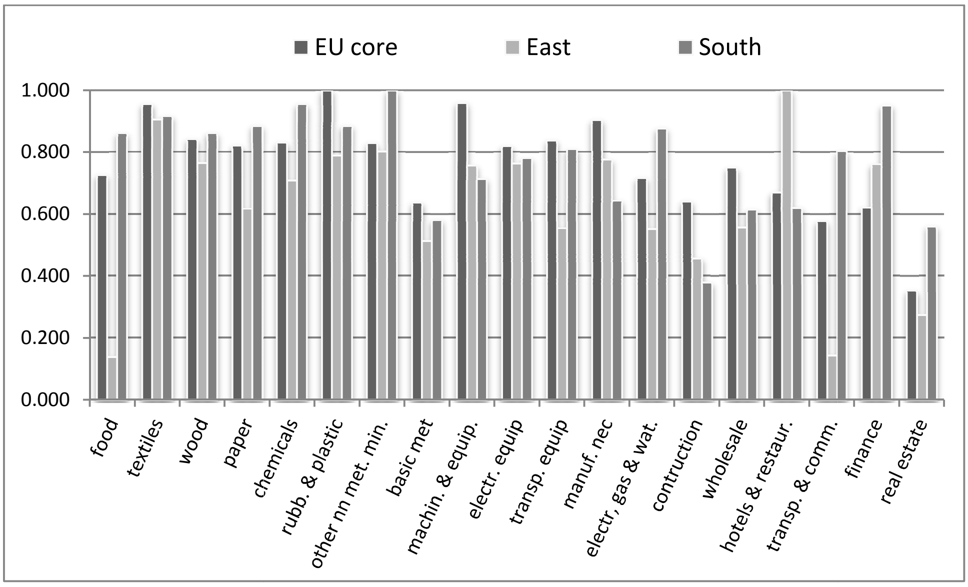


Figure 2 Relative importance of sectors in the transmission of demand-driven pecuniary knowledge externalities

Based on the same results, Figure 2 illustrates differences between the relative demand-side influences of the sectors observable across country groups. Generally, a certain pattern can be recognized that divides East from the other two country groups, EU core and South. Indeed, the latter two groups exhibit more homogenous industrial structures with respect to East. This is particularly true for food, beverages and tobacco; pulp, paper and paper products; chemicals and chemical products; transport equipment; hotels and restaurant service and transport and communication. For the remaining sectors the pattern is much less clear. Indeed, in some cases, East and South seem to show more common characteristics (machinery and equipment; construction; wholesale and retail trade). In some other cases, Eastern European structure is much closer to the one in the core EU (other non metallic mineral products; real estate). Finally, in the case of textiles and textile products; wood and products of wood; and electrical equipment all three-country groups seem to belong together.

The fact that we classify our country sample in three country groups permits us to investigate regional differences in the economic importance of a certain sectoral architecture. In this sense, the geographic dimension is exogenously determined. An interesting exercise would be to endogenize the space variable with the aim to establish the geographic extension of the demand-driven productivity impact between sectors located in different regions. This could be made by considering the global input-output tables and, thus, the international flows of intermediate inputs between sectors located in different countries. On the contrary, given that we dispose of national and not regional input-output tables, we are not able to detect the strength and the special distance within which cross-sectoral knowledge spillovers occur.[20]

Reassuming, with respect to the appreciation of the sectoral architecture, these results seem to confirm on the one hand that each country group exhibits specific characteristics of their sectoral architectures, on the other hand, however, that the architectures of the EU core and South (both old EU members groups) are closer together and further from the structure observed in East.

Our results confirm that the sophisticated procurement of downstream users has important effects on the technological capacity of upstream suppliers. The sophisticated procurement is able to pull innovation upstream both via the traditional loop that relates the extent of the market to the levels of specialization and focused learning processes and by means of the provision from the bottom of knowledge externalities.

