INNOVATION AND FIRMS' PRODUCTIVITY GROWTH IN SLOVENIA: SENSITIVITY OF RESULTS TO SECTORAL HETEROGENEITY AND TO ESTIMATION METHOD

Jože P. Damijan, Črt Kostevc and Matija Rojec

WORKING PAPER No. 41, 2008

INNOVATION AND FIRMS' PRODUCTIVITY GROWTH IN SLOVENIA: SENSITIVITY OF RESULTS TO SECTORAL HETEROGENEITY AND TO ESTIMATION METHOD[1]

Jože P. Damijan[2]

Črt Kostevc[3]

Matija Rojec[4]

WORKING PAPER No. 41, 2008

Editor of the WP series: Boris Majcen

Ljubljana, December 2008

---

[1]. This paper was prepared within the Sixth Framework Programme project *Understanding the Relationship between Knowledge and Competitiveness in the Enlarging European Union (U-Know).*

[2] University of Ljubljana; Vienna University of Economics and Business Administration; Institute for Economic Research, Ljubljana; LICOS, KU Leuven, Belgium. address: Faculty of Economics, University of Ljubljana, Kardeljeva ploscad 17, 1000 Ljubljana, Slovenia, e-mail: joze.damijan@ef.uni-lj.si

[3] University of Ljubljana; Institute for Economic Research, Ljubljana, address: Faculty of Economics, University of Ljubljana, Kardeljeva ploscad 17, 1000 Ljubljana, Slovenia, e-mail: crt.kostevc@ef.uni-lj.si

[4] University of Ljubljana; Institute for Macroecopnomic Analysis and Development, Ljubljana. address: Institute for Macroecopnomic Analysis and Development, Gregorciceva 27, 1000 Ljubljana, e-mail: matija.rojec@gov.si

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

330.342.1

PAVLIČ Damijan, Jože
Innovation and firms' productivity growth in Slovenia: sensitivity of results to sectoral heterogeneity and to estimation method / Jože P. Damijan, Črt Kostevc, Matija Rojec. - Ljubljana : Institute for Economic Research, 2008. - (Working paper / Inštitut za ekonomska raziskovanja, ISSN 1581-8063 ; 2008, 41)

ISBN 978-961-6543-62-0
1. Kostevc, Črt 2. Rojec, Matija
243320576

Abstract

The paper examines implications of endogenous growth theory on the relationship between firm productivity and productivity growth with innovation by combining information on firm-level innovation (CIS) with accounting data for a large sample of Slovenian firms in the period 1996-2002. We employ different estimation methods in order to control for the endogeneity of innovation (Crépon-Duguet-Mairesse - CDM - approach) and sensitivity to outliers (quantile regressions). Our findings support a link between productivity and firm propensity to innovate as well as the link between innovation activity and productivity growth. More detailed empirical tests, however, reveal that these results are mainly driven by the exceptional performance of a specific group of services firms located in the fourth quintile with respect to size, productivity and R&D propensity measure. Quantile regression estimates for manufacturing firms, however, revealed that innovation in benefitting predominantly the slow growing firms, while better performing firms do not extract any additional benefits from innovation.

Keywords: Research and development, innovation, knowledge spillovers, productivity growth

JEL Classification: D24, F14, F21

1. Introduction

The primary aim of the paper is to analyze the link between firm-level innovation activity and productivity. Endogenous growth theory suggests, firstly, that technological progress is endogenous and driven by the deliberate investment of resources by profit-seeking firms (Smolny, 2000) and, secondly, that a firm's innovation activity is central to its technological progress and productivity growth. The direction of causality therefore has to run from higher productivity to higher innovative activity (propensity to innovate) and consequently from higher innovative activity (propensity to innovate) to higher productivity growth.

