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Abstract: This papers studies the sectoral differences in the impacts of various innovation policies, human capital and R&D intensity on the productivity growth using econometric panel data techniques. We analyze the development of the sectoral productivity as depending on both knowledge creation and knowledge adoption, where both channels of productivity growth can be influenced by various types of R&D related public policy. We use the combination of the most recent EU-KLEMS database and OECD data for econometric analysis on six aggregated sectors of the economy. In contrast with other existing studies our econometric analysis covers the whole of the economy and includes various traditional, industrial and services sectors. The main contribution of the paper is in highlighting the differences between economic sectors and identifying potential for sector-specific innovation policies.

1. Introduction

Understanding the impacts of various types innovation-relevant policies on productivity growth is at the center of current debates for both industrial and regional economic policy. Properly understanding sectoral dimension of productivity development and its links with various governmental policies is of large importance to properly formulating both regional smart specialization polices as well as growth enhancing industrial policy that utilizes comparative advantage of a country.

Our research contributes to the current policy debates by investigating the impacts of different types of both monetary and non-monetary innovation-relevant policies on the development of sectoral productivity using sector-specific and pooled regressions. More specifically, the set of policies we assess in this paper are: (a) state control, namely governmental distortion in the market such as price ceilings, (b) barriers to entrepreneurship, (c) barriers to trade and investments, (d) government-financed R&D expenditures that represent subsidies to private R&D , (e) public expenditures on education and social programs and (f) public expenditures on R&D that represent R&D in the public sector itself.

Our paper relates to a limited body of literature that aims to investigate the structural determinants of TFP growth. This literature usually pools information on country level data on TFP growth rates and constructs a reduced form specification of the innovation-imitation processes as implied by the basic Schumpeterian growth theory (Nicoletti and Scarpetta (2003), Aghion and Howitt (2008), and Benhabib and Spiegel, (2005)). In this so-called, multi-factor productivity growth model, a number of control variables are

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usually added to understand the effects of the variables of interest on TFP growth. Nicoletti and Scarpetta (2003), for example, used this approach to show the positive impact of trade liberalization and privatization on TFP growth . Similarly, Griffith and Howitt (2003), using firm level data document the positive role of product market competition on innovation. Our analysis follows a similar approach except that we are looking at different, compared to the literature, policy measures that affect innovation. In addition, and unlike most other studies, our paper extends the analysis across different sectors often considered important to growth dynamics of a country.

In this respect, our paper is more closely related to the well-known study of Griffith et al (2004), who where the first to use industry level data in the context of multi-factor productivity model. Their analysis, however, relies on OECD/STAN data unlike ours which is based on the EU-KLEMS data and hence allow us to look at sectors beyond manufacturing. This is especially important given that some studies point out the role of other than manufacturing industries, and in particular market services, as a key driver for the productivity gaps between countries, and especially between EU and the US (Havik et al (2008)).

Our econometric results identify three key regulation policies (state control, barriers to entrepreneurship and barriers to trade and investment) that could have important consequences to productivity growth. That is, deregulating markets and facilitating new market entry could improve productivity growth potential up to a particular point after which more market competition will lead to negative impacts on the level of R&D investments and productivity growth.

Our sector-specific regressions are nonetheless useful for understanding which drivers of productivity growth are more important in various economic sectors. Our econometric analysis have shown that R&D is quite important determinant for productivity growth in both knowledge intensive services and in other services sectors whereas human capital plays as important role in the technology adoption process of medium-technology manufacturing . In general the empirical results in our paper allows one to combine the insights from sector-specific econometric analysis in case of the role of R&D and human capital with the roles of various macro-economic policy instruments from the pooled regression in order to work towards the policy mixes that take into account sectoral specialization of various EU-countries and their regions.

The paper is structured as follows. Section 2 present the theoretical framework used for the econometric analysis in the paper. Section 3 describes the database used for econometric analysis and functional form of regressions. Section 4 presents the results of econometric analysis both at the aggregate level and for each of six aggregate economic sectors separately. Finally Section 5 concludes the paper and provides some policy debate.

2. The role of R&D in knowledge creation and knowledge adoption

The theoretical underpinnings of our empirical approach follow Acemoglu et al, (2006) who analyze an economy where firms undertake both innovation and adoption of technologies from the world technology frontier. In this context, the selection of high-skill managers and firms is more important for innovation than for adoption. As the economy approaches the frontier, selection becomes more important. Countries at early stages of development pursue an investment-based strategy, which relies on existing firms and managers to maximize investment but sacrifices selection. Closer to the world technology frontier, economies switch to an innovation-based strategy with short-term relationships, younger firms, less investment, and better selection of firms and managers. They show that relatively backward economies may switch out of the investment-based strategy too soon, so certain policies such as limits on product market competition or investment subsidies, which encourage the investment-based strategy, may be beneficial. However, these policies may have significant long-run costs because they make it more likely that a society will be trapped in the investment-based strategy and fail to converge to the world technology frontier.

