Center for
European,
Governance and
Economic Development Research

cege

Discussion Papers

Number 101 – June 2010

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ISSN: 1439-2305

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Abstract

This paper investigates empirically the occurrence of pecuniary knowledge externalities at the sectoral level across European economies. The main results suggest that, although some sectors can be considered as playing a particularly important role as a source of pecuniary knowledge externalities in the majority of examined countries, there exist significant national differences in the occurrence of these effects. Moreover, such external effects influence the dynamics of total factor productivity in downstream sectors and appear as a relevant source of growth in modern economies. As such, the concept of pecuniary knowledge externalities, as opposed to pure knowledge externalities postulated in the new growth theory, provides a new clue to understanding of the growth process.

Key words: pecuniary knowledge externalities, pure knowledge externalities, knowledge production function, intermediate goods transactions

1. Introduction

The awareness about the complexity of any context of economic activity involving innovations brought recently important extensions in the economic literature that gradually permitted to create a more complete view of the process of economic development. In the new growth theory, the inclusion of technology as an endogenous production factor was without doubt a crucial factor in this sense (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). Also the pioneering contributions due to Schumpeter (1942), related to his considerations on the dynamics of industrial transformations, provided an important insight and motivated the construction of models of the new growth theory (in particular, Aghion and Howitt, 1992).

Although in the majority of these models the generation of technological knowledge gives raise to externalities in the subsequent path of development, there exist some shortcomings in the way external effects are defined and described in their working out of further influence on the production system as a whole. In particular, knowledge externalities considered in the growth literature are supposed to exert an influence on the production system with no consequences in terms of costs following the adoption of knowledge from external sources. Contrary to this view, it appears more realistic to imagine that professional users need to incur some costs in order to combine external sources of technological knowledge with internal knowledge and, finally, to use these complementary knowledge inputs in the generation of new technological knowledge as well as in the standard production of goods. These costs, however, are lower than in equilibrium, with the latter describing a situation in which knowledge would possess the characteristics of a normal good.

This last argument constitutes the basis of the conceptual treatment over pecuniary knowledge externalities (PKE), as defined by Antonelli (2008a, 2008b), and taken under examination in the present work. In particular, the main focus of the study consists in underlying the relevance and a specific nature characterizing pecuniary effects based on upstream-downstream transmission of technological knowledge, in influencing the dynamics of total factor productivity observed downstream. This is made by applying the concept of PKE in the study of the economic structure and its dynamics in 13 European countries, though considered separately, each decomposed in 25 sectors of economic activity. Emphasis is put, basically, on the analysis of differences and similarities among European countries and the role played by each single sector in the occurrence of PKE is also examined.

It is well known, ever since the pathbreaking investigations of Keith Pavitt that in all national contexts there are sectors of economic activity that, thanks to their particular characteristics and innovative potentials, exert a non negligible impact in the system of intersectoral relations based on the transmission and further influence of technological knowledge (Pavitt, 1984). In this context we investigate empirically the role of PKE in shaping vertical relations between upstream innovative producers and downstream professional users, and consequently in influencing the direction of technological change.

The paper is organized as follows. The next section will concern innovation-based externalities, as discussed in the literature so far. As an important extension in this sense, the concept of pecuniary knowledge externalities will be defined. Section 3 is dedicated to the examination of the evidence with which PKE occur in national contexts of 13 European economies. The last section concludes.

2. Theory and motivation

Complexity, uncertainty and unpredictability of innovative activity constituted the subject of many theoretical contributions and has been confirmed to be an inseparable element of any analysis regarding innovations[1], growth as well as dynamics of structural change. Such a design of the innovation process is strictly connected with specific characteristics possessed by technological knowledge and with external effects accompanying its generation, transmission to the rest of the economy and its further transformation.

The occurrence of external effects being produced in an innovative environment has been widely discussed in the economic literature concerning growth, industrial interdependences and spatial dimension of innovative activities.

Till now, however, attention has been mainly concentrated on the reciprocal influences between producers coming from the “atmospheric” nature of technological knowledge. According to these contributions, knowledge cannot be fully appropriated by producers and spreads freely in the air with no consequences in terms of costs on its receivers. An alternative view here followed argues that the generation and transmission of technological knowledge is accompanied by pecuniary externalities that exert non negligible consequences on the innovativeness of downstream producers. In this sense, Scherer (1982) shows how a relevant

[1] See Kline and Rosenberg (1986).

part of the benefit generated by upstream industries in the production of new goods will be passed on to buying industries, influencing their productivity growth.

The particular category of externalities here examined, namely, pecuniary knowledge externalities (PKE), provides a new understanding of the process of long-run growth of an economy, where the linear dynamics postulated in the modern growth models is replaced by a more complete picture, with sectoral interdependences at the centre of any process involving generation of innovations, and more generally, structural development.

2.1. Externalities, innovation and growth

The literature on externalities builds upon three complementary traditions: the MAR (Marshall-Arrow-Romer), Jacobs and, finally, Porter externalities. All these lines of theoretical development focused on a localized nature of technological knowledge. Generally, the MAR tradition emphasizes the role of vertical specialization, while Jacobs (1969) and Porter (1990) underline horizontal differentiation as an engine of local innovative capacities.