One of the most influential studies on innovation and productivity growth is that of Crepon, Duguet, and Mairesse (CDM, 1998), who combine a knowledge-production function, relating R&D activity to patenting or innovative activities, with economic performance as measured by labor productivity. The paper by Crepon et al. (1998) has influenced a new and burgeoning literature on the relationship between innovation output and firm performance. The main finding of these studies is that, regardless of how performance is measured, innovation output positively and significantly affects firm performance. The exception to this is the study by Klomp and van Leeuwen (2001) that finds a negative but insignificant effect of innovation output on employment growth. Studies have been done on developing countries as well. Two of these, Benavente (2006) on Chile and Mohnen (2006) on Tanzania, show that innovation output (or R&D activity) does not influence firm performance. The findings of Jefferson et al. (2002) for China are more optimistic.

Some of the studies distinguish between product and process innovations. The findings of Harrison et al. (2005), Griffith et al (2006), Parisi et al. (2006), and Hall et al. (2007) tend to demonstrate that process innovations have labor displacement effects and are therefore expected to result in significant productivity growth, while, due to the demand effect, product innovations may likely cause employment growth and, thus, may not result in significant productivity growth.

So far, with some notable exceptions (Parisi et al. 2006, Hall et al. 2007[5]), the vast majority of the relevant empirical work focuses on the first part of the causality equation only, i.e. on the link between innovation and firm productivity levels. Our paper, instead,

[5] Harrison et al. (2005) and Hall et al. (2007) do not focus on the link between innovation and productivity growth, but the relationship is included in their decomposition of the effects of innovation on employment.

takes into account both aspects of productivity-innovation nexus. We first empirically establish the causal relationship from productivity level to propensity to innovate, while in the second we focus on the impact of successful innovation on firm productivity growth.

Our empirical strategy is as follows. In order to examine the productivity (productivity growth)-innovation nexus, we combine firm-level innovation data taken from Community Innovation Survey (CIS) with accounting data for a large sample of Slovenian firms in the period 1996-2002. , we apply the CDM approach to establish the knowledge-production function of Slovenian firms by simultaneously linking the research capital equation with both the innovation equation and the productivity equation. In the second step, we then study the impact of innovation on firms' productivity growth. We apply ordinary least squares on first-differenced data by taking as our main measure of innovation variable either the innovation variable from the CIS or the probabilities to innovate estimated by using the CDM approach in the first step.

We find robust evidence of a positive link between firm-productivity and their propensity to innovate OLS estimates provide support for a positive impact of innovation on productivity growth. Further empirical tests, however, reveal that these results are mainly due to the exceptional performance of a specific group of services firms in the fourth quintile with respect to size, productivity and R&D propensity measure.

The remainder of the paper is structured as follows. Section two provides the theoretical background on R&D, innovation, and firm performance. Section three briefly discusses the extent and determinants of the innovation activity of Slovenian firms. Section four applies the CDM approach to Slovenian data in order to estimate consistently the probabilities to innovate, while section five provides estimations of the effect of innovation activity on firms' productivity. The last section presents the conclusions.

2. Theoretical background: R&D, innovation activity, and firm performance

Griliches (1979) was the first to introduce R&D capital stock as a factor of production into the residual computation framework pioneered by Solow (1957). In this approach, R&D activities add to the existing stock of accumulated knowledge of firms, leading to productivity growth through product and process innovation. Romer's (1990) model predicts a link between R&D activity and productivity growth, and Cohen and Leventhal (1989) point to the importance that R&D activity can have in absorbing technology produced in other firms. Studies of the relationship between knowledge creation and productivity appear at different levels of aggregate (economy, sector, firm) depending on the objective of the analysis.[6]

Early models developed by economists affiliated with the NBER incorporate a variable that captured the 'economically valuable technological knowledge', or what Griliches (1979) termed 'knowledge capital' and said very little regarding what knowledge is, or regarding how it becomes important for innovation and growth. These models focused mainly on the relationship between R&D activity and productivity growth within a production function framework (Wieser, 2005) that includes 'knowledge capital' in addition to the traditional inputs. It is the elasticities of output with respect to each of the inputs that will matter most for the analysis. Studies of the direct relation between R&D and firm performance give mixed results.[7] These include Schankerman (1981) and Griliches (1980, 1986) on the value-added of U.S. firms in selected industries in 1963 and 1972, respectively, Griliches and Mairesse (1984) on sales of U.S firms from 1966 to 1977, Cuneo and Mairesse (1984) on French scientific firms from 1972 to 1977, Hall and Mairesse (1995) and Mairesse and Hall (1996) on sales and value-added in U.S. and French firms in the 1980s, Bartelsman, et al. (1998) on value-added in Dutch firms in the late 1980s, Cincera (1998) with regard to the world from 1987 to 1994, O'Mahoney and Vecchi (2000) on sales of U.S., European, and Japanese firms in the mid-1990s. Wieser (2005) carries out a meta-analysis of these studies and provides five conclusions:

1. Despite considerable variation across studies, the analysis suggests a strong and positive relationship between R&D expenditures and the growth of output or total factor productivity.

2. Studies confirm that firms accrue spillover benefits from R&D activity in other firms. They also suggest that spillovers between industries are more important than those within industries.

3. There is considerable variation in the rates of return on R&D activity within firms, but no apparent trend across industries.

4. It is not clear whether the relationship between R&D activity and firm performance is strengthening or weakening over time.

---

[6] Relevant reviews of the literature include Nadiri (1991), Griliches (1992), Mairesse and Mohnen, (1995), Cincera (1998), and Wieser (2005).

[7] There is also group of studies that focus on the rate of return on R&D activity at the firm level. These include Mansfield (1980) and Link (1981, 1983) on the United States, Griliches and Mairesse (1983, 1984, 1990) on the United States, France, and Japan, Hall and Mairesse (1995) on France, and Cincera (1998) on the world.

5. The rates of return on R&D activity are similar across countries.

Pakes and Griliches (1984) developed a variant of this framework in which changes in knowledge capital, defined as the level of economically valuable technological knowledge, are unobservable, which allows for the inclusion of several interrelated innovation inputs. Crepon et al. (1998) extended this model to explore the channels through which R&D activity influenced innovation and productivity growth for a cross-section of firms in the French manufacturing sector for 1992. The model combines a knowledge-production function, relating R&D activity to patenting or innovative activities, with economic performance as measured by labor productivity. It contains a system of three simultaneous equations where R&D activity and other factors generate new knowledge, which then propels innovation (output) and finally productivity growth. Other supply and demand factors as well as sectoral differences and unobserved heterogeneity are also included in the model to improve its explanatory power. One novel aspect of the model is that the authors incorporated indicators derived from a French innovation survey into the framework. They found evidence in support of a positive effect on R&D activity and innovation output measured by patent numbers, as well as a positive and significant effect on the value-added per employee of French firms.

The paper by Crepon et al. (1998) has influenced the growing literature on the relationship between innovation output and firm performance. Firm performance variables may include value-added, sales or exports per worker, sales per worker, and the growth rate of value-added, sales, profitability, or employment, and sales margin, profit before and after depreciation (in level and growth rates). The main finding of these studies is that, regardless of how performance is measured, innovation output positively and significantly affects firm performance, with the exception of the study by Klomp and van Leeuwen (2001), which found a negative but insignificant effect of innovation output on employment growth (Hall and Mairesse, 2006; Raymond et al., 2006). Lööf and Heshmati (2006) performed a sensitivity analysis of the different measures of firm performance and found the same pattern of positive and significant effect of innovation output on firm performance.

Similar results are found in other papers. Mohnen et al. (2006) estimated the relationship between innovation output and firm performance by using micro-aggregated data from seven countries (Belgium, Denmark, Ireland, Germany, the Netherlands, Norway, and Italy) for 1992. They also observed that firm productivity correlates positively with higher innovation output, even when correcting for the skill composition of labor and capital intensity, but they also found that simultaneity tends to interact with selectivity, and that both sources of biases must be taken into account together.[8] Griffith et al. (2006) estimated a variation of the model for four European countries (France, Germany, Spain, and the UK), using firm-level data from CIS3 carried out in2000. This model differentiates between the labor displacement effect of process innovation and the compensation effect caused by higher demand. They found that job loss due to process innovation is partly compensated for by the displacement effect and that there is no evidence of a displacement effect when there is product innovation, even when old products are no longer produced. Although they find that the results are similar across these four countries, the employment effects are different. For example, there is no sign of a displacement effect from process innovations in Spain, whereas product innovation generates more employment in Germany and less in the UK. Similarly, Parisi et al. (2006) found that process innovations significantly impacted the productivity growth of Italian firms in the late 1990s, while product innovations had a much less significant effect. A common explanation for this may be the different displacement and compensation effects of product and process innovations. As shown by Harrison et al (2005) and Hall et al. (2007), due to demand effect, product innovation may likely result in employment growth, while process innovation is likely to have labor saving effects.

