Wiener Institut für Internationale Wirtschaftsvergleiche
The Vienna Institute for International Economic Studies

Working Papers | 89 | July 2012

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Manufacturing Productivity: Effects of Service Sector Innovations and Institutions

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This publication was produced in the framework of WIOD (http://www.wiod.org/), an international economic research project focusing on the analysis of international input-output linkages. The project is funded by the EU's Seventh Framework Programme with socio-economic sciences and humanities.

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Manufacturing Productivity: Effects of Service Sector Innovations and Institutions

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Abstract

A major international transmission channel of productivity increases is trade in intermediate products and services. This paper analyses international rent spillovers at the industry level and for the first time investigates effects from the service sector in this international framework. The World Input-Output Database (WIOD) allows us to improve over the traditional approach of using trade in intermediates in the estimation of international spillovers by making use of input-output linkages between industries in different countries. Our results using this novel approach confirm the productivity effects from international manufacturing spillovers found in recent literature. As regards services, which provide a substantial component of the manufacturing sectors' inputs, our results indicate significant positive productivity effects from innovations in this sector. Furthermore, we control for the effect of domestic institutions on productivity. A high quality of contract enforcement and property rights protection is found to foster firm development and increase productivity in the country. Last but not least educational institutions in the reporter country are an important determinant of productivity developments.

Keywords: *productivity, research and development, services, spillovers, institutions*

JEL classification: *F14, F43, O31, O43*

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Manufacturing productivity: effects of service sector innovations and institutions

1. Introduction

A vast empirical literature has evolved in the last two decades analysing the extent of spillovers across firms, industries and countries. The importance of this question is evident since the size of these technology transfers shapes the worldwide distribution of productivity. Limited diffusion likely leads to global divergence whereas large spillovers promote convergence.

Past studies in this framework however have focussed on trade in goods and neglected the service sector as a source of spillovers. Services provide not only more than 30 percent of the intermediate inputs of the manufacturing sector in the European Union, but also occupy a central position with respect to innovations. The telecommunication industry as well as software development firms have greatly changed the way business is done in the past decades. Their annual R&D growth rates from 1995-2005 in the EU are around double the size of the highest ones in manufacturing.[1]

In our analysis of these changes, we will focus on rent spillovers. They occur whenever prices of intermediate products are not fully adjusted for quality improvements. If suppliers to a firm innovate and produce goods of a higher quality at the same price or the same goods at a lower price, the firm using these intermediates becomes more productive. The studies analysing international rent spillovers mostly follow the international spillover framework designed by Coe and Helpman (1995). The authors use import weights in order to measure the importance of spillover channels across trade partner countries, finding that foreign R&D has positive effects on domestic productivity and that the size of the spillover effect depends on the trade openness of the country. A notable correction of the model by Lichtenberg and van Pottelsberghe de la Potterie (1998) lead to an alternative construction of the foreign knowledge variable in the subsequent literature. Kao, Chiang and Chen (1999) later criticized the OLS estimation method under panel cointegration and show that alternative estimation procedures, such as Fully Modified OLS and Dynamic OLS have superior small-sample properties.

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* The authors are grateful to Bruno van Pottelsberghe de la Potterie and Bart Los for comments and the whole WIOD team for the great collaboration in the construction of the database. This publication was produced in the framework of WIOD (http://www.wiod.org/), an international economic research project focusing on the analysis of international input-output linkages. The project is funded by the EU Seventh Framework Programme with socio-economic sciences and humanities.

[1] In the European countries in our sample, the annual R&D growth rate for NACE 60t64 'Transport, storage and communications' is 13.7% and the one for NACE 71t74 'Renting of Machinery & Equipment and Other Business Activities' 10.7%. The highest ones in Manufacturing are 6.64% in NAVE 25 'Rubber and Plastics' and 5.86% in NACE 34t35 'Transport Equipment'.

At the industry level, most early studies were restricted to the analysis of domestic inter-industry technology transmission due to data limitations (Bernstein, Nadiri, 1988; Terleckyj, 1974). Keller (2002) finally incorporated the analysis of domestic spillovers between industries into an international setting. The international spillover component is thereby constructed using trade in advanced intermediate goods. Input-output relations have shown to be the preferable method of constructing domestic inter-industry spillovers since they perform better than technology flow matrices, which indicate the usage of technology developed in other industries (Keller 2002). Keller's findings suggest that the productivity effects from international and domestic spillovers are substantial and as large as the effects of the industries' own R&D efforts. Another industry level study by Wang (2007) analyses trade related North-South and indirect South-South technology spillovers. The results clearly show that innovations from R&D transmitted via North-South trade have a substantial impact on Total Factor Productivity (TFP) in the South.

