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KNOWLEDGE EXTERNALITIES AND DEMAND PULL: THE EUROPEAN EVIDENCE

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Knowledge externalities and demand pull: The European evidence

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Abstract

This paper elaborates the microeconomic foundations of the demand pull hypothesis stressing the role of vertical knowledge externalities stemming from the complementarity between knowledge interactions and user-producer transactions. The increase in the demand can pull the rate of technological change in the system when it concerns the derived demand of innovative sectors. In this framework, technological change is an emergent property of any dynamic system, where external knowledge made available by each agent plays a key role in the introduction of innovations by each other agent. Demand pulls the introduction of innovations when and where it comes from innovative customers. Using input output tables that grasp user-producer interactions, the paper provides an empirical test of these hypotheses for 15 European countries in the years 1995-2007. The evidence confirms that the increase of total factor productivity of the upstream supplying sectors is positively influenced by the sector-level derived demand, according to the rates of introduction of innovations and to the intensity of their user-producer interactions. The policy implications of the analysis enable to elaborate and implement the notion of a 'competent' public demand.

JEL classification: L16; O3; O52

Keywords: Derived demand; Knowledge externalities; User-producer interactions

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1. Introduction

Innovation-led economic growth since decades stays at the heart of the European integration process. Nevertheless, given the complexity of the process, it is crucial to make out the very mechanisms driving it. In this regard, the understanding of the economic complexity intrinsic to technological change enables to grasp the systemic properties of the dynamics embedded in the productivity growth. This approach permits to implement the microeconomic foundations of the demand pull hypothesis in a novel interpretative context that stresses the central role of innovative customers in supporting the arrival of innovations of upstream producers.

The original Kaldorian demand pull hypothesis was elaborated in macroeconomic analytical framework, strongly focusing on increasing returns from public intervention to support aggregate demand. As a complement to the analysis of Kaldor, the later work by Schmookler provided additional clearness in explaining the causal chain of effects linking the increase in aggregate demand to positive impact on investment and subsequently on technological advance. In the analysis of Schmookler, not a generic demand pull, but rather specific effect of the derived demand, originating from private investment in particular sectors, plays a substantial role in shaping the future technological development, crucially based on effective and continuous interactions between upstream producers and downstream users.

Nevertheless, none of these contributions elaborated a microeconomic analysis of the mechanisms that relate the increase of demand at the aggregate level with the increase in the rate of introduction of innovations.

Past empirical investigations around the standard demand pull hypothesis brought the evidence of a positive influence of investment-sustained derived demand on upstream innovativeness, stressing the role of upstream profitability in providing the necessary incentive to innovate. Quite surprisingly, none of these past empirical investigations implemented input output analysis that, instead, is equipped with the detailed information about the relations among sectors along the vertical chain of production.

Our contribution aims at revisiting the original demand pull argumentation by integrating the macroeconomic approach with a microeconomic analysis that elaborates upon the intrinsic economic complexity of technological change. In this spirit, positive demand-driven effects consist in an influential interaction, in which innovative downstream users stimulate upstream innovative activity. This is to say that upstream innovations require not only positive profit incentive, but also and crucially dynamic interactions with the users. In such a system of vertical interactions, the more intensive knowledge externalities are, the more efficient is the expected outcome both for the system as a whole and for each single node of the vertical chain. To benefit the system, knowledge externalities are strongly conditioned on market transactions-*cum*-interaction, in which both knowledge producers and knowledge users actively participate.

The microeconomic framework of analysis of the demand pull hypothesis motivates the use of input output tables that have the merit of grasping inter-sectoral relations between industrial sectors in their quality both as producers and as users.

Our theoretical argumentations are tested empirically using dynamic system GMM methodology. The results support the hypothesis that user-producer interactions play a crucial role in determining the innovative dynamics of the industrial system. In particular, upstream innovative outcomes are not driven by positive generic demand-side influence, yet by interactions with the downstream innovative users who direct their derived demand for intermediate inputs towards upstream sectors.

The rest of the paper is structured as follows. Section 2 recalls the foundation of the economic complexity approach to technological change and frames the analysis of the demand pull hypothesis into the systemic determination of the total factor productivity growth. Section 3 presents the main econometric analysis, which is strengthened with a sensitivity check. The conclusions in the last section summarize the results, emphasizing their European dimension and providing crucial though preliminary implications for the European industrial development.

2. Theoretical framework

The demand pull approach, according to which innovation is driven by the increase of demand, has received very little attention in the recent literature. This is consistent with the mismatch between the macroeconomic foundations of the demand pull hypothesis and the strong microeconomic flavor of the literature on the economics of innovation. The demand pull hypothesis has been elaborated in the post-Keynesian tradition to substantiate the need for structural, as opposed to conjectural, public intervention and specifically the positive effects of public support to increasing the levels of aggregate demand.

The first specification of the demand pull hypothesis was articulated by Nicholas Kaldor who made explicit the macroeconomic and post-Keynesian framework of analysis (Kaldor, 1966 and 1972). Kaldor suggested that all increases of public expenditures able to support the expansion of aggregate demand would have –also- positive effects on output via the interaction between the multiplier and the accelerator. Eventually, increase in investments could be also achieved. Additional flows of investments were expected to fasten the diffusion of technological innovations embodied in new vintages of capital goods. Hence, the eventual increase in efficiency of the system would follow, leading ultimately to the increase of output and consequently of the flows of fiscal receipts to repay the original spending. As a matter of facts, the Kaldorian approach to demand pull did focus more on the positive effects of fixed investments on the diffusion of innovations that were necessarily embodied in capital goods, rather than on the specific stimulation of aggregate demand leading to the actual introduction of technological innovations. The main aim of Kaldor's analysis was to substantiate the case for increasing returns and to show the need for the continual expansion of public expenditures. The increase of efficiency engendered by the increase of investments stemming from additional public expenditures and the accelerated diffusion of new vintages of capital goods would in fact generate additional fiscal receipts neutralizing the effects on the stock of public debt.

The intuition of Nicholas Kaldor that public intervention can act so as to become a structural component of growth of an economic system is worth additional work. The aim of such an analysis should be to better qualify the mechanisms by means of which the increase of the aggregate demand is able not only to fasten the diffusion of existing innovations, but actually to affect the rates of generation of technological knowledge and introduction of technological innovations.

The sophisticated analysis of Jacob Schmookler's *Invention and Economic Growth* (1966) complements the strong post-Keynesian flavor of the Kaldorian analysis. But additionally, it makes an important step forward in articulating the causal chain of arguments that relate the increase of the aggregate demand to investment and finally to the actual generation of new technological knowledge and the introduction – as distinct from absorption - of technological innovations.

He focuses attention on the role of a highly specific derived demand, originating from private investments in well defined sectors of the economic system, rather than on the generic increase of aggregate demand engendered by public expenditures. The historic analysis of Jacob Schmookler shows how, in the US experience, technological innovation had been pulled by specific waves of investments in a sequence of activities that were strongly related, such as canals, railroads, electric power (…).Schmookler shows how ever since the first great undertaking, with the creation of a national system of canals, dedicated investments that were able to increase the demand for upstream industries producing intermediary inputs and capital goods and consequently their profitability could also stir the inventive activity of firms, favoring their knowledge interactions with scientists and universities at large. Each of these waves of investments had the twin effect of stirring the increase of the innovative activities in upstream sectors and of creating the conditions for further investment. The successful wave of investments that led to the creation of a new web of canals connecting the Great Lakes with the ports of New York City and New Orleans, made agriculture viable in the Far West and paved the way to its inclusion in the American economy. They also favoured the demand for transportation infrastructure and the ensuing creation of a new railroad system. In turn, investments in railroad had the twin effect, on the one side, to stimulate the introduction of technological innovations in upstream industries providing capital and intermediary inputs to the newly establishing industry and, on the other side, to increase the derived demand for steel.