Let us denote the growth of the world technology frontier, $\overline{A}_t$ by g so that

$$\overline{A}_t = \overline{A}_0 \left(1+g\right) \tag{1}$$

For each representative country its state of technology is less than the frontier technology $A_t \le \overline{A}_t$. The productivity of sector that produces intermediate good v at time t is expressed as

$$A_t\left(v\right) = s_t\left(v\right)\left[\eta \overline{A}_{t-1} + \gamma_t\left(v\right) A_{t-1}\right] \tag{2}$$

Where $s_t\left(v\right) \in \left\{1,\sigma\right\}$ denotes the size of the investment with $s_t\left(v\right)=1$ for large sectors, $\gamma_t\left(v\right)$ denotes the probability of new innovation. Equation above captures the two dimensions of productivity growth: adoption and innovation. By adopting existing technologies firms benefit from the world state of technological knowledge. In addition to it there is a productivity growth due to innovation building on the local sector-specific knowledge A_{t-1} and success of innovation depends on the probability of new innovation. The larger is investment the higher is the productivity growth.

If we rearrange the terms we get the following equation that includes the distance to the technological frontier $\overline{A}_{t-1} / A_{t-1}$

$$A_t\left(v\right) / A_{t-1} = s_t\left(v\right)\left[\eta \overline{A}_{t-1} / A_{t-1} + \gamma_t\left(v\right)\right] \tag{3}$$

In case when the country and sector is far from the technological frontier the major source of growth is the technology adoption. In case when the technological gap becomes close to unity that is the country is close to the frontier innovation becomes an important source of productivity growth.

This part of the model is based on the papers by Benhabib and Spiegel (2002) “”Human capital and technology diffusion” and Helson and Phelps (1966) “Investment in human, technological diffusion and economic growth”. Helson and Phelps (1966) assume that there is a difference between actual level of the state-of-the-art technology and the theoretical level of technology that would prevail if technological diffusion was instantaneous. The technology diffusion can be modelled as follows:

$$\frac{T\dot{F}P_{i,t}}{TFP_{i,t}} = g\left(H_{it}\right) + c\left(H_{it}\right)\left(\frac{TFP_{m,t}}{TFP_{i,t}} - 1\right) \quad (4)$$

Where $TFP_{i,t}$ is the TFP of the country and $TFP_{m,t}$ is the TFP of the technological leader (country with the highest TFP) and $H_{i,t}$ is the human capital that is measured as the average number of years of education of the labour force/employed.

Another variation of the technology diffusion and catch-up processes is the logistic technology diffusion model which adds an extra term that captures the difficulty of adopting distant technologies:

$$\frac{T\dot{F}P_{i,t}}{TFP_{i,t}} = g\left(H_{it}\right) + c\left(H_{it}\right)\frac{TFP_{i,t}}{TFP_{m,t}}\left(\frac{TFP_{m,t}}{TFP_{i,t}} - 1\right) \quad (5)$$

TFP in our framework is explained by the combination of technology adoption via the technological diffusion process described above and technological innovation linked to the knowledge created by the industry itself ($I_{i,t}$):

$$\frac{T\dot{F}P_{i,t}}{TFP_{i,t}} = aH_{it} + bH_{it}\left(\frac{TFP_{m,t}}{TFP_{i,t}} - 1\right) + cI_{i,t} \quad (6)$$

3. Empirical analysis

Following the paper of Griffith, Redding and Van Reenen (2001) our model assumes that R&D has two roles in the development of TFP. The first role is in knowledge creation or stimulation of innovation that has received a lot of attention in both theoretical and empirical literature. The second role is in facilitation of adoption or imitation of knowledge that has been created in other countries or sectors. Griffith, Redding and Van Reenen (2001) use a panel of OECD countries and find a strong empirical evidence for the second role of R&D in adoption of knowledge. Griffith, Redding and Van Reenen (200) present a general equilibrium model of endogenous growth through increasing productivity that incorporates both role of R&D investments. They augment the conventional quality ladder model to allows the size of innovations to be a function of the distance behind the technological frontier and an equation for TFP growth of the following form is derived:

$$\Delta \ln A_{ijt} = \beta \Delta \ln A_{Fjt} - \delta_1 \ln\left(\frac{A_i}{A_F}\right)_{jt-1} - \delta_2 \left(\frac{R}{Y}\right)_{ijt-1} \ln\left(\frac{A_i}{A_F}\right)_{jt-1} - \delta_3 H_{ijt-1} \ln\left(\frac{A_i}{A_F}\right)_{jt-1} + \rho_1 \left(\frac{R}{Y}\right)_{ijt-1} + \rho_2 H_{ijt-1} + u_{ijt} \quad (7)$$

Where the growth is TFP over a certain period of time $\Delta \ln A_{ijt}$ depend of the knowledge adoption that is captured by the growth of the technological frontier $\Delta \ln A_{Fjt}$ and interaction between technological gap $\ln\left(\frac{A_i}{A_F}\right)_{jt-1}$ and R&D per unit of sectoral output $\left(\frac{R}{Y}\right)_{ijt-1}$ as well as the interaction between technological gap $\ln\left(\frac{A_i}{A_F}\right)_{jt-1}$ and human capital H_{ijt-1}. The level of human capital and R&D capture the absorptive capacity of the particular sector. The growth of TFP is also linked to knowledge creation that is explained by R&D $\left(\frac{R}{Y}\right)_{ijt-1}$ and human capital stocks H_{ijt-1}.