In particular, the Marshallian tradition, that can be dated back to the seminal contribution of Marshall (1890) and further developed by Viner (1931), Meade (1952) and Scitovsky (1954), elaborated a central distinction between technological and pecuniary externalities. Such a distinction has been also emphasized by Griliches (1979, 1992), who dedicated a relevant part of his work to the search for research and development spillovers.

Technological externalities apply when producers are connected by direct interdependences, i.e. actions that do not occur through market supply of goods or services, but consist in direct influences, or in the words of Scitovsky, in “inventions that facilitate production and become available to producers without charge” (p. 144). Similarly, Grilliches (1979) recalls the concept of “pure knowledge spillovers” to refer to “ideas borrowed by the research teams in industry *i* from the research results of industry *j*” (p. 14).

The contribution of Grilliches has been fruitfully adopted in the new growth theory, where the idea of externalities incorporated in knowledge spillovers as a consequence of the generation of new knowledge within the research sector is central to the most of theoretical models of endogenous growth (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Jones, 1995).

The other category of externalities previously mentioned, pecuniary externalities, refers to indirect interdependences that are mediated by means of the price system. Pecuniary externalities stem from the provision of innovative inputs to the downstream producers. These inputs embody technological innovations and are offered to the downstream sectors at less than their full quality price.

As argued by Antonelli (2008b), in the model of growth though creative destruction elaborated by Aghion and Howitt (1992) one can observe the operating of pecuniary externalities as well. The central contribution of their model consists in illustrating the successful generation of innovative intermediates, created thanks to the activity of the research and development sector. Innovative inputs are sold to downstream producers at a price lower than it would follow from the quality increase. Nevertheless, this pecuniary effect does not have any impact on the final result of the model: the balanced steady-state growth is reached as a consequence of the upstream positive TFP dynamics. There is no place, in fact, in their model, for any kind of effects allowing downstream users to arrive at innovative result themselves. Upstream innovative activities do not stimulate downstream users to respond creatively with an intentional generation of an in-house technological knowledge and, consequently, to switch to a new technological content. They remain very much passive (Antonelli, 2008b).

2.2. Pecuniary knowledge externalities – a theoretical view

The dissatisfaction with the passiveness of downstream producers in front of idiosyncratic sources of external knowledge and, at the same time, the recognition of their "creative ability to intentionally generate technological knowledge" (Antonelli, 2008b), brought into discussion the possibility of the occurrence of a particular category of external effects, labeled as pecuniary knowledge externalities (PKE).

Provided that potentially innovative users populate downstream sectors, externally generated technological knowledge will be implemented by downstream professional users in a process of transformation and further generation of innovative results. This refers both to the tacit sources of external knowledge when it is embodied in intermediate products and services, and to codified knowledge acquired through patents and licenses, but also to circumstances in which knowledge spillovers are apparently disconnected from market transactions. In all these cases the downstream activity of knowledge assimilation and further exploitation requires dedicated interaction and resources. This means that external knowledge used as a production input is never a free factor and professional users can take advantage of it only at a cost. Nevertheless, thanks to the partial appropriability, intrinsic nonexhaustibility and nondivisibility of knowledge, these costs are lower than in equilibrium, meant as a hypothetic situation in which knowledge would possess the full range of characteristics of a normal good. In such a context, PKE offer a knowledge-related cost opportunity and motivate downstream producers to combine external knowledge with internally generated one in the process of generation of further technological knowledge and in the production of new goods.

To put it in terms of an anecdotic example, let's imagine a scientific laboratory where a new technology is successfully developed in order to design a new computer model. The technology is passed on to the computer company which arrives at obvious quality improvements in the construction of its computers. New computers are acquired by other computer-using companies and step by step replace the old models. Consequently, their use permits to improve the work of secretaries, able to accomplish their duties in a shorter time. This is, namely, what the model of growth by Aghion and Howitt aims to predict: firms acquire and successfully implement new computers used to improve the status quo internal working process. Nevertheless, in such a context firms remain passive in front of technological knowledge embedded in new machines. Contrary to this view, the presence of PKE brings a new light to the activity of computer-buying firms. The acquisition of computers is accompanied by the transmission of new technological knowledge which, after a process of transformation internal to the firm and accommodation with internal source of knowledge, leads to further innovative results, for example in the way the previous tasks of secretaries could be performed. In such a way, the secretaries can accomplish their duties not only faster, but also in an innovative manner. However, in order to master the innovative way of working, the secretaries are trained and are given specific instructions from the computer company itself. As a result, the computer-using company will become a knowledge-intensive service company that provides advanced typing services to its customers. An innovation has been introduced in downstream activities: it takes advantage of knowledge spilling from upstream innovators, but it is the result of the original implementation of new knowledge in the downstream industry. This last activity is by no means a free lunch for the computer-using firm that has to support costs of the training or of other professional interactions. These costs are, nevertheless, lower than the costs of the early generation of innovation incorporated in new computers and pecuniary knowledge externalities apply, giving the opportunity to the firm to become an innovator herself.

The particular category of external effects here examined has not been sufficiently appreciated so far as a separate mechanism having the potential of shaping the development path of an economic system. The new growth theory has been dominated by the convincement that external knowledge spills over freely between producers, but it does not engage any creative reaction in its users. Contrasting these ideas, the notion of PKE offers a new understanding of growth-supporting mechanisms.