The demand pull hypothesis articulated by Schmookler retains the basic macroeconomic framework as it stresses the vertical links between specific flows of investment, additional derived demand to upstream sectors and increased levels of inventive activity. Schmookler, however, is aware of the need of microeconomic foundations and argues that the additional derived demand stirs the profitability of firms and this in turn would explain their rates of introduction of innovations. In so doing, Schmookler provides an elementary microeconomic framework of analysis that highlights the role of profitability.

After the founding contributions, the demand pull hypotheses received some attention by subsequent empirical studies that confirmed the positive effects of derived demand and investments on the intensity of innovative activity. 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). Also different aggregation levels have been applied to verify the demand pulling impact:sector-level, firm-level (Brouwer and Kleinknecht, 1999; Piva and Vivarelli, 2007) and the case study (Walsh, 1984;Nemet, 2009; Guerzoni, 2010). The empirical evidence confirms the positive role of demand on the intensity of innovative activity and stresses the central role of profitability as the key factor in exploiting the crucial demand side impact. New investments feed the derived demand directed towards upstream sectors, hence increase their profitability and provide at the same time incentives and opportunities for the more systematic introduction of innovations (Andersen, 2007).

The demand pull hypothesis failed to gain a broader consensus. Mowery and Rosenberg (1979) raise a critical methodological issue, arguing that the evidence provided by the case study as well as by the early econometric investigations could not disentangle the effects of technology pushes from demand pulls. As Mowery and Rosenberg noted, the increase in the demand is not a determinant but often and quite obviously a consequence of the introduction of an innovation and of the corresponding reduction of –hedonic- prices. As Dosi (1982) notes, the demand pull approach failed "to produce sufficient evidence that 'needs expressed through market signaling' are the prime movers of innovative activity". The demand pull hypothesis suffered from the missing attention and analytical grasping of the relation between the changes in the demand levels and the working of the mechanisms of the generation of technological knowledge and the introduction of technological innovations (Di Stefano et al., 2012).

Quite surprisingly, the empirical literature has made little use of input output tables to investigate the relations between innovation and demand. Yet input output matrices provide a unique opportunity to grasp a full spectrum of bi-directional relations among industrial sectors. They precisely describe intermediate input requirements in the sector-level process of output generation. But most importantly, input output tables permit to assess the role of the derived demand as distinct from the final demand.

A remarkable exception in the implementation of input output framework is provided by the analysis of Crespi and Pianta (2008) who use Eurostat input output tables for 22 manufacturing and 10 services sectors in Germany, France, Italy, the Netherlands, Portugal and the United Kingdom.[1] Their results confirm that demand pulls productivity growth in European industries only when a combination of technology factors and demand dynamics is taken into account. In so doing, Crespi and Pianta make an important step forward in providing a broader analytical framework arguing and testing the hypothesis that there is a complementarity of technology and demand effects.

The appreciation of the complementarity between technology and the actual effects of demand pull finds strong support in the literature on procurement.[2] Vernon Ruttan (2006) shows that the positive effects of military procurement experienced in the US case have been determined by their high levels of technological competence. This finding supports the view that demand pulls technological change when it is qualified by the identification of advanced technological standards. The results of Ruttan confirm the early evidence that demand pulls technological change only when it is able to stir an appropriate flow of knowledge externalities (Scherer, 1964). More generally, the results of Ruttan indicate that a microeconomic approach to the demand pull hypothesis is necessary to complement and qualify its macroeconomic origins.

As a matter of fact, there is an interesting mismatch between the original formulation of the hypothesis in a macroeconomic context by Kaldor and Schmookler, and much of the subsequent empirical analysis. Much of the empirical literature already recalled tests the demand pull hypothesis elaborated in a macroeconomic framework of analysis with microeconomic evidence provided using firm-level and sector-level data. Very little attempt has been made to elaborate a microeconomic framework of analysis that

[1]It is important to mention here that there has been an attempt by Bartelsman et al. (1994), though not pointing explicitly on the demand pull hypothesis, to exploit input output framework in the study of different types of externalities occurring between customers and producers. In particular, they find evidence underlying the relevance of the linkage between each sector and its customers in the transmission of external effects.

[2] In Project "HIND-SIGHT", the US Department of Defense focused on the crucial role of "need", intended as qualified demand, driving the successful development of 710 key military innovations (Nemet, 2009).

explains the analytical chain of arguments generating the expected macroeconomic outcome, according to which an increase in the aggregate demand pulls an increase in the rate of introduction of innovations. The consensus about the role of profitability seems more of a surprise, rather than the test of a specific hypothesis. A large literature has actually shown that the relationship between profitability and innovation is not linear as often innovation is the result of the efforts to cope with the actual fall of profitability.

The lack of an appropriate microeconomic basis leads to persistent ambiguities and skepticisms about the role of demand in pulling innovation activity. As Geroski and Walter note "Although the assertion that demand matters is controversial to some, what makes understanding the relationship between demand and economic activity really difficult is the diversity of views which exist about whether demand makes innovative activity pro or anti-cyclical, and about whether changes in demand are exogenous to the process of producing and using innovations" (Geroski and Walter, 1995:918).

The new approach to the economic complexity of technological change makes it possible to reconsider the demand pull hypothesis in a microeconomic context that stresses the relevance of user-producer transactions and interactions as carriers of knowledge externalities. The analysis of the economic complexity of technological change puts into evidence the role of knowledge interactions in the generation of new technological knowledge. In this approach, the generation of new technological knowledge consists in the recombination of existing units of knowledge. Hence, knowledge is at the same time an input and an output. The access to existing knowledge both internal and external to each firm is crucial. In this context knowledge interactions are necessary because of the strong tacit content of existing knowledge. The generation of new knowledge can take place effectively only when, where and if external knowledge can be accessed at low costs via knowledge interactions. The access to external knowledge at costs that are below equilibrium levels, in turn, makes it possible to increase total factor productivity.

This approach stresses the role of vertical knowledge externalities stemming from the user-producer interactions that take place along with user-producer transactions. Vertical knowledge externalities can be identified as an important input of the knowledge generation process that differ both from the intra-industrial Marshall externalities (often referred to as MAR externalities, after the original contribution of Marshall and of subsequent works by Kenneth Arrow and Paul Romer) and inter-industrial, mainly horizontal, Jacob's (1969) externalities that typically take place in localized urban environments. Vertical knowledge externalities add to intra-industrial knowledge externalities that take place between competitors in the same industry and to Jacob's horizontal knowledge externalities that take place among commercially unrelated industries. Knowledge vertical external effects take place within the chain of relations that link users to producers located either in the same or different industries. But most importantly, vertical knowledge externalities are typically pecuniary as they take place in a context where knowledge interactions are strictly associated to market transactions.

Within this context, it is possible to grasp the central role of the derived demand expressed by innovative customers. The appreciation of the vertical knowledge externalities permits to better identify the positive effects activated by the increase of the aggregate demand and appreciate how they are actually associated with knowledge interactions and the consequent knowledge externalities.

The positive effects of demand pull more specifically refer to the relationship between derived demand and increased innovative intensity that takes place when innovative customers in downstream industries are able to stir and support the innovative activity of upstream industries. Such a positive productivity dynamics is enabled not only because of increased profitability but also and crucially as a consequence of intensive user-producer relations and closer participation of each industrial node to the collective innovative efforts generated along the vertical filiére of productive activity. The user-producer relations are crucially based on transactions among sectors that provide and receive sequential inputs to the production of final goods. Among the inputs, externally generated technological knowledge is exchanged on the market and triggers pecuniary knowledge externalities that catalyse innovativeness of the economic system at large (Antonelli, 2008; Gehringer, 2011a).