The intensity of trade relations however is not the only factor affecting the size of the spillover effect. Institutions are increasingly viewed as one of the key factors influencing Total Factor Productivity (TFP) with part of this effect being caused by their influence on R&D spillovers (Coe, Helpman, Hoffmaister, 2009). One determinant of the spillover effect that has been extensively discussed in the literature is the quality of educational institutions which influence the level of absorptive capacity (Engelbrecht, 1997; Frantzen, 2000; Falvey, Foster, Greenaway, 2007). The paper by Wang (2007) is one of the few studies analyzing the importance of absorptive capacity for spillovers at the industry level. Her findings suggest that increases in human capital in developing countries, proxied by the secondary school completion ratio of the population aged 25 and above, play a significant role in facilitating spillovers. Wang states that according to the estimates, increases in human capital in developing countries have a much larger impact on Multi Factor Productivity (MFP) than additional spillovers from increased R&D in the North.

Another important component of the institutional infrastructure is the quality of contract enforcement and property rights. A recent paper by Coe, Helpman and Hoffmaister (2009) estimates the effects of various institutional characteristics at the country level. There are various reasons why the quality of contract enforcement and property rights are interesting to look at with respect to R&D spillovers at the industry level. On the one hand, lax law enforcement, especially with respect to patent protection, will decrease returns to R&D, usually leading to an underinvestment in this country (Kanwar and Evenson, 2003; Arora, Ceccagnoli and Cohen, 2003).

In this paper we will use, among other sources, the newly constructed World Input-Output Database (WIOD) in order to take a closer look at these rent and knowledge spillovers empirically. International input-output tables covering 40 countries and 35 industries will enable us to go beyond the traditional approach of using trade in intermediate goods and incorporate services trade in to the analysis. Similar to manufacturing intermediate inputs, inputs from services sectors might enable the industry to be more productive without increasing productivity itself (through business, management and technical consulting, telecommunication, market research, etc). In the baseline specification we consider spillovers with respect to industry proximity measured by input-output linkages. We then include institutional variables from the World Governance Indicators and the Barro and Lee dataset and analyse their influence on technology spillovers.

Section 2 sketches a theoretical model and describes the related empirical specification, Section 3 gives an overview of the data, the results are presented in section 4 and finally section 5 concludes.

2. Theory and empirical estimation

In our theoretical model, productivity depends upon R&D investment and technological improvements transmitted via trade in intermediate inputs. The output Y of a country is produced using the inputs labour L and capital K with A denoting a positive constant.

$$Y = A\,L^{\alpha}K^{1-\alpha} \tag{1}$$

The capital good is produced according to the function

$$K = \left(\sum_{m=1}^{M} \chi(m)^{1-\alpha}\right)^{1/(1-\alpha)} \tag{2}$$

where $\chi(m)$ denotes a capital good of variety *m* (Keller, 2002). The number of employed varieties *M* can differ across countries and industries. Furthermore the R&D investment of a country influences χ, the production function of the capital good.

Trade in intermediate products and services allows firms to profit from the more efficient production of goods through R&D in other countries. It is hereby straightforward to extend this framework in order to split the components into intra and inter-industry linkages and products from the service sector

$$K_{ci} = \left(\sum_{\substack{m=1\\ m\in M_{ci}^{ci}}}^{M} \chi_{ci}(m)^{1-\alpha} + \sum_{\substack{d=1\\ d\neq c}}^{C}\sum_{\substack{\acute{m}=1\\ \acute{m}\in M_{ci}^{di}}}^{M} \chi_{di}(\acute{m})^{1-\alpha} + \sum_{d=1}^{C}\sum_{\substack{j=1\\ i\neq j}}^{I}\sum_{\substack{\hat{m}=1\\ \hat{m}\in M_{ci}^{dj}}}^{M} \chi_{dj}(\hat{m})^{1-\alpha} + \sum_{d=1}^{C}\sum_{\substack{\ddot{m}=1\\ \ddot{m}\in M_{ci}^{s}}}^{M} \chi_{ds}(\ddot{m})^{1-\alpha}\right)^{\frac{1}{1-\alpha}} \tag{3}$$

The first terms are now own-industry intermediates in country *c* and industry *i*, followed by intermediates from firms in this industry operating in other countries *j* $\chi_{di}(\acute{m})^{1-\alpha}$. The next term represents intermediates of industries other than *i*, $\chi_{dj}(\hat{m})$. Finally products from the service sectors are denoted by $\chi_{ds}(\dddot{m})$ with *s* being the service sector. M_{ci}^{dj} stands for intermediates produced in the industries *j* in country *d* and employed in industry *i* in the country *c*.

