The relationship between R&D expenditures and productivity in studies on industry and/or firm level - review

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Abstract: In this article we summarized the newest approaches used in the literature about the relationship between R&D expenditures and productivity. Our attention is oriented on studies concentrating on this relationship on sectorial levels and/or firm level. We monitor the methods and models used by the authors to describe this relationship and compare the independent and dependent variables used in these models. In most of the studies the positive relationship between investment in R&D and increased productivity has been proven.

Keywords: research and development, productivity, production function, panel data.

1 Introduction

The reseaecrh and development on the business level is one of the key factors that leads to successful innovation of products and processes and new knowledge. Thanks to the work done in the departments oriented on research and development activities companies can bring to the market new products or introduce new processes that lead to higher productivity and higher revenues.

The investment in research and development is different from other forms of investment since in this field even high investment do not necesserily lead to high profits. The obstacles of this transformation are connected also with creativity at different stages of the process – in changing the investment into new ideas, in transforming the new ideas into new products or processes and also the creativity in bringing these new products and processes to the market and to the end consumers and in persuading them to buy the products. Only then can the initial investment into research and development transfer into higher productivity or higher profits.

2 R&D and productivity

In this article we make an overview of the models and methods that were published about the relationship between research and development and productivity in the last few years. We specially concentrate on articles and studies about the influence of R&D expenditures on productivity on the microeconomic level – the level of companies and industrial sectors. Some of the articles also compare this relationship in various sectors, some of them compare companies in the same sector.

We focus on methods the authors use in order to track down the influence of R&D om productivity and also on models that help them to describe the relationship. We looked for the used explanatory variables, proxies and dummies. The outcome should serve as a base for our continuing work on building a model, stating the variables for the model and proving the

existence of a positive relationship between research and development investment and increase of labor productivity on firms and sectoral level.

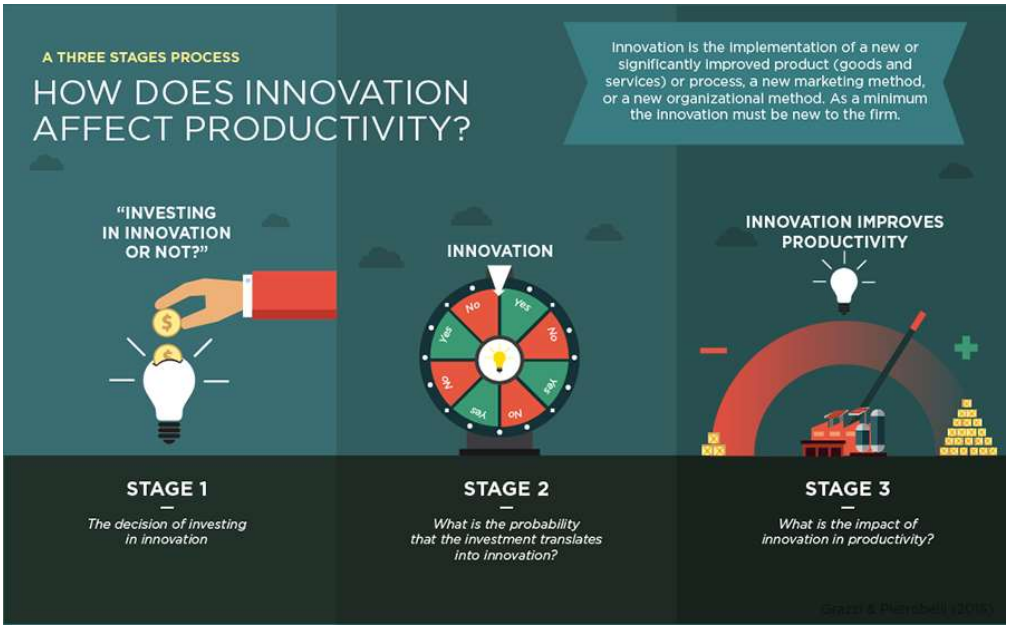

Fig. 1 http://www.firmsinlatinamerica.com/en/

3 Relationship between R&D and productivity on firms' and sectoral level

In our review we concentrated on more than 30 recent studies (2012-2016) from this field and two seminal works with an older date of publication. From these studies most of them concentrate on firms within the same industry, many of them compare same industries from different countries and few others do several models within one article – one within an industry, one between industries. The most interesting industry seems to be the manufacturing industry, followed by pharma industry and services. Some studies make a different division according to technological difficulty of various industries = and divide companies or sectors in high tech, medium tech and low tech industries (Ortega, Argiles, 2010; Blanco et all, 2016, Lu et al, 2010). In coupla of articles the authors compare various industries on the european or OECD level (Ortega, Argiles, 2010; Liik, Masso, 2014). One article was dedicated to agriculture (Alston, 2010).