The new approach to the economic complexity of technological change articulates the hypothesis that innovation is an emergent property of the economic system into which firms are embedded. The characteristics of the system in terms of flows of knowledge externalities play a crucial role in assessing the actual outcome of the reaction of myopic firms caught in out-of-equilibrium conditions by unexpected changes in both product and factor markets. At each point in time, firms make decisions that lead to the commitment of irreversible resources in the attempt to identify the equilibrium conditions. Yet, due to the complexity of changes, they cannot foresee all the possible alterations that hit the market place. When the actual conditions of both product and factor markets differ from the expected ones, as they usually do, firms try to react (Antonelli, 2011). Following Schumpeter (1947), their reaction can be either adaptive or creative. In the former case, firms' reaction is locked in the existing technology, as they only move on the existing map of isoquants, adjusting quantities to prices and changing their production techniques, but not their technologies. Instead, the reaction of firms is creative, when they contribute to the increase of dynamic efficiency by introducing themselves new technologies. This corresponds to the shift downwards of the existing map of isoquants and the achievement of a more efficient production result.

The reaction of firms can be - even more - creative when they have access to pecuniary knowledge externalities that make it possible to activate successfully the recombinant generation of new technological knowledge and the eventual introduction of innovations. The access to pecuniary knowledge externalities, in fact, makes it possible to exploit cost opportunity in the exploitation of externally generated knowledge and to take advantage of the supply of a key intermediary input at costs that are below equilibrium levels. Indeed, due to the quasi-public good characteristics of knowledge, its production and eventually the introduction of technological and organizational innovations makes the production of all the other goods more efficient. Moreover, assuming that downstream knowledge users possess innovative abilities, the cost advantage from pecuniary knowledge externalities will be transformed in an innovative activity downstream.

The increase of total factor productivity is directly explained by pecuniary knowledge externalities that make available external knowledge, a crucial input in the generation of new technological knowledge at costs that are below the equilibrium level (Antonelli, 2008). Firms access such pecuniary knowledge externalities when they try and react to out-of-equilibrium conditions engendered by unexpected changes of their markets.

Because of the idiosyncratic characteristics of knowledge as an economic good in terms of imperfect appropriability, non-exhaustibility, cumulability and complementarity stemming from non-divisibility and especially its strong tacit component with the associated characteristics of stickiness, knowledge is at the same time input and output of the same knowledge generation process.

Moreover, due to the same idiosyncratic characteristics of knowledge, no agent can control all the existing knowledge. In turn, no new knowledge can be generated, and hence, no innovation can be introduced without the access to already existing knowledge. Hence, each agent can generate new knowledge and, eventually, introduce new technologies only if external knowledge can be used as an intermediary input. As it is the case in normal circumstances of the market, where firms aspire to the most profitable outcome, the cost and access conditions of knowledge will be determinant in the actual success of the business undertaking.

The access to external knowledge requires systematic and repeated interactions between knowledge holders and prospective knowledge users (Antonelli, 2008). The strong tacit component of knowledge makes it sticky to the routines and the organizations where it has been conceived. Its use as an intermediary input into the recombinant generation of new knowledge requires necessarily transactions *cum* dedicated interactions. Such interactions are not free, yet they require dedicated resources for their implementation, in addition to the intentional and active participation of both parties. Pecuniary knowledge externalities thus are conceptually distinct from pure technological externalities that postulate an unrealistic assumption of the absence of any cost connected with the knowledge-based relations (Gehringer, 2011a). In this sense and in a strong contrast with pecuniary knowledge externalities, pure technological externalities would imply interactions-*sine*-transactions.

It is, moreover, plausible to expect that, due to innovative capacities not only of producers but also of users along the vertical chain of production, the exchange of external knowledge will be channeled, yes, from producers to user, but from users to producers as well. The role of users is non-trivial. Their use of inputs is not limited to an adaptive - even though efficiently performed - activity. Instead, their progressive learning by doing, by experiencing and, finally, by interacting, leads to the generation of downstream knowledge. Innovative users constitute at the same time an opportunity and a challenge for their upstream suppliers who often have to implement creative efforts to maintain their market position. To this end, upstream producers often need to engage in intentional interactions with customers in order to understand and respond creatively to the innovative needs of the latter. Being such an interaction based on externally generated knowledge coming from the downstream users, upstream suppliers will experience a cost saving in their in-house innovative activity. This implies that pecuniary knowledge externalities operate not only from producers to users, but from users to producers as well.

User-producer transactions in the real world markets for all types of goods and services provide the most effective context for knowledge transactions-*cum*-interactions to take place. Within the context of user-producer transactions, both parties, the customers of final, intermediary and capital goods, and their respective producers have the opportunity and the incentive to implement knowledge interactions that are an indispensable and inseparable component of the transaction (Lundvall, 1985; Von Hippel, 1976, 1988, 1994, 1998, 2005).

In such user-producer relationships, the access conditions to external knowledge are determined by the characteristics of the system, in which technological change is its emergent property. External knowledge that results from the system's dynamics is, in turn, an essential input in the generation of brand new knowledge, in the transformation of the already existing one and in the eventual, yet crucial, introduction of new technologies. The chances that firms caught in out-of-equilibrium conditions are actually able to implement a creative reaction, as opposed to an adaptive one, depend upon the amount of pecuniary knowledge externalities that are available at each point in time through the flows of user-producer transactions.

The above discussion, aimed at illustrating the complexity approach to the understanding of the economics of technological change, implies the need to implement the correct methodology in assessing the microeconomic foundations of the demand pull hypothesis. From a microeconomic Schumpeterian viewpoint the increase of the demand above expected levels is one of the main causes of the out-of-equilibrium conditions that push firms to try and react in a creative way. In such a manner, firms introduce innovation that, in turn, makes it possible to cope with the unexpected levels of demand and to efficiently profit from the latter.

When the demand for the products of the firms exceeds the production capacity and the firms is constrained by irreversible commitments concerning both capital and labor, they may try and improve their efficiency so as to be able to produce a larger output while retaining the current levels of inputs. This necessarily requires that the reaction would be creative and no more adaptive. Consequently, their reaction will be actually creative and leads to the increase of total factor productivity levels when and if they can rely upon knowledge externalities that are channeled by the user-producer inter-sectoral relations, taking place within the vertical filiéres.

User-producer relations, with the equal importance of both upstream and downstream operators, play a crucial role in this approach. The increase in the demand is actually able to pull the reaction of upstream firms only when the specific vertical effects in terms of introduction of innovation of each downstream sector are accounted for. Innovativeness of upstream sectors, thus, positively and decisively depends upon the joint effects of the intermediate demand of downstream sectors together with their rates of introduction of innovation. In that sense, downstream creative producers, by demanding intermediate inputs, motivate and actually induce both the immediate and decelerated reaction of upstream suppliers, making their reaction creative – as opposed to adaptive - with the active support provided by the intentional dissemination and sharing of users' innovative knowledge.

On the other hand, the innovative activity of each downstream sector is enhanced by the innovative activity of the upstream sectors offering intermediary inputs. Here, again, upstream innovative capacities channeled by user-producer relations across vertical filiéres and incorporated into transactions, enriched by knowledge interactions, contribute to the innovative activity of the downstream sectors. Innovation in the upstream sector in the economic system does not spill in the atmosphere: it can actually affect positively the innovative activity of each downstream sector only when the specific flows of user-producer transactions are able to complement the necessary knowledge interactions so as to make knowledge pecuniary externalities actually and effectively available.

Along these lines it becomes clear that, at the microeconomic level, what matters is the derived demand of innovative customers, rather than the final demand of generic customers. This leads to articulate and revise the demand pull hypothesis stressing the complementary role of the increase of the derived demand *cum* knowledge externalities. The latter are activated by the transactions-*cum*-knowledge interactions that take place along the vertical filiéres in inter-industrial relations.