2.3. PKE as a result of knowledge production process

This section provides a more technical illustration aimed at explaining the occurrence of pecuniary knowledge externalities.

Recalling the contribution of Nelson (1982) on the importance of the analysis concerning the role of knowledge in modeling continuing technological change in an industry, the process of knowledge generation may be synthesized in the following knowledge production function[2]:

$$T = f\left(Ext; Int\right) \tag{1}$$

where T stays for technological knowledge, Ext expresses external sources of knowledge and Int refers to internal sources of technological knowledge, both considered as complementary inputs, necessary to implement in the knowledge production process.

Internal knowledge is obtained mainly by means of successful R&D activities. External knowledge, in turn, requires dedicated resources necessary to support the purchasing value of knowledge in addition to the cost of interaction and transaction. Nevertheless, thanks to the partial appropriability of knowledge, its nonexhaustivity and indivisibility, the actual cost of knowledge adoption and exploitation is lower than its "normal" equilibrium level would suggest, giving raise to PKE.

As a result of knowledge production, realized with a perfect combination of internal and external resources, the downstream producer obtains a superior knowledge outcome that enters the standard production function in the expression of the technology component.

Let's consider a Cobb-Douglas production function:

$$Y = A L^{\alpha} K^{\beta} \tag{2}$$

[2] For a more complete treatment of the concept of knowledge production function, see Antonelli (2007) and Patrucco (2009).

where Y is the total output, L and K are labor and capital inputs with the corresponding coefficients, α and β, and A measures influence of the technology component not captured by the standard production inputs, labor and capital.

Here, the technology component, A, is measured in terms of TFP and is intended to capture the positive influence coming from the knowledge production process. In this way, the dynamics of TFP can be conveniently viewed as an indirect evidence of PKE. Indeed, in order to properly measure PKE, it is not sufficient to look exclusively at the TFP dynamics, but it is necessary to consider cost conditions associated with the assimilation of knowledge. To this end, intersectoral market relations registered in input-output transactions will provide the evidence of these costs. In that way, a positive PKE-driven TFP growth in the downstream sector will be linked with the acquisition of innovative intermediate goods.

3. Empirical evidence from the occurrence of PKE in Europe

The present section is dedicated to the analysis of the results obtained from a panel estimation aimed to establish the presence and patterns with which PKE appear in the national European economies.

The next section (3.1) describes the model. Following section (3.2) offers the description of the data used in the estimation. Finally, section (3.3) illustrates the methodology applied and analyzes the results obtained.

3.1. The model

The main purpose of the estimation procedure is to assess the occurrence of PKE across 25 manufacturing and service sectors in a group of 13 European countries considered separately.

The equation used to capture the process dynamics observed in each country is the following:

$$\begin{aligned} d(TFP)_{i,t} = \beta_1 a_{i1,t} d(TFP)_{1,t} + \beta_2 a_{i2,t} d(TFP)_{2,t} + \ldots + \beta_{25} a_{i25,t} d(TFP)_{25,t} + \\ \gamma d(w)_{i,t} + \delta R\&D_{i,t} + e_{i,t} \end{aligned} \tag{3}$$

where the dependent variable is the growth rate of TFP in sector i at time t. Explanatory variables are given, for every sector j, where $j = (1,2, \ldots , 25)$, by a product of the expenditure coefficient a_{ij} and the corresponding growth rate of TFP, namely $d(TFP)_j$.

There exists a consistent body of authors who discuss the plausibility of the use of the rate of change of TFP as an appropriate measure of technological change.[3] In particular, the methods of calculation assuming a Cobb-Douglas production function are sensitive to the strong analytical assumptions about perfect competition in input and output markets. Nevertheless, given that other techniques, as for instance the use of patent statistics or expenditures in R&D, suffer considerable shortcomings, the rate of change of TFP is considered as the most reliable expression of output changes due to technological forces incorporated elsewhere than in the standard production inputs.[4]

Bearing in mind the aforementioned computational problems connected with the use of TFP as a measure of productive efficiency, two control variables are included, i.e., the rate of change in sectoral wages and the level of sectoral expenditures in R&D. Their inclusion is aimed to account for possible influences on the growth rate of TFP coming from sources other than newly generated technological knowledge. In particular, the measure of labor change in the calculation of the TFP growth rate may not fully account for wage dynamics stemming for example from positive changes in human capital that, consequently, affects changes of the residual. Also the R&D expenditures are not included in standard measures of production inputs, capital and labor, and may exercise influence on the output. The inclusion of R&D expenditures is thus aimed to single out the effect of formal innovation on the TFP dynamics.

The coefficient a_{ij} expresses the relative weight that expenditures in intermediate inputs, coming from sector j and acquired by sector i, have over the total value of the output obtained by sector i. These coefficients have been calculated using the Input-Output tables at constant prices. They are supposed to mirror market transactions through which downstream sectors acquire innovative intermediates and at the same time receive technological knowledge in them embedded. The expenditure coefficient has been multiplied by the rate of change of TFP of the supplying industry. In that way, the composed variable is aimed at capturing upstream-downstream transfers of knowledge by means of market transactions and their influence on the downstream rate of change of TFP. Thanks to external sources of knowledge, downstream users interact with upstream producers and are addressed by pecuniary knowledge externalities in the process of adoption and transformation of external knowledge (performed at costs that are lower than in equilibrium) and experience a positive TFP dynamics. In other words, if a sector j is supposed to exercise a significant influence on a receiving sector i by

[3] For a summary discussion of the subject, see Lipsey and Carlaw (2004).