Our attention was first oriented at the models used in chosen studies. It can be said that only few types of models were used even though in more variations. To the most used models belong Crepon Duguet Mairesse model (CDM), CDM model is names after its authors who were the first to include in a model on the firms' level the relationship between R&D, innovation and productivity. They divided the relationship in three stages and built a function for each of them. First stage encomprises the decision wheter to invest in innovation. This is followed by the second stage where the authors built an innovation function to connect the innovation expenditures with their outcome – innovated product or process Through the Cobb Douglas production function in the third stage is the innovation connected with labor productivity. (Crepon, Duguet, Mairesse, 1998).

The second most used method is Data Envelopment Analyies (DEA). DEA is quite a new way to evaluate the performance of so called Decision making Units. (Cooper, et al, 2011) Also panel data analysis is frequently employed. In one article Bustos model (Dilling-Hansen, Smith, 2014) –a model that divides firms into three groups according to their heterogeneity with regard to export and R&D investment (Bustos, 2011), was used and in one SFA model – similar to the panel data (Liik, Masso, 2014).

As the base the articles used various production functions, some of them divided in several stages. In most of the models we see Cobb-Douglas production function

$$Q(L,K) = AL^{\beta}K^{\alpha}, \quad (1)$$

Q – quantity of product

L – quantity of labor

K – quantity of capital

A – positive constant

α, β – coefficients

or augmented production function

$$ln(VA/E) = \alpha + \beta \ln\left(\frac{K}{E}\right) + \gamma \ln\left(\frac{C}{E}\right) + \lambda \ln(E) + \varepsilon, \quad (2)$$

VA – value added

E – employement

VA/E – value added over total employement

K/E – R&D stock per employee

C/E – physical capital expenditures per employee (Ortega, Argiles, 2010).

Next area of interest comprises the dependent variable – we concentrate on the proxies the models use for productivity. The labor productivity is the obviously prevailing dependent variable (Ortega-Argiles, 2010, 2014; Srithanpong, 2014; Heshmati, 2011; .Kumbhakar, 2012; De Fuentes, 2015, Belitz et al, 2011; Chevalier, 2012;…). Labor productivity is very import measure because it serves as a measure of economic growth in a country. It can be calculated in two ways – as the amount of goods and services produced by one hour of labor – labor productivity per hour worked – or as labor productivity per worker. In our models manly the logged value added per employee or per hour ratio was used.

In other models the total factor productivity was used. (Aw, 2010; Sharma, 2011; Sharma, 2014; Tello, 2015; Blanco et all, 2016; Kleis et al, 2014). The total factor productivity (TFP) measures the increase in total output of an economy, industry or firm that cannot be explained by the influences of factorsas capital and labor. It stands for the more efficiency and often is considered as the most important factor that for the economic growth. Singh (Singh, 2016) used both proxies for productivity – labor productivity as well as total factor productivity.

The range of independent variables is much bigger. The most interesting for us – the variable for research and development – stands in the models as own R&D stock or R&D stock per

employee, R&D expenditures, total number of R&D researchers, knowledge capital per employee, investment or R&D intensity, previous patent application, the plants'own R&D, R&D investment, ICT expenditures.

Some studies go deeper and divide the R&D variable further – either differentiate the effects of local and foreign R&D (Zamborsky, Jacobs, 2016), or compare three innovation outputs – patent application, product and process innovation and sales of new products and their individual relationship with productivity (Barge-Gil, et al, 2015). In two articles instrumental variables were used – one was capital stock per employee and in the other one other firms' R&D and R&D in the parents'firm other plants (Kumbhakar, 2012; Bogliacino et al, 2012) .

Dummies help to build the models – dummy or indicator variable is used in statistical regression and takes the values of zero or one – for categorical variables. In the studies that we have observed prevails the export dummy – used in order to distinguish between companies that do export and do not (Manez, et al 2015). To the other dummies counts size, import, foreign ownership public financing, foreign firms dummy, industry dummies (technological intensity).