3.1 Empirical specification and estimation issues

The empirical specification of our methodology follows Nicoletti and Scarpetta (2003), Aghion et al. (2004), Griffith et al. (2006) and Bourlès et al. (2013), where TFP growth is modelled as follows:

$$\ln\left(\frac{TFP_{cst}}{TFP_{cst-1}}\right) = b_1 \ln\left(\frac{TFP^*_{st}}{TFP^*_{st-1}}\right) + b_2 \ln\left(\frac{TFP_{cst-1}}{TFP^*_{st-1}}\right) + b_3 H_{t-1} + b_4 H_{t-1} \ln\left(\left(\frac{TFP_{cst-1}}{TFP^*_{st-1}}\right) + b_5 RD_{t-1} + b_6 RD_{t-1} \ln\left(\left(\frac{TFP_{cst-1}}{TFP^*_{st-1}}\right) + b_7' X_{s_{t-1}} + d_s + d_{sc} + d\_ct \quad (9)$$

where the subscripts *c, s* are country and sector indexes respectively, while *t* denotes the time period taken to be 5 years. The level of total factor productivity is given by *TFP*, with *TFP** being leader's total factor productivity. The variable *H* denotes the level of human capital stock as measured by the share of high skilled people to total employment, and *RD* is the level of R&D intensity as measured by the private expenditures per value added (output). We estimate equation (9) using the least square dummy approach (or within group estimator), where we also add three different types of dummy varies that capture industry specific fixed effects (d_s), country-industry specific fixed effects (d_{sc}) and country specific trends (d_{ct}),.

The first two terms in equation (9) are standard in the literature and measure productivity growth at the frontier and the technological gap between the frontier and non-frontier sectors ("catch-up" term) respectively. The productivity growth of the technological leader captures the link between TFP growth for the catching-up sector through the innovation and knowledge spillovers. On the other hand, the catch-up term aims to explain how the adoption of new technologies affect the innovation process of sectors. The idea here is that there are greater potentials in adopting new technologies the higher the technological gap is. In other words, we assume that the adoption of existing technology and knowledge could occur via different channels (machinery and equipment, trade, employment, networks etc.) that show up in the productivity gap between industries.

According to Griffith et al. (2006), R&D usually plays two separate roles in this equation: firstly because higher R&D spending could create new knowledge and secondly because it facilitates the adoption of knowledge or technology created elsewhere. For this reason, we directly include in our regression the interaction of RD and productivity gap. Benhabib and Spiegel (2005) have also proposed a similar idea holds for human capital. On the hand, higher human capital could create more knowledge in the economy, on the other hand, could increase the ability of a firm to adopt new technologies. To check, therefore, the latter effect we decided to include another interacting in our regression term between human capital and productivity gap.

In the baseline specification descripted above we then investigate the impact of specific governmental policies by adding to the econometric model six different variables(a) state control, namely governmental distortion in the market such as price ceilings, (b) barriers to entrepreneurship, (c) barriers to trade and investments, (d) government-financed R&D expenditures that represent subsidies to private R&D , (e) public expenditures on education and social programs and (f) public expenditures on R&D that represent R&D in the public sector itself.

To limit possible reverse causality and multi-collinearity problems the policy vector is lagged one period, which in our case we took this to be 5 years, and include each variable one by one. Each among these variables have received, in various different contexts, the attention of the literature with their effects being disputed, and thus no unanimity exists about their impact on TFP growth. The inclusion of these variables therefore serve to contribute in this debate, and thus offer new evidence about their impact based on a new data sample.

3.2 Database for econometric analysis

For our econometric exercise we combine four different databases that provide information about the variables of our model. For sectoral level data, we use the EU-

KLEMS database which covers 28 countries of which most of them are OECD countries until the year 2015. Depending on the variable, the data series spans a wide time period from roughly 1970 for mainly Western European countries, Korea and Japan and from the 1990s from non-Western European countries.

In this database information is given for totally 107 categories of industries of which 37 categories form head categories on a 2-digit level of which one is a 1-digit level for total industries. The coverage for services counts 45 sectors in which both 3-and 2-digit category levels are included. Within the business services category 12 out of totally 32 represent head categories on a 2-digit level. The personal services category have in total 7 head categories on 2- digit level of which two services sector no data is given. We use the latest release of the database from end 2017 that uses NACE Rev2 sectoral classification that is presented in the table below.