[4] Antonelli and Scellato (2007).

means of interactions involving upstream generated technological knowledge with the consequence of the occurrence of PKE, one can expect a significant and positive β coefficient associated with the composed variable related to sector j. Expenditure coefficients and the growth rates of TFP are contemporary, in the sense that if the former expresses the relative expenditures of sector i toward sector j at time t, the latter measures the growth rate of TFP in sector j between $t-1$ and t, with an annual time span. In this way, it is assumed that the new technological knowledge is transmitted through the market transactions occurring in the same year.

To sum up, the positive dynamics of sectoral TFP can be considered only as an indirect measure of PKE. Indeed, these external effects do not spill over in the air, but occur as a consequence of the acquisition of innovative intermediates and of the following reduction in costs, enjoyed by the downstream producer in the process of assimilation of external knowledge as an input into the generation of further knowledge.

3.2. Data

The analysis concerns 13 European countries, namely, Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Spain and the United Kingdom. For every country a separated panel has been constructed, with 25 sectors, over ten years from 1995 to 2004[5]. For every sector the TFP growth rate has been calculated, using the Thörnquist-Theil Divisia index that determines the logarithmic growth rate of TFP as a difference between the logarithmic growth rate of value added and the logarithmic growth rates of labor compensation and of capital stock, the last two multiplied by the averages over two subsequent years of α and β coefficients from the standard Cobb-Douglas production function. The α coefficient has been computed as a fraction of capital over value added, while the β coefficient is its complement to one.

[5] For some countries the time spread has been chosen differently: for Norway it was possible to construct a longer panel going from 1992 to 2005. For the Czech Republic, due to the missing data for the volume value added, for the employment and for the capital stock, the panel starts in 1996, but ends up in 2006. For Finland, France, Germany and Sweden the time spread goes till 2005, while for Austria and Belgium two years, namely 1996 and 1998, are missing due to unavailable Use tables for these years. Also for Spain and UK some observations are missing, particularly 2002-2004 in the case of Spain and 2004 for the UK.

The variables necessary for this calculation come mainly from the OECD-STAN database. Additionally, for some countries it was necessary first to construct time series of capital stock starting from the data on fixed capital formation, according to the perpetual inventory method.

Expenditure coefficients have been calculated from previously deflated Input-Output and the Use tables, taken from the Eurostat database, as a fraction of the expenditure of sector *i* made in intermediate inputs provided by sector *j* over the total value of production performed by sector *i*.

3.3. Estimation method and the main regression results

Equation (3) has been estimated separately for each country with the fixed effect method[6]. In this way, all influences on the dependent variable other than these predicted in the explanatory variables – ex. generally defined institutions, commercial reputation, brand names, or simply measurement errors - are put outside of the estimation procedure. This is essential particularly in the light of the critiques concerning the use of TFP as a measure of technological change.

In all estimations the F test concerning the joint hypothesis of explanatory power of independent variables rejected the null, meaning that the variables used for the estimation reliably predict the dependent variable. Table (3.1.) summarizes the results, showing the t values of the coefficients in sectors that in a particular country were found to be significant at 5% of significance level as a source of PKE.

A negative value of the t statistic means that also the corresponding coefficient was negative. This was found only in two cases, namely in mining and quarrying sector in Austria and in real estate services in Finland. In all other cases the t values and, thus, the estimated coefficients were positive, suggesting that the impact of technological knowledge transferred from upstream to downstream sectors by means of market transactions produced further positive effects on the innovativeness of the latter sectors.

The first two explanatory variables are the control variables for the sectoral R&D expenditure and for the rate of change in wages. Only in Norway the latter appeared to be slightly significant. The evidence on R&D expenditures confirms its questionable role in influencing the rate of change of TFP in the same sector in which these expenditures were

[6] Due to a low correlation coefficient in all estimations, the fixed effect method prevailed over the random effect method.

made. This is because they measure only a part of the overall effort made in the process of introduction of new technology, disregarding internal learning and the use of external sources of knowledge. This confirms the results obtained by Scherer (1982) who shows the evidence of a poor performance of product R&D, as opposed to *used* R&D.

Table 3.1. Results of the estimation with fixed effect model[7] – t values of the estimated coefficients.