In conclusion, from a microeconomic viewpoint that implements the Schumpeterian notion of innovation as a form of reaction supported by knowledge externalities, the demand pull hypothesis applies when it is actually combined with the access to pecuniary knowledge externalities. They are channeled by user-producer bilateral relations both upstream-downstream and downstream-upstream. Firms within a sector, facing the specific increase of the derived demand for their intermediate products, channeled by the downstream relations with the innovative users, can innovate as long as they can actually rely upon pecuniary knowledge externalities. These, in turn, stem for a single sector both from the innovative efforts of the upstream sectors that provide intermediary inputs and the innovative efforts of downstream customers that demand those inputs. Creative customers, even before they arrive at a marketable result of their own invention, have a clear incentive to share their knowledge with their suppliers. This would generate a double positive effect, for the customers receiving innovative inputs and for suppliers able to face creatively their increasing demand for intermediary inputs and capital goods.

3. The empirical analysis

The focus of the empirical analysis consists in assessing the role of the microeconomic foundations of the demand pull hypothesis together with that of user-producer relations where vertical pecuniary knowledge externalities come into evidence. By its nature, input output tables provides an adequate framework to test the joint role of user-producer interactions and demand pull. They enter into the details of the effects of both the demand side pecuniary knowledge externalities channeled by the downstream derived demand of innovative users and of the supply side pecuniary knowledge externalities channeled by the supply of upstream innovative producers.

Input output methodology seems to be the most appropriate empirical framework of analysis to grasp the effects of vertical user-producer knowledge interactions that take place along with and because of user-producer transactions (Lundvall, 1985; Von Hippel, 1988; Gehringer, 2011a, 2011b, 2012).

The empirical analysis of the demand pull hypothesis has to tackle a central methodological problem that consists in the identification of the 'true' demand effects as distinct from the increase in equilibrium quantity stemming from the cost reductions. Ex-post, both the upward shift of the demand curve and/or the downward shift of the supply curve, engendered by increased cost efficiency, can cause an increase of the equilibrium output. The demand pull hypothesis concerns the first case, yet it seems not trivial to disentangle this effect from the downward shifts of the supply curve. It is clear that the discovery of an empirical validation of a relationship between the levels of innovative activity and the increase of the equilibrium demand may be tautological. The levels of innovative activity would be the cause rather than the consequence of the increase of the equilibrium demand, leading to the obvious endogeneity concerns. Much empirical investigation aware of the problem has elaborated statistical procedures based upon time lags between the dependent and explanatory variables. The growing evidence about the persistence of innovative activity, however, undermines the statistical reliance of these procedures (Antonelli et al., 2012). The evidence on the persistence of innovative activity, in fact, implies that the levels of innovative activity at time ($t+n$) are strongly correlated with the levels of innovative activity at time t. Hence, the attempts to estimate the effects of investments at time t on the levels of innovative activity at time ($t+n$) as a procedure able to avoid the endogeneity problems are biased by the powerful effects of innovation persistence and the consequent effects of innovation activities at time ($t-1$) on investments themselves at time t. To face those problems, we concentrate on the contemporaneous demand pulling effects in the study of which we apply dynamic panel techniques based on the system GMM methodology. This techniques, developed in a microeconomic framework of analysis, deals with endogeneity concern by instrumenting the variables in levels with their first differences and the variables in first differences with their lagged levels.

In the remaining subsections, we first describe the data and methodology implemented to construct the variables used in the empirical analysis. Subsequently, we present the main econometric specification matching our conceptual model and we describe the empirical methodology used in the estimation. Then, we present and discuss the results obtained. Finally, in order to validate the main model, we proceed with sensitivity analysis.

3.1 Data and methodology

The empirical investigation is based on an unbalanced panel of industry-level yearly observations related to 15 EU countries in the time span between 1995 and 2007.[3]

[3] Countries included in the analysis comprise prevalently the old EU member states (Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, the UK), in addition to a few Eastern European new members from the 2004 EU enlargement wave (Czech Republic, Hungary and Slovak Republic). Due to limited data availability especially for the remaining Central and Eastern European countries, we had to exclude the rest of the actual EU-27. Also the choice regarding the time span is conditioned on data availability before 1995 and after 2007. Moreover, due to a possible incidence of the recent crisis, the inclusion of the observations after 2008 should be explicitly tested for the presence of a structural break. However, given that the economic turmoil of the current crisis continues to persist, the extension of the time dimension for the years after 2008 would not permit to make any unequivocal conclusion on the matter.

We implement two main sources of data. The data necessary to construct sector-level TFP growth and unit wage come from OECD STAN 2011 database. Our annual input output tables come from the World Input-Output Database (WIOD) project, made publically available in April 2012.

TFP methodology

Following Jorgenson and Griliches (1967) and Jorgenson et al. (1987), and assuming the standard growth accounting framework with a constant returns Cobb-Douglas production function, the logarithmic growth rate of TFP is defined as

$$\Delta \ln \mathrm{TFP}_{ikt} = \Delta \ln Y_{ikt} - \bar{\alpha}^{K}_{ikt}\Delta \ln K_{ikt} - \bar{\alpha}^{L}_{ikt}\Delta \ln L_{ikt} - \bar{\alpha}^{X}_{ikt}\Delta \ln X_{ikt} \tag{1}$$

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

$$\bar{\alpha}^{f}_{ikt} = \left(\alpha^{f}_{ik(t-1)} + \alpha^{f}_{ikt}\right)\Big/2 \tag{2}$$

whereas

$$\alpha^{L}_{ikt} = L_{ikt}/Y_{ikt}\ ; \quad \alpha^{X}_{ikt} = X_{ikt}/Y_{ikt} \text{ and } \quad \alpha^{K}_{ikt} = 1 - \alpha^{L}_{ikt} - \alpha^{X}_{ikt}\ . \tag{3}$$

A common practice in the literature using some kind of measure of TFP as a proxy of productivity, is to assume a constant share of capital over output, α=1/3. We consider such an assumption as a serious drawback, shading the intrinsic dynamics of industries, countries and over time. For that reason, we depart from the simplifying assumption of a constant α and adopt a variable measure, reflecting better the changing conditions of each industry, country and in a particular moment of analysis.[4]

Input output methodology

In order to exploit market based inter-sectoral linkages and their influence on the sector-level productivity growth, input output framework has been implemented. The annual national input output tables from World Input-Output Database (WIOD) are industry per industry tables that have been derived following the Eurostat Manual for Supply, Use, Input-Output Tables methodology (model D).[5] In the present analysis, we concentrate on domestic input output relations. Consequently, given dynamic changes that occurred in the structure of intermediate transactions under the ongoing globalization era, further analysis should be dedicated to disentangle the effects of trade relations on the domestic arrival rate of innovations.

[4] There is also a consistent body of literature discussing the use of TFP as an adequate measure of productivity. For an overview, see Gehringer, 2011b.

[5] For a detailed explanation of the methodology, see Eurostat (2008).

Let's consider a simplified structure of a symmetric input output matrix referred to a country *k* at time *t*, with$(s_1, \dots, s_n)$ sectors, where *n* is the total number of sectors(Table1).

Table 1
A simplified representation of the input output framework

sector/sector	s_1	s_j	s_n	final demand	output
s_1	$x_{1,1}$	$x_{1,j}$	$x_{1,n}$	d_1	y_1
s_i	$x_{i,1}$	$x_{i,j}$	$x_{i,n}$	d_i	y_i
s_n	$x_{n,1}$	$x_{n,j}$	$x_{n,n}$	d_n	y_n
output	y_1	y_j	y_n		

The central part of the matrix describes inter-sectoral linkages based on intermediate inputs. The last row represents the total output of each sector - those same values are encountered in the last column. Finally, the column of final demand summarizes the sum of the alternative uses made in final consumption, fixed capital formation and exports.