Other papers, including Lööf et al. (2002), showed that there was considerable variation between Finland, Norway, and Sweden in the early 1990s. They argue that this variation may be due to data errors, the econometric model (3SLS), model specifications, or unobservable country effects. Using CIS data from France in 1993, Duguet (2000) shows that strongly innovative firms are much more likely to improve their TFP than weaker firms, and that the return on innovation increases with the degree of innovation opportunities that firms have. The model also shows that the Solow residual at the industry level is linked to radical innovations at the firm level. Janz et al. (2004) pooled observations from Germany and Sweden to show that there is a strong link between innovation output and sales per employee in knowledge intensive manufacturing firms independent of the country. Using data on the Netherlands from 1997, van Leeuwen and Klomp (2006) show that the impact of innovation differs between measures of firm performance and that additional information on the technological environment of the firm

[8] Mohnen, et al. (2006) use a generalized tobit model together with a variation of the production accounting framework and include size, industry, ownership type, continuous R&D, cooperative R&D, R&D intensity, proximity to basic research, and perceived competition as independent variables.

can improve the estimation. Mohnen and Therrien (2003) compared Canada with selected European countries in the late 1990s and found Canadian firms were more innovative as a whole, but with a lower share of sales from innovative products for its innovative firms. These results led the authors to suggest that the national samples may not be representative and that differences in the questionnaire or perceptions of the questionnaire matter. Criscuolo and Haskel (2002) used a matched innovation survey and Census data to investigate the link between innovation and productivity growth in the UK. They found a statistically significant association between (process) innovations and TFP growth.

Lately, there have also been studies looking at the impact of innovative activity in less developed countries. Benavente (2006) applied the Crepon et al. (1998) model and estimating procedures to Chile during the period 1995 to 1998. He found that R&D and innovative activities are related to firm size and market power, but that innovation output (or R&D activity) does not influence firm performance. By contrast, Jefferson et al. (2002) showed that there is a strong relationship between R&D intensity and new product sales and returns on R&D expenditure after correcting for size, industry, profitability, and market concentration. Using data from the World Bank Investment Climate Survey covering the years 2000 to 2002, Mohnen (2006) showed that innovation output (or R&D activity) did not influence firm performance in Tanzania, but that the institutional arrangements had an important impact.

These robust conclusions suggest there might be a persistence of innovation which is important to many of the neoclassical endogenous growth models (Romer, 1990; Aghion and Howitt, 1992) and the Schumpeterian inspired evolutionary models (Malerba and Orenigo, 1996). Studies of input measures by Manez Castillejo et al. (2004) and Peters (2005) and of output measures by Duguet and Monjon (2002) found the persistence in innovation activities to be high between R&D and innovation survey data, whereas they tend to be lower with patent and major innovations (Raymond et al., 2006). Raymond et al. (2006) tested the persistence of innovation using Dutch firm data from three waves of innovation surveys, covering the periods 1994-1996, 1996-1998, and 1998-2000. Using a dynamic panel data type 2 tobit model that accounts for individual effects and handles the initial conditions problem, they found that there is no evidence of true persistence in achieving technological product or process innovations, while past shares of innovative sales condition, albeit to a small extent, current shares of innovative sales.