As stated above, the production function χ is assumed to depend upon R&D investment as changes in productivity stem from innovations. Thus productivity increases through spill-overs depend upon the R&D expenditures of the donor industry as well as the quantity and variety of products employed from it. Hence the technology spillover variable is constructed by weighting the R&D stock of the trading partner industry by the intermediate input share between the recipient and the donor industry. This approach is a major improvement over the traditional spillover literature conducted at the industry level, which has been severely restricted by data limitations. There are a number of disadvantages of the hitherto existing approach regarding foreign intermediates of the same and other industries. First of all, import input-output tables are usually not available – at least not for all countries. Therefore domestic tables or tables of other 'similar' countries are used for the weighting of imports. Since outsourced activities have certain characteristics and input requirements different from those domestically, assuming that the input/output structure of domestic activities is similar to those of foreign suppliers is quite bold. Furthermore input-output tables are usually only available for a few or even one year, disregarding recent changes in the vertical specialization of firms. More specifically, Keller (2002) in his seminal work assumes in the construction of the spillover variable of foreign intermediates of the same industry that all foreign intermediates produced in industry *i* are used as intermediates in industry *i*, whereas they might of course be used in other industries as well.

The World Input Output Database contains continuous input/output tables at basic prices, allowing us first of all to include changes in the structure of industries. We are also able to obtain specifically the intermediate inputs of industry *i* in country *c* from industry *j* in country *d* at time *t,* allowing us to construct the intermediate input shares ω_{icjdt} used for the construction of the spillover variables. Note that these shares already include measures of trade openness as foreign intermediate shares are always relative to total intermediates used (as criticised in Lichtenberg and van Pottelsberghe de la Potterie, 1996).

Based upon the above we can construct the baseline specification of our model

$$\log\ MFP_{ict} = \beta_1 \log RD_{ict}^{s} + \beta_2 \log RD_{ict}^{fs} + \beta_3 \log RD_{ict}^{o} + \beta_5 \log RD_{ict}^{serv} + \\ + \alpha_{ci} + \alpha_t + \varepsilon_{ict} \qquad (4)$$

MFP_{ict} stands for multifactor productivity, RD_{ict}^{s} is simply the R&D stock of industry *i* and RD_{ict}^{fs} denotes the variable capturing foreign spillovers from industry *i*. RD_{ict}^{o} represents domestic and foreign spillovers from industries other than *i*. Finally the coefficient for RD_{ict}^{serv} captures both domestic and foreign spillovers from the service sector. In order to control for initial differences in productivity across countries as well as industries, a set of interacted country and industry dummies α_{ci} is included. Moreover time dummies α_t control for common productivity trends.

The spillover variables are simply constructed by weighting the R&D stocks by intermediate input shares, which measure the inputs sourced from these industries (equations 5 and 6). With this specification, there are two ways for productivity to increase in industry *i* without its own R&D efforts increasing. Firstly, other industries can increase their R&D, upgrade the quality of their products or lower their price, and thus increase productivity in industry *i* which is employing these products. Secondly, industry *i* can use more imports from industries which have higher R&D stocks and thus profit more from their output.

$$RD_{ict}^{s} = R_{ict} \qquad RD_{ict}^{fs} = \sum_{\substack{d=1 \\ d \neq c}}^{C} \omega_{icidt} * R_{idt} \tag{5}$$

$$RD_{ict}^{o} = \sum_{d=1}^{C} \sum_{\substack{j=1 \\ j \neq i}}^{I} \omega_{icjdt} * R_{jdt} \qquad RD_{ict}^{serv} = \sum_{d=1}^{C} \omega_{icsdt} * R_{sdt} \tag{6}$$

In a next step, we test whether the estimated R&D parameters vary across countries according to institutions. In the past decade, institutions have been increasingly viewed as key determinants of growth and productivity. The baseline specification will thus be extended with proxies for the institutional quality in the home country.