	At	Be	Cz	Dn	Fn	Fr	Ge	It	Ne	No	Sp	Sw	UK
R&D													
d(w)										2.78			
Agr	3.15												
Mng	-2.85												
Food					6.10		3.66	4.71					
Txt		8.28	3.87		3.96	3.98	3.62	4.97	6.03	5.80		3.52	5.13
Wood	5.02	2.94	2.95	3.13	4.38		4.87	4.62	7.32	5.06		3.35	2.81
Pulp	4.84		4.59		3.73		3.81			3.10		3.79	2.80
Chm	3.28	5.11	2.93	3.04	4.29	8.52	5.67	3.35	3.59	5.45		2.92	4.33
Rub			3.11					4.49	2.87				
nmt	2.92					4.46			4.33	4.36	3.37		
met		2.89			3.44	2.94		3.61		7.23			3.90
Mch		5.59			4.83	5.42	5.00	3.77	6.06	6.08			
El&op		9.65			7.86	6.28	8.87		13.36	4.66	5.41	15.11	
Trsp	3.12	4.60	4.83	7.78	7.38	14.55	9.32	4.54	6.88		3.89	5.16	
Manu	4.89	10.64				5.68	3.21	4.06	3.56	3.26		2.95	
Elc	4.05		3.78		2.80	7.24	4.58	5.33	4.11	4.65		3.29	2.70
Cnst					3.32	2.87							
Whl		6.04											
Hot						5.08			3.57				
Tr&c				2.78		4.56							
Fin	3.64	6.56	3.77	2.83	8.15	4.28	5.35	4.77	3.71	4.08	7.75		7.07
Real					-4.00								
P.ad													
Edu					2.78								
Hlth													
Other										2.83			

The other explanatory variables are given, for every sector, by the product between the annual growth rate of TFP and the expenditure coefficient as defined before. They are supposed to measure the impact that new technological knowledge, generated upstream and transferred through intermediate market transactions, has on innovative capacities of

[7] Detailed results of the estimation for each country are reported in Appendix A.2.

downstream producers via the working of PKE. The estimation results permit to identify a group of sectors exercising a relevant influence on the rest of the economy in a majority of countries. Most importantly, the role of financial intermediation in determining the growth dynamics in the modern economies, discussed in numerous contributions so far, has been confirmed. Also electricity, gas and water supply and, among manufactures, the sector of transport equipment; chemical industry; wood and products of wood and, finally, textiles assume an important position in a majority of analyzed national economies. This evidence is important particularly for the aforementioned service sector, for transport equipment and for chemical industry. It confirms their central role as a sources of relevant external knowledge that, thanks to PKE, can be successfully used by the rest of the economic system as an input in the further generation of technological knowledge and eventually in standard production process of goods. Another group of sectors, namely, manufacturing n.e.c; electrical and optical equipment; pulp, paper, paper products, printing and publishing; machinery and equipment n.e.c; and metal products industry appeared to exert a slightly weaker importance in terms of PKE-generating knowledge transmission. Quite surprising and contrasting with the evidence from previous contributions[8] are the results regarding real estate, renting and business activities that appeared to be passive in the transmission of technological knowledge. This may be due to the fact that new technologies offered as a tool in the process improvements are assimilated by the users without provoking further consequences in terms of innovative capacities downstream.

As a robustness check, in addition to the estimations based on equation (3), the growth rate of TFP in sector i has been regressed in function of the growth rates of TFP in each sector j. The aim of the estimation was to confirm that the sectoral TFP growth rate downstream is significantly influenced not by the pure technological effect, but by the network of intersectoral relations based on the exchange of innovative intermediates. Indeed, for all analyzed countries the results of this additional estimation have appeared to be insignificant.

4. Conclusions

An increasingly articulated study of economic growth in the modern economies brought relevant extensions that permitted a better and a more complete understanding of the complexity accompanying the process. In particular, in the new growth theory an effort has

[8] See Jorgenson and Stiroh (2000) and Oliner and Sichel (2000).

been made to include technological knowledge between standard production inputs and to describe external effects deriving from the generation of innovations.

Extending these contributions, the present analysis discusses the role of PKE in shaping the growth dynamics of modern economies. In particular, through upstream-downstream intermediate goods transactions, downstream producers are able to take advantage from under-the-equilibrium cost conditions in the acquisition and further transformation of external knowledge. As a consequence, they experience a positive TFP growth and become innovators themselves.

The empirical relevance of PKE has been confirmed in a panel exercise applied on 13 European economies and their 25 sectors over the period 1995-2004 in the framework of input-output analysis.

The results pointed out on a group of few sectors that in quite all analyzed countries were found to exercise a significant influence on the rest of the economy in terms of PKE-generating transmission of technological knowledge. Among these sector there are textiles, textile products, leather and footwear; wood and products of wood and cork; chemicals and fuel products; transport equipment; electricity, gas and water supply and, most importantly, financial intermediation. These sectors, consequently constitute a group of relevant PKE suppliers that in all analyzed countries confirmed to play an important role.

The present analysis suggests that PKE bring a new and non negligible element into the study of economic development that has been omitted in previous contributions concerning growth. Intersectoral dependences, based on upstream-downstream transfers of technological knowledge and the occurrence of PKE accompanying further transformation of externally generated knowledge permit to explain positive TFP growth rates not only upstream, but also downstream. This appears to be an important, though so far unexplored growth mechanism.