In the sense of columns, a generic sector *j* is a producing sector, using $x_{.j}$ inputs from the other upstream sectors and generating a total output, y_j. In the sense of rows, a generic sector *i* is a supplying sector of the total quantity, y_i, which will be dedicated to the intermediate use, $x_{i.}$, by each of the column sector and to the final demand, d_i. On the main diagonal, where *i=j*, intra-sectoral relations can be observed. For instance, $x_{1,1}$ seen from the input perspective (in the sense of columns), stays for intermediate inputs that sector 1 receives from itself and uses as intermediate input in the process of internal production. Instead, seen from the output perspective (in the sense of rows), it represents the quantity of intermediates offered by sector 1 to that same sector 1.

From the vertical entries of an input output table, expressing the intermediate needs of each producing column sector *j*, and considering additionally the last row of sector-level output, one can obtain a matrix of technical coefficients, **A**, where the single component, a_{ij}, represents the fraction of inputs received from the supplying sector *i* over the total output produced by sector *j*. Analytically this can be written as

$$a_{ij} = \frac{x_{ij}}{y_j} \tag{4}$$

In other words, coefficient a_{ij} expresses units of direct intermediate requirements delivered by sector *i* that are necessary to generate 1 unit of total output by sector *j*.

From matrix **A**, an inverted Leontief matrix, $\mathbf{L}^{-1}$, can be obtained through the following transformation:

$$\mathrm{L}^{-1} = (\mathrm{I} - \mathrm{A})^{-1} \tag{5}$$

where **I** is the identity matrix, having on the main diagonal all elements equal to unity and out of the main diagonal – all nulls. A generic element of the inverse Leontief matrix, l_{ij}, expresses direct and indirect requirements demanded by sector *j* from sector *i* in terms of intermediate inputs that are necessary to obtain 1 unit of final demand referred to sector *j*.

Let's define matrix **B** as the matrix of the absolute volumes of direct and indirect intermediate requirements. This matrix is obtained starting from the inverse Leontief matrix and multiplying its single column referred to sector *j* by the corresponding value of final demand offered by that sector to the economy at large. To give an example, considering textile sector, the column vector coefficients from the Leontief inverse matrix corresponding to this sector will be multiplied by the value of final demand of textile products in order to obtain the vector of direct and indirect intermediate requirements necessary in the production process of sector *j*. In analytical terms, the *j*-th column of matrix **B** is obtained as:

$$\mathbf{B_j} = \left(\mathbf{L}^{-1}\right)_{\mathbf{j}} y_j \tag{6}$$

where $\left(\mathbf{L}^{-1}\right)_{\mathbf{j}}$ is a *j*-th column of the inverse Leontief matrix. A generic component of **B**, b_{ij}, refers to all inputs coming directly or indirectly from sector *i* that are necessary to obtain *y* units of final demand directed towards sector *j*. In the sense of columns, thus, we can read the values of intermediate inputs that are directly and indirectly required by a column sector *j* in order to supply the total value of final demand directed towards this sector. Instead, in the sense of rows, one can read the values of intermediate inputs that are directly and/or indirectly produced by a row sector *i* and that are demanded by the column sectors in the production of their respective values of final demand.

Finally, considering matrix **B** and defining matrix **T** as a symmetric matrix, where all rows are the same and each equal to a row, with each single entry given by sectoral TFP growth rate, let's define two more matrices, **R** and **S**.

$$\mathbf{R} = [\mathbf{B} \cdot \mathbf{T}]' \tag{7}$$

$$\mathbf{S} = \left[\mathbf{B}' \cdot \mathbf{T}\right]' \tag{8}$$

In the sense of columns, the elements $r_{\cdot j}$ of matrix **R** express direct and indirect intermediate inputs requirements that all sectors refer towards sector *j*, but taking into account productivity growth effect of each demanding sectors. Matrix **R** constitutes the crucial element to measure the demand-driven influence on the productivity growth of each single upstream sector *j*. This demand-driven effect should come not as a pure intermediate demand effect, yet as an efficiency-enhanced demand effect, stemming thus not uniquely from the downstream sectors' demand for intermediate inputs, but also and crucially from an increased total factor productivity of these same demanding downstream sectors.

Instead, each column in matrix **S**, referred to a single downstream user of intermediate inputs, reports direct and indirect requirements supplied by its all upstream producers, but accounting for the efficiency effect, as measured by $\Delta\ln\text{TFP}_i$ that a downstream user could experience when demanding intermediate inputs from its upstream producers. This matrix, thus, accounts for efficiency-enhanced supply effect.

3.2 Econometric specification

In line with our theoretical discussion, the focus of the forthcoming empirical investigation is on the quantification of user-producer market interactions and their influence on sector-level productivity growth. The peculiar feature of our specification consists in creating a unified framework, where we focus on the demand pulling forces, but at the same time we account for the average supply pushing influence. Consequently, we aim to explain innovativeness of sectors that on their own qualify as producers, when they offer intermediates to the other demanding sectors, and as users, when they receive inputs from their upstream suppliers. Accordingly, among explanatory variables, we distinguish between disaggregated user-driven (demand) and averaged producer-driven (supply) factors. The common feature of both types of factors is that they are catalyzed by the operating of vertical pecuniary knowledge externalities in the sense that both demand-side and supply-side influence is qualified by innovative capacities of users and producers, respectively.

The econometric model that reflects the key hypothesis that innovation of each agent (sector) is pulled by the demand of downstream innovative users assumes the following expression:

$$\Delta\ln\text{TFP}_{jkt} = \beta_1 + \beta_2\Delta\ln\text{TFP}_{jkt-1} + \boldsymbol{\beta}_3^{'}\mathbf{R_{jkt}} + \beta_4 S_{jkt} + \boldsymbol{\beta}_4^{'}\mathbf{Z_{jkt}} + \gamma_k + \delta_j + \mu_t + \varepsilon_{jkt} \quad (9)$$

where β_1 is a constant, $\Delta\ln\text{TFP}_{jkt-1}$ is the lagged dependent variable, γ_k, δ_j and μ_t are the country, sector and time specific effects, respectively, and ε_{jkt} is the idiosyncratic error term. Vector $\mathbf{R_{jkt}}$ corresponds to column *j* of matrix **R** at time *t* and includes explanatory variables measuring the demand-side influence. In the estimation of equation (9), we included 19 sectors, corresponding to 12 manufacturing in addition to 7 market service sectors.[6] Consequently, agriculture, mining and quarrying, as well as non-market services were not considered. This is mainly because, in formulating the estimating equation, we were aiming at limiting the risk of over-specification deriving from the inclusion of too many sectors. In this sense, we concentrated our attention on the impact coming from manufacturing and market services, based on the presumption that the efficiency-driven impact of demand coming from the excluded sectors is rather marginal. Consequently, we expect that the cost of such exclusion is less considerable than drawbacks deriving from over-specification. At the same time, we considered necessary the inclusion of both manufacturing and service sectors in a unified framework. The motivation of this choice derives mainly from the fact that a selective analysis of only manufactures or only services could lead to an estimation bias. This is because sectoral productivity growth is supposed to come as a result of interactions with both manufacturing and service sectors. Consequently, the inclusion of only either of the group could lead to overestimated effects.

[6] The list of sectors with their acronyms used in the empirical analysis is in Appendix A.