These results are quite important from a theoretical viewpoint because they provide empirical support to the hypothesis that knowledge externalities originated downstream do affect the technological capacity of upstream suppliers. This 'second' bottom-up mechanism is quite distinct from the top-down flow that received more attention in the literature. According to our results its effects are important enough to deserve a wider attention.

5 Conclusions

This paper has elaborated an original approach to appreciate the systemic character of the innovative performances, highlighting the crucial role of the knowledge externalities that contribute the innovation process. The generation of technological knowledge and the consequent introduction and adoption of technological innovations do not take place in isolation. Firms rely on each other in accessing the collective pools of technological knowledge that become available because of its limited appropriability. The mechanisms by means of which external knowledge actually spills and can be accessed, however, are quite sophisticated: knowledge does not spill freely in the atmosphere. Dedicated interactions are necessary for knowledge to actually spill from its originator so as to be used by third parties. User-producer interactions play a central role in this context. The transactions of goods are the most effective carriers of knowledge interactions and enable customers and suppliers to share and access the knowledge base of the products being traded. Although some knowledge interactions may take place without actual exchanges of goods, the bulk of knowledge interactions are likely to take place jointly with the transactions of all other goods. The reciprocal

[20] A prominent attempt in this direction has been offered by Bottazzi and Peri (2003) who base their estimates of knowledge spillovers in Europe on European patent data. They find that the spillovers are very localized and exist only within a distance of 300 km.

levels of technological advance of customers and suppliers can be considered a reliable proxy of the knowledge opportunities that are external to each innovative unit. Indeed, such knowledge opportunities are traded by the market transactions, which therefore do perform effective role as carriers of knowledge spillovers. From this point of view the unit of analysis is not simply the amount of inter-industrial trade, but the combination of inter-industrial flows of goods and levels of technological advance. This approach enables to grasp the central role of the sectoral architecture of economic systems and to appreciate the strategic role of technological congruence, that is the matching between the levels of output elasticity of intermediary inputs and their price in intermediary markets. Sectoral architectures - that are able to provide large and cheap intersectoral flows of key inputs to the rest of the system - can *coeteris paribus* support faster rates of increase of total factor productivity.

The identification of the flows of goods among industrial sectors – made possible by input-output tables - weighted by the levels of technological advance of each sector, provides a unique – if not exclusive - map of the actual flows of knowledge spillovers based upon the knowledge interactions that take place in an economic system. This procedure has made possible to distinguish two separate mechanisms of dissemination of knowledge externalities that take place by means of knowledge interactions: A) the top-down flows of knowledge spillovers that take place from the suppliers of goods that embody technological advances to their customers, B) the bottom-up flows of knowledge spillovers that take place from sophisticated customers to their suppliers. This paper concentrates the analysis on the latter. The empirical analysis of this mechanism has enabled to appreciate the effects of a qualified-demand-pull hypothesis, where the rate of technological advance of a sector is positively influenced by the extent to which it is the recipient of the derived demand of advanced customers. The results confirm that the rate of total factor productivity of upstream sectors is strongly and positively influenced by the relative strength of the demand originated from the downstream sectors to the upstream ones according to their own levels of technological advance.

These results seem important from a theoretical viewpoint as they confirm the strong systemic character of the innovation process. Innovation cannot take place in isolation where each agent commands all the existing knowledge. Innovation is intrinsically a collective process, where the innovative performances of each agent depend upon the amount of external knowledge that can be accessed and used in the recombination process. These elements make possible the generation of new knowledge and the eventual introduction and creative adoption of technological innovations. Knowledge externalities do not spill only within the familiar top-down mechanism by means of which suppliers provide users with technological innovations and external knowledge. Bottom up mechanisms, where creative users provide their suppliers with external knowledge essential for the introduction of new technologies, do play a central role in the general systemic process of recombinant generation of knowledge. The amount of knowledge externalities, activated and made accessible by the qualified-demand-pull dynamics, plays a central role in this systemic context.