The extended specification of the model is presented in the following equation

$$\begin{aligned} log\ MFP_{ict} = {} & \beta_1\, log\ RD_{ict}^{s} + \beta_2\, log\ RD_{ict}^{o} + \beta_3\, log\ RD_{ict}^{fs} + \beta_4\, log\ RD_{ict}^{serv} + \\ & + \beta_5\ LAW_{ct} + \beta_6\ EDU_{ct} + \alpha_{ci} + \alpha_t + \varepsilon_{ict} \end{aligned} \tag{7}$$

The domestic institutional variable LAW_{ct} and EDU_{ct} capture the direct effect of institutional quality on productivity. LAW_{ct} stands for the quality of contract enforcement and property rights. EDU_{ct} is the secondary school completion ratio for the population aged 15 and above and should give an indicator of the absorptive capacity of a country (see for example Wang, 2007). For EDU_{ct} we also estimate a second specification where we interact the domestic indicator with the foreign spillover variables in order to obtain $EDUint_{ct}$ as can be seen from equation (8). Finding a positive and significant effect for $EDUint_{ct}$ would mean that the size of the spillover increases the higher the education level in the country. This concept of absorptive capacity can only be studied in this framework if we assume that the usage of intermediate goods and services not only produces rent spillovers, but knowledge transfers as well. Since past studies have pointed out the difficulties when trying to disentangle the two effects (López-Pueyo, et al., 2008), it seems feasible to make this rather common implicit assumption (Falvey, Foster, Greenaway, 2007; Wang, 2007).

$$EDUint_{ct} = \sum_{\substack{d=1 \\ d \neq c}}^{C} EDU_{dt} * \sum_{j=1}^{I} \omega_{icjdt} * R_{jdt} \tag{8}$$

3. Data

In this paper we use data from 1995 to 2005 for 18 countries, which together make up a large part of the world economy.[2] Our dataset includes productivity, R&D and institutional data for these countries as well as input-output linkages between the countries and their industries. Indicators from five different data sources were combined to form the final data-set.

The input/output linkages were taken from the newly constructed World Input-Output Data-base (WIOD) containing data on 40 countries and 35 industries. The database is the result of an effort to bring together information from national accounts statistics, supply and use tables and data on trade in goods and services. Starting from national supply and use ta-bles (SUTs), which contain information on the supply and use of 59 products in 35 indus-tries, detailed trade data was used to split up the SUTs by sourcing origin. The detailed bilateral trade can be differentiated by use categories (intermediates, consumption and investment goods) – hereby a modified version of the hitherto existing broad end-use cate-gories was used. Services trade data, which are only available from Balance of Payments (BoP), was also merged to the SUTs and the differentiation into use categories was based on information from existing import use or import input-output tables. Finally, the resulting set of international SUTs was then transformed into an international input-output table us-ing standard procedures.

Multifactor productivity data based on value added were taken from the EU Klems data-base. The OECD STAN ANBERD database was the source for the R&D data. It uses the industry classification ISIC Rev. 3, which is compatible at the 2-digit level with NACE Rev. 1, that is used in the other databases. In order to make R&D investments comparable across time and countries, they were adjusted using purchasing power parity exchange rates and deflated using the gross fixed capital formation deflator taken from Eurostat. From the original R&D flows, stocks were constructed according to the perpetual inventory method assuming a 10% depreciation rate. The initial R&D stock R_o was calculated ac-cording to the commonly used formula $R_o = \frac{RINV_0}{g+\delta}$ introduced by Griliches (1979). $RINV_0$

2 The countries in the sample are Australia, Belgium, the Czech Republic, Germany, Denmark, Finland, France, Great Britain, Hungary, Ireland, Italy, Japan, the Netherlands, Portugal, Slovenia, Spain, Sweden and the United States.

denotes the R&D investment in the initial year, δ represents the depreciation rate of R&D capital and g the growth rate of the R&D investments over the analysed time period.

The institutional data are obtained from the Worldwide Governance Indicators (WGI) and the Barro and Lee dataset (Barro and Lee, 2000). The WGI dataset is based on responses given by a large number of enterprise, citizen and expert survey respondents. The aggregate indicators of governance are constructed using an unobserved components methodology described in Kaufmann et. al. (2010) and measured in units ranging from about -2.5 to 2.5, with higher values corresponding to better governance outcomes. The indicator LAW_{ct} captures perceptions of agents with respect to the quality of contract enforcement, property rights and the courts. For companies this indicator is especially important regarding long-term investment as building up human resources, infrastructure and conducting R&D. The firm for example has to be sure that after a long phase of research, the monopoly rent of the innovation outcome is not lost.

The indicator LAW_{ct} is highly correlated with the corruption indicator in the WGI dataset, with a correlation coefficient of 0.94. The regulatory quality index, which captures perceptions of the ability of governments to implement sound policies that promote private sector development, also has a rather high correlation (0.72) with the law enforcement indicator. When included into the regression, the corruption and regulatory quality indexes are insignificant and cause multicollinearity problems as can be seen from regression (x) and (xi) in Table 5 in the appendix. The indicator LAW_{ct} however remained significant and thus likely captures not only the quality of contract enforcement and property rights but also general private sector policies and the extent to which public power is exercised for private gain.