3. The extent and determinants of firms' innovation activity in Slovenia

Firms' innovation activity in the European Union member states is measured in a standard manner by the so called Community Innovation Surveys (CIS). In Slovenia, CIS surveys are conducted by the Slovenian statistical office every even year, starting in 1996. We have at our disposal four waves of innovation surveys, covering the periods 1994-1996, 1996-1998, 1998-2000, and 2000-2002). These innovation surveys are carried out among a wide sample of manufacturing and non-manufacturing firms with no restrictions put on the actual R&D activity by these firms. The number of firms covered by the innovation survey increased constantly during the 1996-2002 period (stratified random sampling, see Table 1). Hence, these surveys allow for a broad picture of determinants of innovation activity and its impact on the performance of Slovenian firms.

Table 1 reveals that the rate of innovation activity, which captures both product innovation and process innovation, is comparatively low in Slovenia. Only about 20% of Slovenian firms innovate, i.e. claimed to have conducted at least one innovation with respect to products and services or regarding the innovation of processes in the respective 2-year period. What is striking is the negative trend of the innovation activity of Slovenian firms, which shows that the share of innovative Slovenian firms shrunk from 1998 to 2002.[9] This is predominantly due to the low innovation activity of domestic firms (only 17% of domestically owned firms are innovative). Among foreign owned firms (firms with 10% or higher foreign equity share) the share of innovative firms is twice as high as in domestic firms. This indicates a more competitive and innovation conducive environment in foreign owned firms. Still, higher innovation activity by foreign owned firms is not necessarily backed by their higher own R&D expenditures (relative to total sales). The fact is that in the 2000 innovation survey foreign owned firms show proportionally less R&D expenditures compared to domestically owned firms, and in the 2002 survey approximately the same. Hence, their higher propensity to innovate must be driven by other factors, such as a constant transfer of technology and other knowledge spillovers from their parent companies.

[9] The share of innovative firms is shrinking in spite of the fact that total R&D expenditure is increasing.

Table 1: R&D expenditures and innovation activity of Slovenian firms by type of ownership, 1996-2002 (%)

	N	R&D/Sales (Innovative firms)	R&D/Sales (Non-Innovative firms)	Fraction of Innovative firms
All firms				
1996	1,454	1.5	0.026	21.7
1998	1,777	1.6	0.003	23.0
2000	2,518	6.0	0.021	21.2
2002	2,564	6.5	0.015	20.6
Domestic				
1996	1,148	1.4	0.027	18.6
1998	1,371	1.5	0.003	19.5
2000	1,923	7.1	0.023	17.5
2002	1,935	6.4	0.004	17.3
Foreign				
1996	306	1.8	0.023	33.3
1998	406	1.9	0.003	34.7
2000	595	4.1	0.012	32.9
2002	629	6.6	0.055	30.5

Source: Statistical office of Slovenia; own calculations.

Determinants of innovation activity by Slovenian firms were extensively studied by Damijan et al. (2006) by using the same dataset. Table 1 reveals the basic descriptive statistics of the innovation activity of Slovenian firms, showing that innovative firms are on average larger in terms of employment, have higher R&D expenditures, receive more R&D subsidies, are more export oriented, and are more likely to be foreign owned. At the same time, Table 1 shows also that the innovation activity of firms is persistent over time.

Table 2: Determinants of firms' innovation in Slovenia, 1996-2002 (in %)

	No.	INOV_ t-2[1]	rVA/ Emp[2]	Employ -ment	R&D/ Sales[3]	R&D/ VA[4]	Total sub./ R&D[5]	Public sub./ R&D[6]	Foreign sub./ R&D[7]	Exports / Sales	IFDI[8]
Innovative firms											
1996	316	-	1.26	346.7	1.55	5.39	5.39	3.12	0.27	43.9	0.388
1998	409	0.643	0.84	312.9	1.62	5.96	4.07	2.42	0.85	43.1	0.397
2000	533	0.554	1.11	278.5	6.02	19.22	4.33	3.42	0.59	38.1	0.368
2002	527	0.694	1.09	283.6	6.47	18.42	4.98	3.14	1.08	43.7	0.364
Non-Innovative firms											
1996	1138	-	1.19	122.8	0.026	0.101	0.180	0.066	0.054	25.7	0.254
1998	1368	0.095	1.11	96.5	0.003	0.006	0.004	0.004	0.000	27.3	0.237
2000	1985	0.122	1.01	68.5	0.021	0.047	0.013	0.013	0.000	21.6	0.201
2002	2037	0.113	0.99	67.5	0.015	0.038	0.016	0.000	0.001	22.8	0.215