Variable S_{jkt} is obtained as an average of column *j* from matrix **S** and expresses the average supply-side influence on the productivity growth of sector *j* deriving from all linkages that this sector maintains with its suppliers by means of intermediate inputs transactions.[7]

Among the control variables, we include the rate of change in sector-level unit wages and sector's *j* final demand. The inclusion of the former variable is justified by the presumption that the positive/negative TFP dynamics could be driven by the wage impulses of the same sign. The variable measuring sector's *j* final demand refers to the hypothesis that the demand-side influence on the sectoral TFP growth could come not only from the intermediate part, but could be driven among others by final consumption or external demand for the domestic goods.

It is crucial to observe that the specification of equation (9) and most importantly the use of the information retrieved from input output tables permits to qualify with clearness the exact role played by the sectors within the vertical filiére, both on the right- and left-hand side of the equation. More precisely, considering the variables contained in vector **R**, expressing the dynamically efficient demand-side impact, they refer to the transactions based on derived demand of intermediate inputs coming from downstream sectors and directed towards the supplying upstream sector. In the same equation, the left-hand side sector might be seen in the quality of a downstream sector being influenced by an average supply-side effect.

This means that equation (9) is able to effectively describe and at the same time distinguish all upward and downward relations between vertically integrated sectors. This, indeed, is possible thanks to the input output transactions that describe the direction of interaction between sectors. According to those tables, each sector could and - in most of the cases - actually is user and supplier with respect to each other sector, in addition to being user and supplier of its own.

Given the panel structure of our database, we implement dynamic panel regressions to exploit information from both the cross-sectional and time-series dimension. Table 2 refers to summary statistics of the variables included in the estimation.

Table 2
Summary statistics

Variable	Observations	Mean	Standard Dev.	Minimum	Maximum
ΔlnTFP	4520	0.002	0.040	-0.405	0.369
food	4875	-0.001	0.223	-8.414	4.583
text	4875	-0.002	0.095	-1.886	2.389
wood	4875	0.001	0.021	-0.465	0.471
pap	4875	-0.001	0.060	-1.318	1.051
chem	4875	0.009	0.630	-11.538	26.920
rub	4875	0.003	0.052	-0.540	1.106

[7]We measure demand-side influences coming separately from each downstream sector, whereas supply-side effects are accounted for by means of an average effect. This is not to say that we consider supply-side effects less relevant than the demand-side effects. However, given the interest of our analysis in disentangling the manifold impact of demand, the inclusion of too many explanatory variables expressing sector-specific supply-side effects would impose the risk on the robustness of our specification.

met	4875	0.007	0.234	-4.158	8.481
mach	4875	0.005	0.109	-2.090	2.123
elec	4875	0.017	0.302	-4.075	8.097
treq	4875	0.022	0.531	-11.179	12.395
manu	4875	-0.002	0.058	-1.373	0.931
util	4875	0.003	0.142	-2.640	4.471
constr	4875	-0.040	0.626	-18.483	10.034
whole	4875	-0.000	0.345	-6.691	7.345
hot	4875	-0.019	0.197	-5.128	3.117
trans	4875	0.016	0.279	-3.625	5.279
fin	4875	0.007	0.279	-5.918	5.491
real	4875	0.066	0.708	-7.657	15.322
avsup	4550	0.000	0.186	-0.890	1.073
wage	4849	32404	41518	858	425114
findem	4875	30607	49825	9	461683

We first run equation (9) based on the dynamic fixed effect model. This model is, indeed, dynamic: among the explanatory variables it contains a lagged dependent variable. This method has the advantage to model unobserved heterogeneity that in our framework could play a substantial role, given country-specific differences in economic development of sectors. Nevertheless, this methodology still leaves unresolved the crucial concern of endogeneity, deriving most importantly from the bi-directional influence between the dependent and explanatory variables. Indeed, it cannot be excluded that the change in TFP of sector *j* would influence the contemporaneous verifications of the variables expressing the demand choice of all the other sectors acquiring intermediate inputs from *j*. Moreover, the country and sector specific effects could exercise an influence on the other explanatory variables as well. For that reason, we follow the approach proposed by Arellano and Bover (1995) and Blundell and Bond (1998) and we estimate equation (9) with the system GMM method. This method is based on a system built upon two specifications. 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:

$$E\left[\Delta \ln \mathrm{TFP}_{jk1}\varepsilon_{jkt}\right]=E\left[\mathbf{R}_{\mathbf{j1}}^{g}\varepsilon_{jkt}\right]=E\left[\boldsymbol{Z}_{\mathbf{1}\boldsymbol{t}}^{h}\varepsilon_{jkt}\right]=0,\ \forall g,h \text{ and } t=2,\ldots,T \tag{10}$$

$$E\left[\Delta\Delta \ln \mathrm{TFP}_{jk2}(\gamma_k+\delta_j)\right]=E\left[\Delta\mathbf{D}_{\mathbf{j2}}^{g}(\gamma_k+\delta_j)\right]=E\left[\Delta\boldsymbol{Z}_{\mathbf{2}\boldsymbol{t}}^{h}(\gamma_k+\delta_j)\right]=0,\ \forall g,h \text{ and } t=2,\ldots,T \tag{11}$$

where $g \in \{1 \ldots G\}$ is the number of variables in vector **R** and $h \in \{1 \ldots H\}$ is the number of control variables in vector **Z**.

3.3 Regression results

In Table 3 we report the results of the estimations of equation (9). In column (1), we include the results from the fixed effect model, whereas in column (2) are the results from the system GMM estimation procedure.

Independently of the econometric method used, the results in Table 3 report positive effects on sectoral productivity growth in the case of manufacturing sectors, in particular, for textiles and textile products, wood and products of wood, paper products, rubber and plastic products, other non metallic mineral products, machinery and equipment and manufacturing *nec*. This confirms the evidence of demand-driven positive productivity effects. It is crucial to underline that the positive impact of intermediate demand from those sectors on TFP growth of their suppliers is generated along with efficient industry developments internal to the structure of each user.

Providing a more articulated intuition to the results obtained, the past evidence confirms that textile and clothing industry in Europe experienced major structural changes in the late 90s, with inefficient plants closing their activities. Even if the sector is often classified as low-tech considering the intensity of the R&D activities, thanks to the positive restructuring activities in the past, productivity growth was regarding the entire intra-sectoral chain and some radical innovations occurred recently. Moreover, it has to be recognized that the activity of textile producers is often placed within an industrial district where inter-sectoral linkages with both upstream and downstream producers acquire a peculiar meaning. In such an environment, pecuniary knowledge externalities at play in the market transactions between users and producers constitute an integral part of the landscape and tend to be more incident than in standard non-clustered industrial structure. The recalled evidence regarding the textile sector facilitates the interpretation of the result, confirming its role as an innovative user in contributing to upstream productivity growth.

The case of machinery and equipment is especially relevant. The sector supplies capital goods that embody product innovations, whose adoption feeds process innovations in downstream users. This explains its role as a strategic supplier for many other sectors. Moreover, firms producing machinery and equipment can develop product innovations in response to the specific technical suggestions of their customers as channeled by fertile user-producer interactions (Von Hippel, 1976).

At the same time, the downstream process of development of innovative machinery and equipment will be reflected in the creative adaptation of their upstream suppliers, committed to maintain their market position and thus willing to remain up to date with the dynamic performance of machinery and equipment producers. The loop of circular feedback is especially clear here with downstream producers introducing product innovations and pulling the supply of new products from their upstream producers so as to introduce subsequent innovations downstream. In turn, upstream producers of the machinery industry innovate because they need to face positively the pulling challenges and opportunities provided by the growth of their downstream customers.