A second institutional indicator that theoretically plays a major role for productivity is education and human capital. Following Barro and Lee (2000), who favour secondary school completion ratios over average years of education, we use an annualized version of the five-year averages of the secondary school completion ratio for the population aged 15 and above, as reported in an updated version of the Barro and Lee dataset (Barro and Lee, 2010).

At the centre of the analysis are the manufacturing industries. As can be seen from Table 1, most intermediate inputs of an average enterprise come from other firms in the same industry, both domestic and foreign. Certain industries are deeply interconnected and provide a lot of essential inputs for other industries. For example, the chemical industry provides a large share of the inputs in the 'Textiles, textile products, leather and footwear', 'Wood and Products of Wood and Cork', 'Pulp, Paper, Paper , Printing and Publishing' and 'Rubber and Plastics' industries. Another example is 'Basic Metals and Fabricated Metal'.

Table 1

EU27 domestic and foreign Input-Output linkages in 2005 (shares in per cent of total inputs)

production / use			15t16	17t19	20	21t22	23	24	25	26	27t28	29	30t33	34t35	36t37
domestic	15t16	Food, Beverages and Tobacco	17.8	1.9	0.2	0.4	0.2	1.4	0.3	0.2	0.2	0.2	0.2	0.1	0.4
	17t19	Textiles, textile products, leather and footwear	0.1	23.4	0.2	0.3	0.1	0.2	0.7	0.2	0.2	0.1	0.1	0.4	1.8
	20	Wood and Products of Wood and Cork	0.3	0.1	24.5	0.9	0.0	0.2	0.3	0.7	0.4	0.3	0.2	0.3	10.2
	21t22	Pulp, Paper, Paper , Printing and Publishing	1.6	1.1	1.1	22.8	0.2	1.5	1.4	1.2	0.5	0.8	1.0	0.4	2.0
	23	Coke, Refined Petroleum and Nuclear Fuel	0.4	0.4	0.7	0.4	7.2	2.9	0.8	1.6	0.9	0.3	0.3	0.2	0.6
	24	Chemicals and Chemical Products	0.8	2.8	1.8	2.1	0.8	11.5	9.9	1.9	1.3	0.8	1.1	0.8	1.5
	25	Rubber and Plastics	1.3	1.5	0.7	1.0	0.3	1.4	10.1	0.9	0.8	2.2	1.9	3.2	2.7
	26	Other Non-Metallic Mineral	0.8	0.3	1.1	0.2	0.1	0.8	0.8	15.7	1.0	0.6	0.9	0.7	0.8
	27t28	Basic Metals and Fabricated Metal	1.3	1.0	3.0	0.9	0.5	1.4	3.1	3.0	24.6	16.8	6.9	9.0	10.5
	29	Machinery, nec	0.6	0.9	0.9	0.9	0.3	0.8	1.6	1.9	2.0	12.0	1.4	2.7	1.5
	30t33	Electrical and Optical Equipment	0.3	0.4	0.3	0.5	0.3	0.6	0.7	0.6	0.9	4.0	11.4	2.8	0.7
	34t35	Transport Equipment	0.2	0.3	0.2	0.2	0.1	0.3	0.5	0.4	0.5	1.1	0.5	17.9	0.6
	36t37	Manufacturing, nec; Recycling	0.2	0.5	0.6	0.6	0.1	0.2	0.6	0.6	3.0	0.4	0.3	0.5	5.9
	60t64	Transport, storage and communications	5.3	5.0	6.1	6.9	2.8	4.6	4.9	8.7	4.1	4.1	3.6	3.0	4.8
	71t74	Renting of Machinery & Equ. and Other Business Act.	7.7	6.7	4.3	10.8	2.9	12.0	8.6	8.5	6.2	9.4	10.8	7.5	7.1
foreign	15t16	Food, Beverages and Tobacco	2.4	0.2	0.0	0.1	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.1
	17t19	Textiles, textile products, leather and footwear	0.1	13.8	0.1	0.2	0.0	0.2	0.8	0.1	0.1	0.1	0.1	0.4	2.2
	20	Wood and Products of Wood and Cork	0.1	0.1	9.3	0.3	0.0	0.1	0.1	0.3	0.1	0.1	0.1	0.1	3.8
	21t22	Pulp, Paper, Paper , Printing and Publishing	1.2	0.5	0.7	11.0	0.1	0.9	0.8	0.7	0.2	0.3	0.5	0.2	1.0
	23	Coke, Refined Petroleum and Nuclear Fuel	0.2	0.3	0.6	0.3	3.6	2.5	1.0	0.9	0.6	0.2	0.2	0.1	0.4
	24	Chemicals and Chemical Products	0.9	4.5	3.2	3.2	2.9	22.2	17.1	2.8	1.8	0.9	1.6	1.0	2.3
	25	Rubber and Plastics	0.9	0.8	0.6	0.7	0.1	0.9	5.9	0.6	0.5	1.3	1.3	1.9	1.8
	26	Other Non-Metallic Mineral	0.2	0.1	0.3	0.0	0.0	0.2	0.3	3.8	0.3	0.1	0.3	0.2	0.2
	27t28	Basic Metals and Fabricated Metal	0.4	0.3	1.1	0.4	0.2	0.9	1.8	1.7	21.4	8.8	4.6	5.4	6.6
	29	Machinery, nec	0.3	0.4	0.6	0.5	0.2	0.5	0.9	1.1	1.1	7.8	1.1	1.9	0.9
	30t33	Electrical and Optical Equipment	0.2	0.2	0.3	0.4	0.2	0.6	0.7	0.5	0.9	5.0	26.5	3.3	0.9
	34t35	Transport Equipment	0.1	0.3	0.1	0.1	0.0	0.2	0.4	0.2	0.4	1.1	0.6	18.4	0.5
	36t37	Manufacturing, nec; Recycling	0.1	0.4	0.2	0.1	0.0	0.1	0.2	0.1	0.4	0.3	0.3	0.5	2.5
	60t64	Transport, storage and communications	0.6	0.5	1.0	1.1	0.5	0.7	0.6	1.1	0.6	0.6	0.7	0.5	0.6
	71t74	Renting of Machinery & Equ. and Other Business Act.	1.4	0.8	0.7	2.7	0.4	3.5	1.1	1.2	0.9	1.3	2.7	0.9	1.0
Sum			47.5	69.6	64.8	70.0	24.1	73.9	76.0	61.1	76.0	81.2	81.4	84.5	75.8