Appendix A.1. Sectors and countries included in the panel

List of sectors, compatible with the current STAN database classification:

1	Agriculture and hunting, forestry and fishing
2	Mining and quarrying
3	Food products, beverages and tobacco
4	Textiles, textile products, leather and footwear
5	Wood and products of wood and cork
6	Pulp, paper, paper products, printing and publishing
7	Chemical and fuel products
8	Rubber and plastic products
9	Other non-metallic mineral products
10	Basic metals and fabricated metal products
11	Machinery and equipment n.e.c.
12	Electrical and optical equipment
13	Transport equipment
14	Manufacturing n.e.c.; recycling
15	Electricity, gas and water supply
16	Construction
17	Wholesale and retail trade; repairs
18	Hotels and restaurants
19	Transport, storage and communication
20	Financial intermediation
21	Real estate, renting and other business activities
22	Public administration and defense; compulsory social security
23	Education
24	Health and social work
25	Other community, social and personal services

Countries taken into analysis:

1	Austria
2	Belgium
3	Czech Republic
4	Denmark
5	Finland
6	France
7	Germany
8	Italy
9	Netherlands
10	Norway
11	Spain
12	Sweden
13	UK

Appendix A.2. Single countries estimation results

For each country, the panel contains 200 observations (25 sectors observed between 1995 and 2004, except 1996 and 1998, for which in the majority of countries Input-Output tables are not available).

Table A.2.1. Estimation results of equation (3) with fixed effect method by single country.

	Austria		Belgium	
variable	coeff	std err	coeff	std err
R&D expenditure	-	-	.003	(.003)
wage growth r.	-.118	(.153)	.103	(.060)
TFP growth r. by sector:				
agriculture	1.658**	(.526)	-.200	(.598)
mining&quarrying	-3.634**	(1.276)	-.136	(.688)
food,baverages,tobacco	3.153*	(1.401)	1.303	(.840)
textiles&textile prod.	2.377*	(1.115)	2.668***	(.322)
wood&prod. of wood	3.473***	(.691)	3.070**	(1.044)
paper&paper prod.	3.397***	(.702)	2.851*	(1.122)
chemical&fuel prod.	1.173**	(.357)	1.856***	(.363)
rubber	-.719	(4.077)	-1.618	(1.513)
nonmetal mineral prod.	5.804**	(1.986)	2.587	(1.940)
basic met.&fabricated met.	2.229*	(.994)	1.646**	(.569)
machinery&equip.	4.187*	(1.784)	4.243***	(.759)
electrical&optical equip.	2.535	(2.272)	2.684***	(.278)
transport equip.	3.135**	(1.005)	2.562***	(.557)
manufacturing nec	15.574***	(3.184)	8.947***	(.841)
electr., gas, water supp.	6.001***	(1.483)	3.962	(2.066)
construction	4.125	(5.536)	2.561	(1.597)
wholesale&retail trade	-11.086	(16.020)	31.515***	(5.220)
hotels and restaurants	15.494	(16.586)	4.638	(11.104)
transport and communicat.	7.252*	(3.034)	3.031	(2.293)
financial interm.	4.684***	(1.287)	4.220***	(.643)
real estate	1.564	(2.560)	1.270	(2.392)
public administration	327.866*	(179.575)	368.178**	(112.807)
education	-242.608	(173.501)	1337.406	(818.442)
health	22.489*	(11.145)	402.552	(362.163)
community	3.665	(6.680)	-6.515	(12.865)
cons	.001	(.003)	-.006	(.003)
	R-sq: within = 0.5671		within = 0.8640	
	between = 0.3728		between = 0.7387	
	overall = 0.5077		overall = 0.8334	

significance level at 1 (***); 5(**) and 10% (*).

Table A.2.1. continued

	Czech Republic		Denmark	
variable	coeff	std err	coeff	std err
R&D expenditure	.001	(.002)	-.003	(.012)
wage growth r.	.171	(.149)	-.074	(.131)
TFP growth r. by sector:				
agriculture	.502	(.935)	-.137	(1.544)
mining&quarrying	1.171	(1.173)	.761	(.804)
food,baverages,tobacco	1.256	(.915)	2.644*	(1.032)
textiles&textile prod.	2.122***	(.548)	2.061	(1.759)
wood&prod. of wood	3.175**	(1.077)	2.298**	(.735)
paper&paper prod.	2.369***	(.516)	3.831	(3.032)
chemical&fuel prod.	1.295**	(.442)	.397**	(.460)
rubber	2.774**	(.893)	3.607	(5.276)
nonmetal mineral prod.	2.674	(2.207)	.894	(3.154)
basic met.&fabricated met.	1.160	(1.249)	1.469	(1.420)
machinery&equip.	3.982	(2.360)	1.223	(1.529)
electrical&optical equip.	1.232*	(.472)	-.648	(3.642)
transport equip.	2.402***	(.498)	12.320***	(1.583)
manufacturing nec	2.511	(1.520)	9.964	(8.279)
electr., gas, water supp.	2.102***	(.556)	2.578	(4.740)
construction	2.736*	(1.158)	4.346	(7.743)
wholesale&retail trade	18.820*	(7.959)	-7.155	(6.284)
hotels and restaurants	7.392	(11.649)	-3.491	(28.735)
transport and communicat.	1.974	(1.827)	3.582**	(1.287)
financial interm.	3.676***	(.975)	5.025**	(1.778)
real estate	2.217	(1.308)	-6.960	(7.967)
public administration	92.542	(123.137)	-56.001	(111.807)
education	-100.389	(180.247)	-332.426	(597.408)
health	11470.013	(699.112)	1116.501	(1043.477)
community	-.763	(29.822)	164.719	(126.488)
cons	-.008	(.006)	.001	(.006)
	R-sq: within = 0.6464		within = 0.5623	
	between = 0.6271		between = 0.3911	
	overall = 0.6431		overall = 0.5432	