Table 3

Results from the estimation of equation (9)

	FE	*sys GMM*
*l.*Δ(TFP)	-0.062	-0.017
	(0.041)	(0.040)
food	0.002	-0.001
	(0.003)	(0.004)
text	0.023*	0.018*
	(0.010)	0.010
wood	0.204**	0.149**
	(0.066)	(0.051)
pap	0.041*	0.048**
	(0.018)	(0.015)
chem	0.002	-0.001
	(0.002)	(0.003)
rub	0.091***	0.082**
	(0.022)	(0.028)
onm	0.115***	0.107***
	(0.026)	(0.027)
met	0.004	0.008
	(0.011)	(0.008)
mach	0.025**	0.028**
	(0.008)	(0.009)
elec	0.009	0.003
	(0.010)	(0.009)
treq	0.001	-0.001
	(0.004)	(0.005)
manu	0.051**	0.048**
	(0.015)	(0.016)
util	0.018	0.014
	(0.011)	(0.010)
constr	-0.008***	-0.011**
	(0.002)	(0.004)
whole	-0.007*	-0.008*
	(0.003)	(0.004)
hot	0.003	-0.001
	(0.007)	(0.006)
trans	-0.001	-0.003
	(0.003)	(0.006)
fin	0.001	-0.003
	(0.005)	(0.005)
real	-0.009***	-0.012***
	(0.002)	(0.003)
avsup	0.346***	0.432***
	(0.053)	(0.076)
wage	0.000**	-0.000
	0.000	(0.000)
findem	-0.000	-0.000
	0.000	0.000
observations	4146	4146
R-squared	0.332	
Sargan (p-value)		0.074
AB m-2 (p-value)		0.436

Note: ***, ** and * imply significance levels at 1%, 5% and 10%, respectively. Robust standards errors are included in parentheses. Country and sector dummies are included in the fixed effect model, while time dummies are considered in both specifications. The models are validated with appropriate test: overall R-squared for the fixed effects method and Sargan test of overspecification (p-value). Moreover, Arellano-Bond test for no autocorrelation of order 2 has been also considered for system GMM. Estimated coefficients come from the one-stage, while the results of the Sargan and AB tests are taken from the two-stage estimation.

The strong evidence regarding rubber and plastic product reflects the focus of European industrial policy on the environmental issues. The intensive stimulus provided for the development of innovative products and recycling processes, complying with the environmental protection, led rubber and plastic producers to successful waves of eco-innovations.[8] Moreover, being downstream producers of rubber and plastic in continuous interaction with their suppliers - among which doubtlessly also the producers of rubber and plastic machinery - they managed to activate a dynamic process of transactions-*cum*-interactions with an evident positive impact on sector-level total factor productivity growth upstream.

Already from the previous discussion it appears with clearness that the innovative process is nested in bi-directional user-producer relationships. The importance of this phenomenon is confirmed also in our results, as the average supply-push effect (*avsup*) appeared to be significantly positive as well.[9] This evidence of a significant average effect approaches the findings by Gehringer (2011a, 2011b and 2012) who offers a detailed investigation aiming to reveal empirically the importance of supply-side pecuniary knowledge externalities in the European economies. Finally, the finding confirming the simultaneous role of demand and supply side factors is in line with the arguments of Mowery and Rosenberg (1979) and Arthur (2007).

Instead, negative evidence has been reported for two service sectors, construction and real estate. Regarding construction sector, a number of past investigations suggested that (labour) productivity in construction declined, whereas an opposite tendency could be contemporaneously observed for the majority of manufacturing sectors.[10] This finding, put together with the evidence of the recent overheating of the activity in the European construction sector in European economies, with the most problematic cases of Spain and Ireland, partly seems to support our results. Moreover, rising employment in construction sector was probably linked with unsustainable real estate booms. Nevertheless, given peculiarity of the effects at play in our research framework, further investigation of economic forces driving such effect would be needed to disentangle its real nature.

Finally, controlling for the incidence of the final demand (*findem*) produced an insignificant result in the case of both methods, whereas the impact of unit wages (*wage*) was positive, though only in the case of the fixed effect model.

On the basis of our results, nevertheless, we cannot aim at delivering precise policy options, focusing on one type of sectoral activity or another. This is most importantly due to the fact that we obtained general

[8] New technological process for rubber and plastic recycling enables the complete decomposition of rubber and plastic waste to the commercial components. Similarly, the environmental concerns brought dynamic developments in the automotive sector with the consequent need of high-performance plastic materials, like for instance high temperature-resistance plastics.

[9] Due to a strongly significant result regarding the supply-side influence, in a separate estimation procedure, not reported here, we excluded *avsup* from the estimation. The results relative to the demand-side influence appeared to be stronger than before, justifying the need to consider a joint influence of the supply- and demand-side in a unique specification.

[10] Those studies refer basically to the US data before 2000, as for instance the analysis by Teicholz (2001). The evidence regarding the European economies is missing. Nevertheless, a consensus among authors studying construction sector is that the complexity of the operating in construction sector make it all the more difficult to perform at a level-playing field. For a survey of studies analyzing structural issues in construction sector, see Dubois and Gadde (2001).

European evidence on the demand pulling the innovativeness. Indeed, specific geographic composition of economic activity matters in influencing innovation (Feldman and Audretsch, 1999; Bottazzi and Peri, 2003). Further investigation in a single country perspective is needed to deliver more concrete innovation policy implications.

3.4. Robustness check

In considering the efficiency-driven demand effects on productivity growth in the previous section it was essential to measure the impact of derived demand conditioned on improved innovativeness of downstream users. In the previous investigation thus the explanatory variables in matrix $\mathbf{R_{jt}}$ have been constructed as compound effects of two competing forces. However, a justified suspicion could lead to argue that the evidence of any significant effect would be driven by either of those forces. It is thus reasonable to check for this possibility. To this end, we run further two specifications, one measuring the possible pure demand effect and another one trying to detect pure technological influence.

More precisely, the first estimation consists in replacing vector $\mathbf{R_{jt}}$ of variables expressing the efficiency-enhanced demand effect with vector $\mathbf{B_{jt}}$ corresponding to column *j* of the transpose of matrix **B**. In such a way, we want to take into account the pure effect of sectoral demand for intermediate goods, separated from the productivity effect of the demanding sector. Instead, the second estimation, in analogy to the previous one, consists in replacing vector $\mathbf{R_j}$ with the vector of sectoral TFP growth of the 19 sectors taken under investigation. Recalling the discussion offered in Section 2 regarding the distinction between pecuniary knowledge externalities and pure technological externalities, this second specification is of a great importance, as it verifies the existence (or the absence thereof) of pure technological externalities, to which a great role has been assigned in the past theoretical and empirical literature (Griliches, 1979).

There is, however, one drawback of this second alternative specification. Here, it is not possible to proceed with a clear assignment of the respective roles as downstream and upstream producers within the vertical productive chain played by the sectors on the left- and the right-hand side of the estimating equation, similarly as it was the case in the estimation of equation (9). In particular, when investigating the impact on the productivity growth in sector *j* that would derive from pure technological externalities exercised by the other sectors, among the explanatory variables we include the growth rates of TFP of sectors that at the same time could maintain both upwards and downwards relations with the analysed sector *j*. This is, in turn, fully compatible with the very concept of pure technological spillovers, where the flow of knowledge could assume such a bi-directional nature: from innovative producers towards innovative users and the other way around. Nevertheless, this distinction remains purely conceptual, underlying at the same time the usefulness of the concept of pecuniary knowledge externalities. Indeed, these external effects are rooted in the market transactions that permit to precisely identify the direction of influence of the underlying knowledge interaction.