For the sectoral analysis we grouped our industrial data into six different sectors and run different regression based on the sector specific sample. The sectors we decided to create are a) traditional sector b) high-technology manufacturing, c) medium-technology manufacturing and d) low-technology manufacturing, e) knowledge-intensive services and f) other services. The classification we used are presented in Table 1 and follow Eurostat's definitions where for the purpose of our analysis we put together the groups "high-technology" and "medium-high technology" together and call them "high-technology".

For measuring Human capital stock we used OECD country level data on the share of high skilled people to total employment. Regulation data rely on OECD's Product Market Regulation (PMR) dataset. The PMR dataset is an internationally-comparable set of indicators that measure the economy-wide regulatory and market environments in 34 OECD countries and in another 22 non-OECD countries in 1998, 2003, 2008 and 2013. Among those indicators we use the indices on state control, barriers to investments and trade, and on barriers to entrepreneurship. The scale of each index is 0-6 from least to most restrictive regulation. The state control index captures the degree of governments involvement in business operations. It includes, for example, information about the pervasiveness of state ownership, governments stakes in the largest firms operating within the network sectors (i.e. electricity, gas, rail and air transport, postal services and communication), the degree of coercive regulation used by the government, price controls, existence of special voting rights by the government in privately-owned firms, and so on. The barriers to investments and trade index, as the name suggest, summarize information covering specific barriers to investments or trade and include barriers such as barriers to FDI, tariffs, differential treatment of foreign suppliers. Similarly, the barriers to entrepreneurship index, capture the scale of governmental regulation on issues related to the complexity of regulatory framework in setting up or dissolving a business, the administrative burdens on start-ups, as well as the regulatory protection of incumbents.

Finally, we supplement our dataset with OECD's main science and innovation indicators (MSTI). From this database we use series on government-financed expenditures on R&D that represent the subsidies to private R&D, governmental spending on education and social programs as percentage of government budget allocations for R&D, and on government expenditures on R&D policies that is R&D expenditures in the public sector itself. For the regressions we dropped countries with few or no observations and created a database of an unbalanced panel of thirteen OECD countries between 1995-2015 period.

Table 1 Sectoral classification used for econometric analysis

Sectoral classification	*NACE Rev2 codes*	*Names of the sectors*
Traditional	A01 A02 A03 B	Products of agriculture, hunting and related services; Products of forestry, logging and related services; Fish and other fishing products; aquaculture products; support services to fishing; Mining and quarrying
Low-technology manufacturing	C10-C12 C13-C15 C16 C17 C18 C31_C32	Food products, beverages and tobacco products; Textiles, wearing apparel and leather products; Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials; Paper and paper products; Printing and recording services; Furniture; other manufactured goods
Medium-technology manufacturing	C19 C22 C23 C24 C25 C33	Coke and refined petroleum products; Rubber and plastics products; Other non-metallic mineral products; Basic metals; Fabricated metal products, except machinery and equipment; Repair and installation services of machinery and equipment
High-technology manufacturing	C21 C26 C20 C27 C28 C29 C30	Basic pharmaceutical products and pharmaceutical preparations; Computer, electronic and optical products; Chemicals and chemical products; Electrical equipment; Machinery and equipment n.e.c.; Motor vehicles, trailers and semi-trailers; Other transport equipment
Knowledge intensive service sectors	H50 H51 J58 J59_J60 J61 J62_J63 K64 K65 K66 M69_M70 M71 M72 M73 M74_M75 N78 N80-N82 O84 P85 Q86 Q87_Q88 R90-R92 R93	Water transport services; Air transport services; Publishing services; Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services; Telecommunications services; Computer programming, consultancy and related services; information services; Financial services, except insurance and pension funding; Insurance, reinsurance and pension funding services, except compulsory social security; Services auxiliary to financial services and insurance services; Legal and accounting services; services of head offices; management consulting services; Architectural and engineering services; technical testing and analysis services; Scientific research and development services; Advertising and market research services; Other professional, scientific and technical services; veterinary services; Employment services; Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services; Public administration and defense services; compulsory social security services; Education services; Human health services; Social work services; Creative, arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services; Sporting services and amusement and recreation services
Other service sectors	C33 D35 E36 E37-E39 F G45 G46 G47 H49	Repair and installation services of machinery and equipment; Electricity, gas, steam and air-conditioning; Natural water; water treatment and supply services Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services;

H52 H53 I L68B L68A N77 N79 S94 S95 S96 T U	Constructions and construction works; Wholesale and retail trade and repair services of motor vehicles and motorcycles; Wholesale trade services, except of motor vehicles and motorcycles; Retail trade services, except of motor vehicles and motorcycles; Land transport services and transport services via pipelines; Warehousing and support services for transportation; Postal and courier services; Accommodation and food services; Real estate services (excluding imputed rent); Imputed rents of owner-occupied dwellings; Rental and leasing services; Travel agency, tour operator and other reservation services and related services; Services furnished by membership organizations; Repair services of computers and personal and household goods; Other personal services; Services of households as employers; undifferentiated goods and services produced by households for own use; Services provided by extraterritorial organizations and bodies

4. Empirical results

4.1. Sector-specific regressions

We start our empirical analysis by presenting our results for the traditional sector. In Column 1 of Table 2 below we present our estimates for the baseline model. Columns (2) – (7) incorporate our new estimates by adding one-by-one into baseline specification our chosen policy variables in order to perform sensitivity analysis. We investigate the impact the following governmental policies: (a) state control, namely governmental distortion in the market such as price ceilings, (b) barriers to entrepreneurship, (c) barriers to trade and investments, (d) government-financed R&D expenditures that represent subsidies to private R&D , (e) public expenditures on education and social programs and (f) public expenditures on R&D that represent R&D in the public sector itself. We maintain the same style of presenting our results throughout the rest of this paper.