Table A.2.1. continued

	Finland		France	
variable	coeff	std err	coeff	std err
R&D expenditure	-.000	(.001)	-.001	(.014)
wage growth r.	-.006	(.075)	-.118	(.088)
TFP growth r. by sector:				
agriculture	-.110	(.451)	1.034	(.838)
mining&quarrying	-.089	(.247)	-	-
food,baverages,tobacco	4.457***	(.730)	1.361	(.831)
textiles&textile prod.	3.495***	(.883)	2.860***	(.718)
wood&prod. of wood	5.536***	(1.265)	-	-
paper&paper prod.	4.640***	(1.243)	1.912	(1.187)
chemical&fuel prod.	1.854***	(.432)	4.788***	(.562)
rubber	3.428	(3.670)	-	-
nonmetal mineral prod.	4.482*	(1.817)	5.863***	(1.314)
basic met.&fabricated met.	1.702**	(.495)	1.246***	(.424)
machinery&equip.	3.174***	(.657)	7.750***	(1.429)
electrical&optical equip.	2.365***	(.301)	3.496***	(.557)
transport equip.	6.529***	(.885)	3.571***	(.245)
manufacturing nec	5.702*	(2.306)	17.847***	(3.140)
electr., gas, water supp.	8.143**	(2.907)	7.653***	(1.057)
construction	8.408**	(2.536)	7.424**	(2.590)
wholesale&retail trade	.729	(3.409)	-.303	(3.541)
hotels and restaurants	13.509	(8.640)	29.779***	(5.857)
transport and communicat.	4.078	(3.510)	5.314***	(1.164)
financial interm.	14.010***	(1.719)	3.959***	(.925)
real estate	-15.585***	(3.892)	.128	(2.900)
public administration	93.910	(81.558)	93.914	(179.194)
education	593.828**	(213.462)	-53.605*	(26.484)
health	-1049.710*	(413.806)	59.158	(201.005)
community	10.899	(9.600)	-8.590	(20.961)
cons	-.012**	(.004)	-.007**	(.002)
	R-sq: within = 0.7339		within = 0.8690	
	between = 0.4029		between = 0.8546	
	overall = 0.6735		overall = 0.8613	

Table A.2.1. continued

	Germany		Italy	
variable	coeff	std err	coeff	std err
R&D expenditure	.000	(.000)	.000	(.001)
wage growth r.	-.159*	(.073)	.019	(.059)
TFP growth r. by sector:				
agriculture	-.022	(.358)	-.583	(.478)
mining&quarrying	-.387	(.399)	-.030	(.390)
food,baverages,tobacco	2.462***	(.672)	3.043***	(.647)
textiles&textile prod.	2.488***	(.687)	2.270***	(.457)
wood&prod. of wood	2.964***	(.609)	1.816***	(.393)
paper&paper prod.	2.653***	(.695)	2.115	(1.320)
chemical&fuel prod.	1.775***	(.313)	1.985**	(.593)
rubber	1.504	(2.209)	6.244***	(1.390)
nonmetal mineral prod.	4.772*	(2.350)	1.902	(1.067)
basic met.&fabricated met.	.888	(1.106)	1.957***	(.543)
machinery&equip.	5.160***	(1.033)	5.106***	(1.355)
electrical&optical equip.	3.036***	(.342)	2.062*	(.829)
transport equip.	3.450***	(.370)	3.450***	(.760)
manufacturing nec	5.970**	(1.860)	7.980***	(1.965)
electr., gas, water supp.	4.760***	(1.038)	4.819***	(.904)
construction	-3.268	(7.717)	6.853	(4.023)
wholesale&retail trade	5.061	(2.997)	.696	(2.350)
hotels and restaurants	-35.489	(35.618)	6.453	(6.412)
transport and communicat.	2.063	(1.192)	3.733	(1.954)
financial interm.	3.414***	(.639)	3.963***	(.830)
real estate	.591	(1.451)	-.858	(1.394)
public administration	29.573	(23.142)	686.592	(619.077)
education	171.018	(106.964)	34.935	(137.089)
health	-738.744	(856.162)	94.517	(149.247)
community	8.948	(8.800)	2.159	(6.287)
cons	-.003	(.002)	-.001	(.001)
	R-sq: within = 0.7935		within = 0.7595	
	between = 0.6308		between = 0.7643	
	overall = 0.7572		overall = 0.7551	