Source: Damijan, Jaklič and Rojec (2006). *Notes:* 1/ Past innovation activity, lagged one period, that is two years; 2/ Relative productivity; firm value added per employee relative to the average productivity of particular sector; 3/ R&D expenditures as a share of sales; 4/ R&D expenditures as a share of value added; 5/ The share of total R&D subsidies in R&D expenditures; 6/ The share of public R&D subsidies in R&D expenditures; 7/ The share of foreign R&D subsidies in R&D expenditures; 8/ Foreign ownership.

Based on these data, Damijan et al. (2006) estimated the impact of firms' internal R&D capital, external R&D spillovers, firms' absorption capacity, and other structural indicators (such as firm size and productivity) on firms' innovation activity within an integrated dynamic model. They find that the probability of a firm innovating depends on the following factors:

(i) a firm's own R&D expenditures have a highly significant and positive impact on the probability of it innovating;

(ii) a firm's current innovation activity is heavily dependent on its previous innovation activity;

(iii) a firm's size positively affects its ability to innovate;

(iv) public R&D subsidies as well as R&D subsidies received from abroad significantly improve a firm's ability to innovate,

(v) foreign ownership stimulates firms to innovate, while exporting is not shown to have a significant impact on a firm's innovation activity;

(vi) horizontal knowledge spillovers seem to drive firm innovation activity, while vertical knowledge spillovers are shown to not be important;

(vii) contrary to expectations, the labor productivity and technological intensity of sectors in which a firm operates do not determine its innovation activity.[10]

4. Research capital production function by using the Crépon-Duguet-Mairesse approach

In order to explain the extent of innovation activity of Slovenian firms, we examine the links between firm's research and development, productivity, and innovation by applying the research capital production function introduced by Crépon, Duguet, and Mairesse (1998) (hereinafter CDM). Given that our dataset differs in certain aspects from the one originally used by CDM, we adapted their estimation approach to the available data.

The three stage estimation approach proposed by CDM is based on a structural model that explains productivity by innovation output and innovation output by research investment. The applied econometric methods take into account several key statistical features of the available data: the fact that only a portion of the of firms engage in research and development activities, the endogeneity of productivity, innovation, and research activity, as well as the fact that research investment and (research) capital are truncated variables, while innovative activity is binomial data. The availability of innovation survey data in addition to the usual firm-level accounting information allows us to separate different

[10] In addition to the above estimations, Damijan et al. (2006) also ran a separate estimation for product and process innovations. Results are almost identical for both types of innovation activity. There are only minor differences in estimation results in the sense that process innovations require a slightly larger firm size, while product innovations seem to be more pronounced in foreign owned firms and seem to give slightly higher return on public subsidies.

aspects of the innovation process and directly measure the effects this process has on productivity. Following CDM, we model three simultaneous relationships: the research equation, which links research to its determinants, the innovation equation relating research to innovation output measures, and, finally, the productivity equation relating innovation output to productivity.

4.1. The estimation approach

Following CDM, we present our version of the estimation algorithm to estimate the effects of R&D activity and expenditures on innovation and productivity. The system of equations is split into three sets: the research equation, innovation equation, and productivity equation.

Research equation. Firm research activities are depicted by two equations accounting separately for a firm's decision to engage in research and the magnitude or intensity of these activities. For the research decision, CDM assume that there exists a latent dependent variable g_i^* for firm *i* given by the following equation:

(1) $$g_i^* = x_{0i} b_0 + u_{0i}$$

where g_i^* expresses the decision criterion (such as the expected present value of firm profit accruing to research investment), x_{0i} is a vector of explanatory variables, b_0 the associated coefficient vector, and u_{0i} an error term. Firms with g_i^* above some threshold value (overall or industry specific) choose to invest in research. As was the case for French firms studied by CDM, only a portion of Slovene firms actually invest in R&D.