Table 2 Results of econometric analysis for traditional sector regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.14*	0.14*	0.14*	0.14*	-0.00	0.14*	0.07
Gap	-0.66***	-0.66***	-0.66***	-0.66***	-0.80***	-0.67***	-0.73***
HC	-1.65***	-1.65***	-1.65***	-1.65***	-1.74***	-1.67***	-1.80***
HC # Gap	-0.55	-0.55	-0.55	-0.55	-0.78*	-0.56	-0.43
RD	0.43	0.43	0.43	0.43	2.93	0.26	1.56
RD # Gap	2.54	2.54	2.54	2.54	4.99**	2.58	3.47**
(a)State Control		0.42					
(b)Barriers to Entrepreneurship			-1.54				
(c)Barriers to Trade and Investment				-0.61			
(d)Gov. Financed R&D expenditures					-3.15		
(e)Education and Social Programs (Gov. Expenditures						-0.05	

(f)Gov. Expenditures on R&D							10.87
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	372	372	372	372	300	352	342
Adjusted R^2	0.535	0.535	0.535	0.535	0.571	0.511	0.585

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Looking at the baseline specification, our estimates show that technological spillovers and technological transfers are important for the traditional sector. This can be seen by the statistically significant estimated coefficients of leader's productivity growth, which aims to capture technological spillovers, and of the negative sign in the catch-up term, which captures growth potentials via the adoption processes of newly created knowledge. A unit increase in the growth rate of the leader can bring about 0.14 percentage increase in the productivity growth of this sector over the long-run. Respectively, a unit reduction in the productivity gap via the adoption of new technologies, increases the growth rate of TFP for this sector by about 0.66 percentage points. However, the effectiveness of technological transfers in increasing growth potentials are not, according to our evidence, necessarily linked to R&D expenditures or to human capital. Human capital itself is found to have negative impact on the productivity growth of the traditional sector. Such negative effect might be explained by a relatively small size of the sample for the traditional sector. In case one controls for government financed R&D expenditures or for public investments in R&D, human capital seems to make the adoption of new technologies easier (Column 5). These latter policies, however, may well hinder the TFP development of this sector by nullifying the effects from technological spillovers or by letting more difficult to adopt new technologies via R&D expenditures as is captured by the positive sign in the interacting terms between the R&D and the productivity gap variables (Columns 5 and 7) .

With regards to policies, none was found to be particularly relevant as all of them are statistically insignificant at all levels. This, however, may well be attributed to the nature of our data, which lacks sectoral specific information, and not necessary on the nature of these policies. Nevertheless, our evidence here is still useful, as we can explicitly see that broad based policies have a rather negligible role in affecting the rate of innovation at the traditional sector. As we will see later, this outcome is a recurrent pattern in most of our regressions, and change only when all information across sectors is pooled. The later might also indicate that insignificance of the examined policies may be also related to the small sample size for several of our aggregated sectors.

Table 3 Results of econometric analysis for high-technology manufacturing sector regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.18***	0.18***	0.18***	0.18***	0.13**	0.17***	0.15***

Gap	-0.59***	-0.59***	-0.59***	-0.59***	-0.56***	-0.64***	-0.61***
HC	-7.30	-7.30	-7.30	-7.30	-7.03	-6.63	-7.49
HC # Gap	-0.24	-0.24	-0.24	-0.24	-0.11	-0.21	-0.14
RD	0.16	0.16	0.16	0.16	-0.86*	0.26	-0.29
RD # Gap	0.34	0.34	0.34	0.34	-0.36	0.43	0.02
(a)State Control		0.38					
(b)Barriers to Entrepreneurship			-1.41				
(c)Barriers to Trade and Investment				-0.56			
(d)Gov. Financed R&D expenditures					0.11		
(e)Education and Social Programs (Gov. Expenditures						-0.02	
(f)Gov. Expenditures on R&D							0.54
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	744	744	744	744	600	704	684
Adjusted R^2	0.750	0.750	0.750	0.750	0.764	0.750	0.764

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A similar picture emerges when looking at the high-technology manufacturing sector (Table 3). Technological spillovers and technological transfers, as in the case of the traditional sector, are important to the TFP growth. As before, the adoption of new technologies does not require human capital or other forms of investments. R&D expenditures themselves, also do not play any particular role, while they may well contribute negatively to the pace of technological innovation when financed by the government (Column 5). Most governmental policies, as in the previous case, appear to be statistically insignificant.