Table A.2.1. continued

	Netherlands		Norway	
variable	coeff	std err	coeff	std err
R&D expenditure	.000	(.006)	.002	(.003)
wage growth r.	.100	(.076)	.280**	(.101)
TFP growth r. by sector:				
agriculture	-.445	(.643)	-.794	(1.068)
mining&quarrying	.590	(.340)	1.643	(1.086)
food,baverages,tobacco	-.550	(1.649)	2.600*	(1.017)
textiles&textile prod.	3.061***	(.507)	5.722***	(.987)
wood&prod. of wood	4.560***	(.623)	4.322***	(.855)
paper&paper prod.	2.748*	(1.247)	5.450**	(1.758)
chemical&fuel prod.	1.564***	(.436)	1.837***	(.337)
rubber	9.004**	(3.138)	11.254*	(4.336)
nonmetal mineral prod.	5.023***	(1.160)	8.155***	(1.872)
basic met.&fabricated met.	1.991*	(.784)	3.263***	(.451)
machinery&equip.	3.501***	(.578)	7.967***	(1.311)
electrical&optical equip.	3.040***	(.228)	3.748***	(.805)
transport equip.	3.336***	(.485)	3.606	(2.190)
manufacturing nec	14.931***	(4.191)	16.659**	(5.112)
electr., gas, water supp.	2.629***	(.640)	10.650***	(2.291)
construction	2.672	(1.953)	1.875	(2.596)
wholesale&retail trade	-5.959*	(2.351)	-5.733*	(2.741)
hotels and restaurants	23.803***	(6.672)	28.669	(16.572)
transport and communicat.	-5.847*	(2.501)	2.602	(2.010)
financial interm.	3.856***	(1.038)	9.982***	(2.448)
real estate	-.365	(1.398)	1.333	(4.676)
public administration	3.485	(130.096)	-143.030	(121.605)
education	100.426	(58.117)	-213.422	(346.449)
health	-.581	(152.702)	-781.420*	(327.218)
community	-2.543	(4.291)	117.170**	(41.445)
cons	-.002	(.002)	-.008	(.004)
	R-sq: within = 0.8014		within = 0.6818	
	between = 0.1123		between = 0.1159	
	overall = 0.7024		overall = 0.6324	

Table A.2.1. continued

	Spain		Sweden	
variable	coeff	std err	coeff	std err
R&D expenditure	-.003*	(.001)	-.007	(.018)
wage growth r.	.273*	(.102)	-.171	(.103)
TFP growth r. by sector:				
agriculture	-.752*	(.324)	-1.093	(1.021)
mining&quarrying	1.515	(1.054)	.215	(.943)
food,baverages,tobacco	.137	(1.079)	2.160	(1.125)
textiles&textile prod.	2.281	(1.605)	4.295**	(1.221)
wood&prod. of wood	1.104	(1.375)	5.453**	(1.626)
paper&paper prod.	2.808	(1.466)	4.905***	(1.294)
chemical&fuel prod.	1.101	(1.100)	2.510**	(.858)
rubber	5.266	(2.780)	.155	(3.050)
nonmetal mineral prod.	4.436**	(1.318)	4.920*	(2.228)
basic met.&fabricated met.	1.334	(.871)	.978	(.612)
machinery&equip.	3.064	(4.313)	5.097*	(2.380)
electrical&optical equip.	4.562***	(.843)	2.911***	(.193)
transport equip.	2.826***	(.726)	2.384***	(.462)
manufacturing nec	11.528	(5.997)	14.272**	(4.836)
electr., gas, water supp.	3.472	(4.809)	10.332**	(3.136)
construction	-.586	(2.403)	8.930	(12.823)
wholesale&retail trade	-1.253	(9.503)	15.369	(12.311)
hotels and restaurants	-16.821	(27.878)	42.234	(24.186)
transport and communicat.	10.195	(5.834)	.960	(1.960)
financial interm.	8.813***	(1.137)	2.400	(6.521)
real estate	2.159	(6.786)	-1.721	(2.138)
public administration	-1419.485	(2170.366	-72.094	(38.698)
education	-28.851	(266.594)	-25.864	(122.347)
health	739.968	(309.454)	-198.734	(127.604)
community	36.808	(48.081)	-9.150	(17.329)
cons	-.007*	(.003)	.000	(.003)
	R-sq: within = 0.8280		within = 0.8294	
	between = 0.0646		between = 0.8217	
	overall = 0.5655		overall = 0.8343	

Table A.2.1. continued

	UK	
variable	coeff	std err
R&D expenditure	-.001	(.016)
wage growth r.	-	-
TFP growth r. by sector:		
agriculture	-.137	(.711)
mining&quarrying	.293	(.345)
food,baverages,tobacco	1.427	(1.005)
textiles&textile prod.	3.220***	(.628)
wood&prod. of wood	2.147**	(.764)
paper&paper prod.	4.907**	(1.753)
chemical&fuel prod.	3.571***	(.825)
rubber	2.870	(1.909)
nonmetal mineral prod.	6.486*	(2.772)
basic met.&fabricated met.	2.847***	(.730)
machinery&equip.	-1.826	(1.839)
electrical&optical equip.	2.528***	(.306)
transport equip.	2.202*	(.967)
manufacturing nec	19.440*	(7.635)
electr., gas, water supp.	3.440**	(1.274)
construction	4.074	(2.658)
wholesale&retail trade	-2.275	(3.468)
hotels and restaurants	-42.698	(53.978)
transport and communicat.	2.143	(1.514)
financial interm.	5.276***	(.746)
real estate	2.164	(1.837)
public administration	-96.378	(60.333)
education	-37.791	(49.519)
health	-26.859	(62.311)
community	-1.531	(10.579)
cons	-.001	(.007)
	R-sq: within = 0.6786	
	between = 0.0405	
	overall = 0.5012	

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