The rich dataset available enables us to go beyond the analysis of linkages within manufacturing industries and investigate spillovers from the service sector. To our knowledge, an estimation of rent spillovers from the service sector in an international context has so far not been undertaken. Table 1 highlights the importance of this undertaking as the inputs from the selected service sectors amount to 10-20% of total inputs. Due to possible distortion effects we will not consider some large service industries including ‘Financial Intermediation’, ‘Real Estate Activities’ and "Wholesale and retail trade, repairs". We include the two research-intensive, high-tech service industries "Transport, storage and communications" and "Renting of Machinery and Equipment and Other Business Activities". The latter is a rather broad category including business, legal and management consultancy, software development, technical testing activities, market research, advertising and engineering as well as architectural activities. Moreover it contains the NACE industry ‘Research and experimental development on natural sciences and engineering’ which is interesting from a public good perspective, as fundamental research most likely affects productivity in the long run. As opposed to other manufacturing sectors, these two service sectors provide vital inputs to all manufacturing industries. Note that the input shares in the matrix do not sum up to 100% as some sectors were dropped and primary inputs from agriculture, mining and petroleum, and gas extraction are missing. These products are of course a large chunk of the inputs of ‘Food, Beverages and Tobacco’ and ‘Coke, Refined Petroleum and Nuclear Fuel’.

3.1 Stationarity and cointegration preliminaries

Panel cointegration techniques have become widely used in the spillover literature (Coe et al., 2009, López-Pueyo, et al., 2008). Estimates from cointegrated panels have a number of advantages as they are robust to endogeneity, omitted variables and measurement error (Banerjee, 1999; Phillips and Moon, 2000; Baltagi and Kao, 2000). As Kao et al. (2000) pointed out in their influential paper, the OLS estimator is (super)consistent even under panel cointegration, but has a second-order asymptotic bias that leads to invalid standard errors. Alternative estimation procedures, such as Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) are able to provide valid t-statistics.

Thus in a first step, the panel will be tested for unit roots and cointegration. The Im-Pesaran-Shin test (IPS) (2003) is used to test for the existence of unit roots in the dataset. In contrast to the Levin-Lin-Chu (LLC) and the Harris-Tzavalis and Breitung test, it relaxes the assumption of a common ρ for the whole panel and was found to have a superior test power. The null hypothesis of the test states that all panels have a unit root (H_0: $\rho_i = 0 \; \forall i$) with the alternative hypothesis being that at least one panel is stationary.

Table 2 reports the stationarity tests for the pooled time series. The IPS test results indicate that the null hypothesis of stationarity for all panels cannot be rejected for productivity as well as most RD variables. We can therefore conclude that almost all R&D time series are stationary. For the institutional variables, the null hypothesis is mostly rejected and thus the fraction of stationary panels is non-zero. Note that with the assumption of a common ρ for the whole panel, the Levin-Lin-Chu (LLC) test rejects the null hypothesis that all panels contain a common unit root in all cases.