Table 4 Results of econometric analysis for medium-technology manufacturing sector regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.05	0.05	0.05	0.05	-0.05	0.15	0.12
Gap	-0.90***	-0.90***	-0.90***	-0.90***	-1.02***	-0.98***	-0.90***
HC	3.39	3.39	3.39	3.39	-1.49	2.55	21.95
HC # Gap	-1.85**	-1.85**	-1.85**	-1.85**	-1.73**	-1.91**	-2.10***
RD	3.69	3.69	3.69	3.69	4.07	2.49	3.56
RD # Gap	0.27	0.27	0.27	0.27	0.94	-0.16	-1.44
(a)State Control		-3.48					
(b)Barriers to Entrepreneurship			12.88				
(c)Barriers to Trade and				5.11			

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Investment							
(d)Gov. Financed R&D expenditures					-1.41		
(e)Education and Social Programs (Gov. Expenditures						0.44	
(f)Gov. Expenditures on R&D							-14.31
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	572	568	568	572	460	542	527
Adjusted R^2	0.472	0.476	0.476	0.472	0.521	0.543	0.485

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

For the medium-technology manufacturing sector we find that technological transfers are the single most important factor affecting its TFP development (Table 4). Technological transfers that decrease the productivity gap by one unit, may well lead to as much as a 0.90 percent increase in TFP growth. Unlike, the previous cases, however, for this sector human capital is now found to be linked to the adoption processes of new knowledge or technology, despite the fact that itself may well be an insignificant factor.

Table 2 Results of econometric analysis for low-technology manufacturing sector regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.11***	0.10***	0.10***	0.11***	0.08*	0.10***	0.12***
Gap	-0.58***	-0.62***	-0.62***	-0.58***	-0.54***	-0.59***	-0.58***
HC	0.61	0.63	0.63	0.61	-1.75	0.50	8.22
HC # Gap	0.42	0.38	0.38	0.42	0.37	0.41	0.45
RD	0.86	0.63	0.63	0.86	-1.26	1.28	0.98
RD # Gap	0.52	0.34	0.34	0.52	-0.80	0.87	0.62
(a)State Control		-1.51					
(b)Barriers to Entrepreneurship			0.13				
(c)Barriers to Trade and Investment				2.19			
(d)Gov. Financed R&D expenditures					-0.56		
(e)Education and Social Programs (Gov. Expenditures						0.17	
(f)Gov. Expenditures on R&D							-5.62
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	788	776	776	788	631	748	728
Adjusted R^2	0.610	0.608	0.608	0.610	0.615	0.595	0.616

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5 above shows the results for the last manufacturing sector considered in the present study, namely the low-technology manufacturing sector. As in most other cases, both technological transfers and technological spillovers are found to be statistically significant, and thus important to the growth dynamics of this sector. Their effects are comparable to the magnitude found in the traditional sector, and seem relatively unchanged regardless the policy variable we control for. Again, neither human capital or R&D expenditures are linked to the process of the technological development and are found to be statistically insignificant. Similarly, the policy variables considered here are found non-significant.

Table 3 Results of econometric analysis for knowledge intensive services sector regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.02*	0.02*	0.02*	0.02*	0.02	0.01	0.02
Gap	-0.43***	-0.44***	-0.44***	-0.43***	-0.51***	-0.43***	-0.44***
HC	0.00	0.00	0.00	0.00	0.05	-0.03	0.01
HC # Gap	0.04	0.03	0.03	0.04	0.06	0.04	0.04
RD	0.36**	0.91*	0.91*	0.36**	0.24*	0.36**	0.28*
RD # Gap	0.02	0.31	0.31	0.02	0.07	0.02	0.06
(a)State Control		-0.75					
(b)Barriers to Entrepreneurship			0.05				
(c)Barriers to Trade and Investment				1.10			
(d)Gov. Financed R&D expenditures					-0.14		
(e)Education and Social Programs (Gov. Expenditures						-0.00	
(f)Gov. Expenditures on R&D							0.23
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1863	1831	1831	1863	1491	1766	1720
Adjusted R^2	0.682	0.683	0.683	0.682	0.704	0.710	0.691

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We now turn our discussion to the service sector, starting from the knowledge-intensive services sector (Table 6). Repeating the pattern from the previous analysis, our evidence here again suggests that technological transfers and spillovers from the technological frontier are important to growth. Their magnitude, however, especially with regards to the spillover effects, are weaker compared to the previous sectors analyzed thus far, while technological spillovers are nullified once we control for government expenses (columns 5 – 7). Moreover, and unlike all previous cases, R&D expenditures are found to be important to knowledge creation but not necessary be associated with the process of adopting new technologies. Their effectiveness could be particularly strong and could increase the TFP growth of this sector, from 0.30 to about 0.91 percentage points after a percentage increase in R&D spending, once we control for barriers to trade or investment or to entrepreneurship (columns 2-3). We do not identify any case in which R&D expenditures could become insignificant, which is reassuring given that knowledge in this sector by default is a key input to the production of services. Despite, however, this finding human capital, as in most of the previous cases, is insignificant to the innovation dynamics and play no role either by itself or for the adoption of new technologies. With regards to policies, our results here again indicate that they are non-significant.