Table 4

Alternative estimations of equation (9) considering the pure demand effects and the pure technological externality effect

	(1)	(2)
*l.*Δ(TFP)	-0.012	-0.028
	(0.042)	(0.040)
food	-0.0004	0.018
	(0.0002)	(0.036)
text	0.0004	0.043
	(0.0006)	0.035
wood	-0.0040	0.031
	(0.0043)	(0.031)
pap	0.0001	0.044
	(0.0007)	(0.039)
chem	-0.0002	0.008
	(0.0003)	0.010
rub	0.0002	0.052
	(0.0010)	(0.030)
onm	-0.0003	-0.011
	(0.0022)	(0.039)
met	-0.0003	-0.016
	(0.0112)	(0.041)
mach	0.0003	0.035
	(0.0005)	(0.036)
elec	-0.0005	0.027
	(0.0003)	(0.029)
treq	-0.0001	0.027
	(0.0001)	(0.029)
manu	0.0009	0.042
	(0.0012)	(0.028)
util	-0.0004	-0.016
	(0.0004)	(0.031)
constr	-0.0002	0.018
	(0.0003)	(0.034)
whole	0.0002*	-0.021
	(0.0001)	(0.036)
hot	-0.0003	0.011
	(0.0003)	(0.030)
trans	-0.0003	0.111*
	(0.0002)	(0.053)
fin	-0.0002	0.021
	(0.0002)	(0.021)
real	-0.0002	0.040
	(0.0002)	(0.044)
avsup	0.386***	0.365***
	(0.036)	(0.035)
wage	-0.000	-0.000
	0.000	(0.000)
findem	-0.000	-0.000
	0.000	0.000
observations	4146	4146
Sargan (p-value)	0.073	0.056
AB m-2 (p-value)	0.450	0.558

Note: ***, ** and * imply significance levels at 1%, 5% and 10%, respectively. Robust standards errors are included in parentheses. Country and sector dummies are included in the fixed effect model, while time dummies are considered in both specifications. The models are validated with the Sargan test of overspecification (p-value). Moreover, Arellano-Bond test for no autocorrelation of order 2 has been also considered for system GMM. Estimated coefficients come from the one-stage, while the results of the Sargan and AB tests are taken from the two-stage estimation.

The results in Table 4 report almost no evidence from operating of pure effects both in terms of intermediate demand (column (1)) and as inter-sectoral productivity growth spillovers (column (2)). This lack of evidence is crucial for the findings of the previous section, as it strengthens the hypothesis sustaining that an indispensable element for the demand-pull influence on productivity of producers to occur is given by efficiency of downstream users. This also supports the hypothesis that the assumption of knowledge interactions-*sine*-transactions, typical for pure technological externalities, cannot be supported with empirical evidence (Gehringer, 2011a).

4. Conclusions

The identification of vertical knowledge externalities, based upon the knowledge interactions that take place within the context of user-producer transactions and the appreciation of their central role in the generation of new technological knowledge, provide new foundations to implement and articulate the intuition of Nicholas Kaldor that public intervention can become a structural component of economic policy when and if it consists of a support of aggregate demand, able to pull technological change. The contribution of Jacob Schmookler helped refining the Kaldorian hypothesis, focusing attention on the role of selected investments. Nevertheless, the further implementation of the demand pull hypothesis, building upon the Kaldor-Schmookler line of analysis, requires better understanding of its microeconomic foundations. The new literature on the economics of knowledge provides useful guidance in these attempts and permits better grasping the conditions that make it possible the very generation of technological knowledge and the eventual introduction of technological innovations. This implies the scrutiny of the introduction of technological and organizational innovations as systemic processes, based on the active participation of individual agents to the knowledge commons embedded in the structure of economic systems and implemented by vertical knowledge interactions. A crucial feature of those interactions is their being channeled by user-producer transactions, pushing further the appreciation of the endogenous character of technological change.

Our approach has elaborated the microeconomic foundations of the demand pull hypothesis, building upon the Schumpeterian approach to innovation as a form of reaction to unexpected changes in the conditions of factor and product markets, including the levels of the demand, that becomes actually creative when and where firms can rely upon the access to external sources of technological knowledge. The Schumpeterian microeconomics of the demand pull hypothesis stresses the complementarity between demand pull and knowledge externalities. More specifically, we identified the derived demand of innovative customers as the key mechanism of the demand pull hypothesis. From an empirical viewpoint we contributed the literature on the demand pull hypothesis in two crucial points. First, we filled a major conceptual gap deriving from the lack of a microeconomic understanding of the pulling mechanism of derived demand. Second, by taking advantage of the opportunity provided by the implementation of input output tables, we tested the role of derived demand pull *cum* vertical knowledge externalities on the upstream rates of growth of total factor productivity, channeled by user-producer interactions.

The results of our investigation, performed on a panel of 15 European countries in the years 1995-2007, confirm that the rates of introduction of innovations, as measured by the rates of increase of total factor productivity, are significantly associated with the increase of the derived demand of downstream sectors associated with their own rates of increase of total factor productivity. The evidence supports the argument that generic increases of the aggregate demand are not sufficient to pull the rate of introduction of innovations. Only when the increase of demand is qualified as it is associated to the actual increase of the rates of innovation introduction of the user sectors, the demand pull mechanism becomes effective (Peters et al., 2012). Consequently, such an evidence of an important role played by innovative user in their interactions with innovative producers, combined with the quasi-public good characteristics of knowledge, implies that externalities may be crucial in shaping industrial development in Europe. Additionally, however, we demonstrate that those externalities require a market context and its effective transactions to operate. A crucial result in this sense is thus that technological externalities are not pure yet pecuniary.

The implications of the microeconomic foundations of the demand pull hypothesis are important both from the viewpoint of economics and for economic policy. From the viewpoint of economic analysis the qualification that demand matters in pulling innovation when it is associated with stronger user-producer transactions that channel knowledge interactions amount to suggesting a way to reconcile the Keynesian and the Schumpeterian traditions. Demand matters as in the Keynesian tradition, articulated by Nicholas Kaldor, only when it is derived demand of competent users that have innovated and are able to support the innovative efforts of their suppliers. The new emphasis of knowledge externalities clearly impinges upon the Schumpeterian tradition. From the economic policy viewpoint, the results of our analysis have important implications for public support of innovative initiatives, as they credit the need to identify sophisticated public interventions able to combine the support to the demand with the exploitation of technological opportunities. In this sense, public support to sustain demand should assume a follow-up perspective to take into account and sustain also possible positive repercussions on the supply-side.

The generic support of aggregate demand may speed the diffusion of innovations, as suggested by Kaldor, but is not likely to pull effectively the generation of new technological knowledge and the introduction of innovations. The identification of user-producer transactions-*cum*-knowledge interactions as the systemic mechanisms, by means of which the participation of each agent to knowledge commons is effectively enhanced, stresses the need to proceed to the selection of the filiéres along which competent and innovative users can support the increase of the derived demand, including both the demand for capital goods and for intermediary inputs. This would have the chance to pull the overall increase in the rate of generation of technological knowledge and the introduction of technological and organizational innovations.

A competent and specific demand, as opposed to a generic one, based upon both public procurement and private demand stirred by dedicated regulations can pull effectively the generation of new technological knowledge and the introduction of new technologies. This will become effective provided that the competent users are able to identify the relevant technological opportunities available at each point in time and the structures of vertical transactions that are actually associated to active knowledge interactions.

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Appendix A

Table A.1
Description of analysed industrial sectors and their acronyms.

sector	full name
food	Food, beverages and tobacco
text	Textiles and textile products; leather and footwear
wood	Wood and products of wood and cork; articles of straw and plaiting materials
pap	Pulp, paper, paper products, printing and publishing
chem.	Chemical and fuel products
rub	Rubber and plastic products
onm	Other non-metallic mineral products
met	Basic metals and fabricated metal products
mach	Machinery and equipment *nec*
elec	Electrical and optical equipment
treq	Transport equipment
manu	Manufacturing *non elsewhere classified*; recycling
util	Electricity, gas and water supply
constr	Construction work
whole	Wholesale and retail trade; repairs
hot	Hotel and restaurant services
trans	Transport, storage and communication
fin	Finance, insurance
real	Real estate, renting and business activities