Table 2

Panel unit root test

Variable	log(MFP)	log(RDs)	log(RDfs)	log(RDo)	log(RDserv)	LAW	EDU	EDUint
IPS	1.63	2.34	-1.56*	-2.15**	-0.75	-2.15**	-1.11	-2.01**
LLC	-6.48***	-9.47***	-13.33***	-13.20***	-3.60***	-12.92***	-1.40*	-13.18***

The values represent W-t-bar statistics of the one-sided Im-Pesaran-Shin test (2003) and the Levin-Lin-Chu test. The number of lags included in respective tests is chosen using the Akaike information criterion (up to 5). ***, ** and * denote tests being significant at a 1, 5 and 10% level, respectively.

In a next step we perform the Westerlund error-correction-based panel cointegration tests (Persyn and Westerlund, 2008) to test for cointegration between *log(MFP)* and the rent spill-over variables. The test results are reported in Table 3. The shortness of the time series with a panel of only eleven years clearly poses a problem for the cointegration test and the results are rather ambiguous with respect to the whole panel (Pt and Pa) but strongly reject the null hypothesis that all time series are not cointegrated (Gt and Ga). Unfortunately the WIOD database, containing input-output linkages necessary for the construction of the other R&D variables only goes back to 1995. As can be seen from the last column, a test performed on a longer time series starting in 1987 strengthens the results of cointegration in the panel. Hence we will employ Dynamic OLS in order to obtain valid t-statistics for our estimates.

Table 3

Westerlund ECM panel cointegration tests

log(MFP)	log(RDs)	log(RDfs)	log(RDo)	log(RDserv)	log(RDs) 1987
Gt	- 5.42***	1.30	-2.43***	-0.05	-1.32***
Ga	0.46	-0.97	-1.12	-0.17	-1.70
Pt	- 7.98	-10.21***	-9.28**	-2.98	-14.11***
Pa	0.82	-1.20	-1.40**	-0.15	-1.70***

A rejection of H0 for the Ga and Gt test-statistics should be taken as evidence of cointegration of at least one cross-sectional unit. The Pa and Pt test statistics pool information over all the cross-sectional units and a rejection of H0 provides evidence for cointegration for the panel as a whole. ***, ** and * denote tests being significant at a 1, 5 and 10% level, respectively.

4. Results and discussion

Table 4 presents the estimations for the empirical specifications presented in equations (4) and (7). In line with previous studies (Keller, 2002; López-Pueyo, et al., 2008) the results highlight the significantly positive productivity effects stemming from the industry's own R&D (*R&D*^{s}). Turning to foreign spillovers, other firms in the same industry also provide significant and positive spillovers, albeit of smaller magnitude than domestic ones. As regards spillovers from the service sector, the results document significant productivity effects of services improvements through R&D for manufacturing industries. While other manufacturing industries were not found to be a significant source of spillovers in this decade, the positive productivity effects of the enormous changes in the areas telecommunication and software development are robust across all specifications. This finding underlines the importance of this little reviewed channel as a source for productivity improvements. As regard the estimation method, moving from OLS to DOLS significantly reduces our sample size due to the relatively short time period. The results however remain significant and of a similar magnitude.

Table 4

Regression results

VARIABLES	**Services (i) OLS**	**Services (ii) DOLS**	**LAW (iii) OLS**	**LAW (iv) DOLS**	**EDU (v) DOLS**	**EDUint (vi) DOLS**
β_1: $R\&D^s$	0.052***	0.058***	0.032*	0.055***	0.085***	0.107***
	(3.097)	(2.834)	(1.838)	(2.697)	(4.286)	(5.648)
β_2: $R\&D^{fs}$	0.065***	0.045**	0.044***	0.047***	0.037**	0.069***
	(4.092)	(2.556)	(2.920)	(2.646)	(2.048)	(3.834)
β_3: $R\&D^o$	0.010	0.009	0.019	0.008	0.002	0.050**
	(0.528)	(0.419)	(1.070)	(0.355)	(0.106)	(2.199)
β_4: $R\&D^{serv}$	0.010**	0.022***	0.012***	0.021***	0.026***	0.038***
	(2.194)	(3.818)	(2.747)	(3.736)	(4.504)	(5.115)
β_5: *LAW*			0.187***	0.115*		
			(3.876)	(1.850)		
β_6: *EDU*					0.636***	
					(4.969)	
β_7: *EDUint*						-0.016
						(-0.777)
Country*Industry	yes	yes	yes	yes	yes	yes
Time	yes	yes	yes	yes	no	no
Observations	1,936	1,584	1,760	1,408	1,584	1,584
R-squared	0.748	0.820	0.812	0.863	0.816	0.812

t-statistics in parentheses. The dependent variable is ln(MFP). Coefficients are estimated using ordinary least squares (OLS) with robust standard errors and dynamic ordinary least squares (DOLS) with one lead and lag of the differenced R&D, institutional and GDP variables. ***, ** and * denote coefficients being significantly different from zero at a 1, 5 and 10% level, respectively.