Table 4 Results of econometric analysis for other services sector regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.00	0.00	0.00	0.00	-0.00	0.01	0.00
Gap	-0.48^{***}	-0.52^{***}	-0.52^{***}	-0.48^{***}	-0.49^{***}	-0.49^{***}	-0.50^{***}
HC	-0.06	-0.05	-0.05	-0.06	-0.07	-0.04	-0.02
HC # Gap	-0.16	-0.16	-0.16	-0.16	-0.17	-0.13	-0.13
RD	2.61^{***}	2.52^{***}	2.52^{***}	2.61^{***}	2.65^{***}	2.63^{***}	2.80^{***}
RD # Gap	4.44^{***}	4.41^{***}	4.41^{***}	4.44^{***}	3.26^{***}	4.47^{***}	4.24^{***}
(a)State Control		-0.40					
(b)Barriers to Entrepreneurship			1.47				
(c)Barriers to Trade and Investment				0.48			
(d)Gov. Financed R&D expenditures					-0.17		
(e)Education and Social Programs (Gov. Expenditures						0.01	
(f)Gov. Expenditures on R&D							0.53
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1411	1391	1391	1411	1136	1333	1283
Adjusted R^2	0.719	0.732	0.732	0.719	0.728	0.700	0.729

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Finally, we conclude this section by looking at the last sector we used for the purpose of this analysis comprising all service sectors which are not knowledge intensive services. Compared to the knowledge intensive category, one key difference that emerges from our analysis is that technological spillovers are rather unimportant to this sector, hence mimicking the case of some other sectors like medium-technology manufacturing sector. Interestingly, R&D expenditures themselves seem to be important determinant for TFP growth. Their quantitative impact is found to be particular large, and much larger than the knowledge-intensive services sector, being able to increase TFP growth by about 2.61 percentage points in the baseline regression when RD expenditures increase by one percent. Nevertheless, according to our results an increase is R&D spending for this sector it also makes more unlikely or more difficult to adopt technologies invented elsewhere. All these hold true, regardless the inclusion of policy variable or not, which found to be again non-significant for the other services sector.

4.2. Pooled regression

We conclude our analysis by presenting the results from the pooled regression where we make use of the data from all the economic sectors in EU-KLEMS database. This allows us to investigate how the overall picture looks like by pooling all available information and to check whether the insignificance of the policy variables in the sector-specific regressions might be related to the small size of the used samples. Table 5 shows the main results of the pooled regression where we have baseline regressions and include policy variables one by one for the sensitivity analysis.

Table 5 Results of econometric analysis for pooled regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
D.TFP*	0.05	0.05	0.05	0.05	0.01	0.07	0.06
Gap	-0.77***	-0.79***	-0.79***	-0.77***	-0.88***	-0.82***	-0.80***
HC	0.06	0.04	0.04	0.06	0.12	0.09	0.06
HC # Gap	0.04	0.02	0.02	0.04	0.07	0.06	0.04
RD	0.76*	1.47*	1.47*	0.76*	0.49	0.82*	0.64
RD # Gap	0.19	0.73	0.73	0.19	0.24	0.12	0.13
(a)State Control		-0.79***					
(b)Barriers to Entrepreneurship			-0.33***				
(c)Barriers to Trade and Investment				-1.15***			
(d)Gov. Financed R&D expenditures					2.08***		
(e)Education and Social Programs (Gov. Expenditures						0.00	
(f)Gov. Expenditures on							2.15***

R&D							
Country-Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5750	5682	5682	5750	4618	5445	5284
Adjusted R^2	0.507	0.511	0.511	0.507	0.536	0.549	0.514

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

While technological spillovers were found to be very relevant to some sectors, the fact that for some other industries – especially those classified as medium-technology and knowledge intensive service sectors - do not play any important role implies that their overall importance is not robust. This can be seen, for example, by the statistically insignificant coefficients we found for leader's TFP growth as opposed to the estimated coefficients of the catch-up term, which looks a robust driver in accelerating TFP growth.

Our evidence, therefore, identifies technological transfers into a common determinant, though with a varying degree of impact, on the TFP growth for all economic sectors. Technological spillovers on the other hand exhibit a much more varied pattern with their relevance being much dependent on the economic sector that we investigate. In this respect, our results compare against most of the theoretical or empirical work that tests the assumptions of the Schumpeterian growth theory and which views technological spillovers as a key driver to TFP growth.

The creation of new knew knowledge or technologies is most likely to be stemming from private or public R&D expenditures. In all specifications, private R&D expenditures are found to be statistically significant, unless we control for government expenses such as public R&D expenditures used on R&D in the public sector or government-financed R&D expenditures that represent R&D subsidies to private R&D.