These results are most important with respect to the demand pull hypothesis. They make in fact it possible to rejuvenate and specify the Smithian hypothesis that the increase of the demand favors the increase of the division of labor and, hence, of the levels specialization that. in turn, enable to better focus dedicated learning processes. The ultimate effect consists in favoring the generation of new technological knowledge and the eventual introduction of better technologies. The appreciation of the recombinant character of the generation of technological knowledge and of the essential role of external knowledge as a necessary input enables to better appreciate the specific quality of the knowledge interactions that accompany and qualify market transactions. Knowledge interactions complement and enrich market transactions. Market transactions are effective carriers of knowledge spillovers. The higher are the levels of knowledge advance of the suppliers of inputs and the larger are the chances that creative customers can fasten their recombinant generation of new knowledge and fasten their rates of introduction of new technologies. The demand-pull dynamics, in conclusion, is all the stronger the higher are the levels of technological advance of suppliers. Large flows of derived demand incoming from advanced users make the demand pull dynamics more effective and faster.

This re-interpretation of the demand pull hypothesis qualified our focus on the inter-EU heterogeneity of the national innovative systems and permitted us to reinforce the evidence on intrinsic differences characterizing the composition and the strength of the relative inter-sectoral interactions. From this viewpoint the results of our analysis can be considered a useful starting point to elaborate a selective and yet systemic industrial policy able to direct its interventions towards the elements of the sectoral architectures that are more likely to fasten the general capacity of the system to generate technological knowledge and introduce technological innovations.

These results are more specifically important from an innovation policy viewpoint as they provide a unique map of the actual complementarities that take place within an economic system between industrial sectors and enable to measure the actual effects of the qualified-demand-pull dynamics that supports the innovative process of individual agents. Procurement policies can play a major role in fastening the rate of introduction of technological innovations, provided they can actually activate the demand of sophisticated users.

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Appendix A.1

Table A.1 Full names and acronyms of analysed manufacturing and service sectors.

sector	full name
food	Food, beverages and tobacco
textiles	Textiles and textile products; leather and footwear
wood	Wood and products of wood and cork; articles of straw and plaiting materials
paper	Pulp, paper, paper products, printing and publishing
chemicals	Chemical and fuel products
rubber & plastic	Rubber and plastic products
other non metallic min	Other non-metallic mineral products
basic metals	Basic metals and fabricated metal products
machinery & equip	Machinery and equipment *nec*
electr equip	Electrical and optical equipment
transp equip	Transport equipment

manuf nec	Manufacturing *nec*; recycling
electr, gas & water sup	Electricity, gas and water supply
contruction	Construction work
wholesale	Wholesale and retail trade; repairs
hotels & restaur	Hotel and restaurant services
transport & comm	Transport, storage and communication
finance	Finance, insurance
real estate	Real estate, renting and business activities

Appendix A.2.

The reconciliation of the demand pull and the supply push hypothesis implies that pecuniary knowledge externalities at work in any economic system are of the bi-directional nature. More precisely, in our analysis we concentrate on the demand pulling influence of pecuniary knowledge externalities that stem from the fruitful market transactions-*cum*-interactions between creative users and innovative producers and where the former enhance productivity increases of the latter. This notwithstanding, we recognize that supply pushing influence, originated by the innovative producers and motivating productivity growth by innovative users, cannot be disregarded. We include, thus, among our control variables in equation (9) a variable measuring an average supply-driven pecuniary knowledge externalities effect. This variable is constructed, for every single sector, as

$$s_{j,g,t} = {\sum_i^N b_{ij,g,t} p_{i,g,t}} \Big/ N \tag{A.1}$$

where $s_{j,g,t}$ is the average supply-driven effect for a column sector j, in country g, at time t, $b_{ij,g,t}$ is the corresponding coefficient from the j-th column of the Leontief inverse matrix, $p_{i,g,t}$ is the growth rate of TFP of each supplying sector i and N is the number of sectors taken under analysis.