Investigating educational institutions in regression (v), we observe a positive relationship between the secondary school completion ratio and productivity. The human capital variable included linearly for the reporter country performs better than the interacted one in regression (vi). Upon jointly including them, only the plain educational variable stays significant (see regression (ix) in Table 5 in the appendix). Given that our sample contains rather well developed countries only, the indicator is steadily increasing across all countries during the analyzed time period at a similar pace. Thus, adding time dummies mostly captures the common effect of increased educational levels across countries as can be seen from regressions (vii) and (viii). The picture however looks different upon inclusion of developing countries (Wang, 2007).

Concerning the quality of contract enforcement, property rights and courts we find a significant and positive influence on productivity. One reason for this might be that the security of strong law enforcement and property rights protection, especially in the area of intellectual property rights, enables innovators to work on riskier, long-term projects where potential returns are higher (Coe et al., 2009). This can lead to an R&D stock that has a relatively higher impact on growth and MFP.

5. Conclusions

Rent spillovers arise as firms perform product or process innovations and subsequently sell intermediate products at a lower price or at a higher quality with a price not fully adjusted for the quality improvements. In this paper, the previous literature on international spillovers at the industry level is expanded to include service industries and institutional indicators. Using the World Input-Output Database we are able to improve on the traditional approach of using trade in intermediates for the estimation of international spillovers to the application of input-output linkages between industries in different countries. With this updated method we are able to confirm the existence of positive productivity effects stemming from domestic as well as international manufacturing spillovers, which were previously documented in the literature. Moreover we show that research intensive and high-tech service industries, such as telecommunication and software development, not only account for a substantial part of manufacturing industries' inputs, but are also the source of positive and substantial productivity effects in the manufacturing sector.

As institutions are important determinant of productivity, they are controlled for as well. The results show that educational institutions, proxied by the secondary school completion ratio, are an important determinant of productivity developments in the country. Secondly, a high level of contract enforcement and property rights protection fosters firm development and is found to increase productivity in the country.

Overall the estimations confirm the necessity to take into account the service sector as well as institutional factors when estimating productivity effects of R&D spillovers.

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7. Appendix

Table 5

Additional results and robustness checks

VARIABLES	EDU (vii) DOLS	EDUint (viii) DOLS	EDU & EDUint (ix) DOLS	CORR (x) DOLS	REG (xi) DOLS
β_1: $R\&D^{s}$	0.058*** (2.861)	0.057*** (2.828)	0.084*** (4.287)	0.016 (0.797)	0.022 (1.049)
β_2: $R\&D^{fs}$	0.042** (2.292)	0.053*** (2.917)	0.047** (2.493)	0.020 (1.263)	0.025 (1.542)
β_3: $R\&D^{o}$	-0.008 (-0.329)	0.019 (0.801)	0.014 (0.596)	0.005 (0.227)	0.012 (0.568)
β_4: $R\&D^{serv}$	0.022*** (3.812)	0.028*** (3.756)	0.033*** (4.457)	0.015*** (2.972)	0.016*** (3.019)
β_5: *LAW*				0.226*** (2.798)	0.203** (2.392)
β_6: *EDU*	0.137 (0.790)		0.663*** (5.080)		
β_7: *EDUint*		-0.027 (-1.348)	-0.032 (-1.580)		
β_8: *CORR*				-0.041 (-0.881)	
β_9: *REG*					-0.040 (-0.918)
Country*Industry	yes	yes	yes	yes	yes
Time	yes	yes	no	yes	yes
Observations	1,584	1,584	1,584	1,408	1,408
R-squared	0.820	0.820	0.817	0.862	0.863

t-statistics in parentheses. The dependent variable is ln(MFP). Coefficients are estimated using ordinary least squares (OLS) with robust standard errors and dynamic ordinary least squares (DOLS) with one lead and lag of the differenced R&D, institutional and GDP variables. ***, ** and * denote coefficients being significantly different from zero at a 1, 5 and 10% level, respectively.

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