The latter result is in line with the empirical work of Adams (1990), who showed that public R&D has positive impact on TFP growth. Consistent with earlier findings, human capital or RD spending still found to be unimportant factors in absorbing new technologies. Except the medium-tech sectors, we observe here that there is a systematic pattern rejecting the duel face hypothesis about the role of RD and of human capital in affecting TFP growth by increasing the likelihood of better absorbing new technologies (See Griffith et al. (2006) and Benhabib and Spiegel (2005)) .

With regards to human capital, in particular, our results are in line with the hypothesis that human capital has become a largely irrelevant factor to TFP growth, most notably because of the decrease in the quality of education over the last few decades, as well as because of the decline in returns to education which affects labor productivity and, by extension, the capacity to absorb new knowledge (See Prichett (2001)). Our analysis in this and previous sections, helps to establish that this pattern may well be a common development relevant to all sectors of the economy.

Our second key insight relates to the relevance of public policies. In the previous section we did not identify any particular policy that affects the TFP growth of specific sector. Policies in individual sector regressions turned out to be insignificant. This however does not hold true, once we pool all the sectoral data that we have into one sample. Our pooled estimates suggests that most of these policies have their expected sign and are important to sectoral TFP growth.

Our results here, identify three key regulation policies (state control, barriers to entrepreneurship and barriers to trade and investment) that could have important consequences to productivity growth. Theoretical and empirical studies suggests the existence of an inverted U relationship between market regulation (level of market competition) and economic growth. That is, deregulating markets and facilitating new market entry could improve productivity growth potential up to a particular point after which more market competition will lead to negative impacts on the level of R&D investments and productivity growth.

In our case, state control, which captures the case of regulating markets mostly via price caps or ceilings, found to have a rather negative impact to TFP growth across industries. A unit increase to the score index about the state control, may well bring a decline to TFP growth equal to about 0.79 percentage points.

A similar but less strong impact could result from policies that reduce market competition, for example, by making harder to set-up a business. The most sever regulatory policy according to our results, however, come from an increases in the barriers to trade or investments. This is not surprising, given that many key technological developments are attributed to an exchange of know-how between trading partners as well as directly via trade flows of technological goods. Imposing trade barriers such as for example tariffs or quotas may lead to reduction in productivity growth.

According to the estimates of pooled regression, public expenditures on R&D either via subsidies to private sector (d) or via R&D investments in the public sector (f) boost productivity growth, at least when the full sample of EU-KLEMS is utilized. Depending on which among these two public policies we look at, TFP growth could increase by about 2.08-2.15 percentage point meaning that these public policies are quite effective in boosting productivity growth. Public expenditures on education and social programmes have small positive but non-significant impact on the productivity growth across the economic sectors.

5. Conclusions

In this paper we provided an empirical evidence about the main determinants of sectoral productivity growth including both more traditional explanatory variables such as human capital and R&D intensity as well as a set of innovation-related public policy instruments. To do so, we employed a multi-factor productivity model and used the combination of EU-

KLEMS dataset and OECD data for econometric analysis of five yearly TFP growth on six aggregated sectors of the economy including traditional sector, three manufacturing sectors and two services sectors. We have tested in particular the role of technological spillovers and that of technological adoption and knowledge creation processes, in the process of technological development, along with other important classical determinants of growth such as human capital and private R&D expenditures.

Into this framework, and in order to provide some guidance about industrial policies, we supplemented our econometric model with a number of policy variables often viewed important to growth dynamics. The first set of results highlight that technological adoption or knowledge adoption process entail the single most important determinant common to all sectors of the economy, while technological transfers found to be relevant only at some sectors and not overall. Relatedly, a common pattern that arises across most sectors is the rather unimportant, if not negative, role of human capital in stimulating productivity growth, while investments in research and development although is found to play a positive role in productivity growth for many sectors do not nevertheless contribute in technological adoption, as was argued in the literature.

Finally, we identified a set of country-level innovation-relevant policies that could be effective in boosting overall TFP growth that include a set of market regulation and public investment policies related to innovation and investments. Even though these macro-economic policies were not significant in the sector-specific regressions they were all significant and with the theoretically correct signs in the pooled regression. The latter may indicate that the chosen sectoral dataset used for econometric analysis (EU-KLEMS) has unfortunately too little observations for individual sectors in order to capture the impacts of country-specific macro-economic policies. Besides the relatively short time coverage another caveat of EU-KLEMS data is that is covers only a subset of EU countries plus US and hence does not provide large country variation in the levels of for example human capital and some policy variables.

Our sector-specific regressions are nonetheless useful for understanding which drivers of productivity growth are more important in various economic sectors. Our econometric analysis have shown that R&D is quite important determinant for productivity growth in both knowledge intensive services and in other services sectors whereas human capital plays as important role in the technology adoption process of medium-technology manufacturing . Our paper allows one to combine the insights from sector-specific econometric analysis in case of the role of R&D and human capital with the roles of various macro-economic policy instruments from the pooled regression in order to work towards the policy mixes that take into account sectoral specialization of various EU-countries and their regions.

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