To complete the models and concentrate on the influence of explanatory variables, some control variables were added in the models. Most often seen is the total employement variable (Ortega, et al, 2011, Ortega, et al, 2012, Ortega, et al, 2010). . R&D spillovers, size, debt ratio, capital labor ratio and capital stock also belong to the control variables found in the models (Bednarek, 2014; Barge-Gil, Lopez, 2015; Feinberg, Majundar, 2001; Sharma, 2014).

Other important feuture of the studied models is how they copy with the endogeneity problem. Endogeneity arises in statistical models when a correlation between explanotory variable and error exists. It can be caused by an omitted variable or by simultaneity.In most of our observed models this problem is solved through usage of lagged values, mostly by one year or one period (Ortega et al, 2011; Bogliacino, 2012; Sharma, 2014; Zamborsky, 2016; Aw, 2010). The other observed solution to endogeneity problem was to use predicted values from the innovation function (Srithanpong, 2014; Heshmati, 2011; Alvarez et al, 2015).

Last monitored characteristic is conncted with the results of the studies. Most of the studies have proven the positive influence of R&D on the productivity on both firm and sectoral level. Only one study showed mixed results (Sharma, 2014). The others proved the positive impact according to their range of study – either on firm or on sectoral level or on both of them. Corporate R&D investment has a main role in achieving production growth, the intensity of innovation has a strong impact on firms productivity through innovation output.

More deeply, innovation has a stronger impact on productivity in manufacturing then in services and at the same time cooperation in the area of R&D is more important in the services than in manufacturing (Alvarez et al, 2015). The same staudy also showed that the size of a company is important by turning the investment in R&D into higher productivity. In the US the knowledge spillovers between individual states are important for higher productivity (Blanco et al, 2016),

The importance of corporate R&D investment has been also recognised as aa essential engine for productivity growth both at the macro and microeconomic level both in Europe and in USA, even though R&D expenditures have more impact on productivity in USA then in Europe (Ortega-Argiles, 2014; Castellani et al, 2016).The positive relationship between R&D and productivity across the European industrial and service sectors was proven also by the study from Ortega-Argiles (Ortega-Argiles et al, 2010). and plants'own R&D together with parents'firm R&D help to increase firms productivity.Similar results have brought the studies oriented also on multinational enterprises where the studies show that R&D investment by

local firms is positively associated with the productivity of affiliates of foreign firms (Zamborsky, 2016; Doraszelski, 2013) and the firms' own R&D in connection with parents' firm R&D also help to increase the whole firm's productivity (Bogliacino, 2012; Lehto, 2011).

4 Discussion

This review article is aimed at finding the best possible or proven variables and dummies to create a model that should describe the relationship between research and development and productivity at the firm and sector level. The purpose of writing this article is to construct a reviewof recent literature and to monitor the recently used models,methods and data. With regard to this goal we continue our work in this field and focus on constructing a separate model for firm level and aseparate model for industry level.

We will examine given data from various international well established sources the relationship between productivity and R&D expenditures. The contribution would be in the area of new approaches and newest available data. Special attention will be given to the slovak data on the firms' level. With regard to this review we will include several ecplaanatory variables. To deal with endogeneity we wil lag the explanatory variables. The partial goal will be to find the appropriate lag in this relationship.

5 Conclusions

The goal of the article was to summarize the newest development in the area of inspecting the influence of investment in research and development on labor productivity or total factor productivity. This relationship has been observed on the firm and/or industry level in various separate countries or within a several-countries-comparison (USA-Europe, various OECD countries or various european countries). As such it serves the author as a preliminary article on the way of finding the best approach to this subject to construct a model to describe the relationship betweem research and development and productivity. From this point futher research will be oriented on this relationship with labor productivity as a proxy to productivity, research ande development investment and innovations as proxies to R&D.

To summarize we can say that in majority of the monitored studies the positive impact of expenditures on research and development on productivity was found and proved. Most of the researchers used labor productivity as a proxy for productivity, only few used total factor productivity instead. The range of explanatory variables was bigger, but besides the R&D proxy, export, sales, patents and geographical priximity were almost in all monitored studies. As for the R&D variable the R&D expenditures, R&D as a percentage of GDP, patents filled or accepted served as proxies. In majority of the studies the Cobb Douglas function in different variations serves as the tool to state the relationship.The range of the monitored studies helped us to find the patterns used I this field and also to find a way to move the research further.

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