The intensity of research k_i^* is determined by the second "research" equation:

(2) $$k_i^* = x_{1i} b_1 + u_{1i}$$

where k_i^* is the research capital per employee of firm *i* when this firm does research, x_{1i} is, again, a vector of explanatory variables, b_1 is the associated coefficient vector, and u_{1i} denotes the error term.[11] Even though it needs not be the case[12], we follow CDM and assume that both equations have the same explanatory variables ($x_0 = x_1$). The

[11] We use both logarithm of research capital per employee and logarithm research investment per employee in the estimation. Construction of the research capital variable follows the approach suggested by CDM.

[12] There do not seem to be many theoretically convincing choices of variables that could serve to explain the choice to invest in R&D but not the magnitude of the investment, and vice versa.

explanatory variables we employ in the estimation of equations (2) and (3) differ somewhat from those employed by CDM. Partly due to the restrictions of the dataset, and partly due to our belief that firm's engagement in research depends also on firm's ownership structure and sources of external knowledge spillovers – such as trade and intra- and inter-sectoral knowledge spillovers. The regressors we use are:

$$x_{0i} = x_{1i} = (l_i, s_i, exp_i, fdi_i, HS\_inov_i, VS\_inov_i, T_i, S_i)$$

where l_i is number of employees, s_i is firm's *i* market share (based on NACE 3-digit markets), exp_i is the share or export sales in total revenue, fdi_i represents an indicator variable, taking on value 1 if a firm is in foreign ownership (at least 10% of the capital has to be foreign owned) and 0 if it is domestically owned. We also include horizontal (HS_inov_i) and vertical spillovers (VS_inov_i) from innovation activity of other firms. Horizontal spillovers are measured by the number of innovations done in the same sector. Vertical spillovers are calculated as the number of innovations conducted in the related sectors multiplied by the respective input-output coefficients, where the latter reflect the strength of input – output relationship between the sectors. Finally, *T* and *S* are time and industry dummies. Unfortunately, the innovation survey does not include information on demand pull and technology push factors, nor do we have access to product-level sales information.

Innovation equation. We proxy innovation output with an indicator variable of innovation, which takes the value 1 if a firm has innovated in the past year and 0 if it has not. Furthermore, we are able to differentiate between product and process innovations.[13] On the other hand, we do not observe patent data nor do we have information on the share of sales coming from newly launched products. The innovation equation we estimate is:

(3) $$p_i^* = \alpha_k k_i^* + x_{2i} b_2 + u_{2i}$$

where p_i^* is the latent probability to innovate, k_i^* is the latent research variable, x_{2i} is a vector of other explanatory variables, and u_{2i} is the heterogeneous error term. We assume that the error term is normally distributed with zero mean and constant variance. In contrast to CDM, in two innovation equations, where the regressants are patents and share

[13] In the regressions presented here we do not discriminate between product and process innovations, but include both forms in the indicator variable. As a robustness check, we ran regressions on product and process innovation dummies individually and found no appreciable difference in the results.

of innovative sales, respectively, we estimate (3) using a probit model.[14] The exogenous variables x_{2i} used in the actual estimation are:

$$x_{2i} = (l_i, a_i, T_i, S_i)$$

with the notation the same as above. As suggested by CDM, the market share variable is not included directly into the innovation equation, but only indirectly through research capital. This also helps impose structure on the model and allows us to use market share as an instrument.

Productivity equation. Lastly, we use the results of the previous two stages to augment the standard Cobb-Douglas production function with innovation output. Given the specification of the innovation equation, innovation output will be measured by the probability that firm *i* will innovate in the current period. The productivity equation to be estimated is:

$$q_i = \alpha_I p_i^* + x_{3i} b_3 + u_{3i} \tag{4}$$

where q_i is the logarithm of labor productivity (log value added per employee), while the factors of productivity (other than innovation output) captured in x_{3i} are:

$$x_{3i} = (l_i, c_i, T_i, S_i)$$

where c_i is the logarithm of physical capital per employee. Again, our choice for the regressors in the productivity equation differs from the one suggested by CDM as we do not have data on the shares of engineers and administrators in the total number of employees.

4.2. Estimation issues

In estimating the above system of equations (1)-(4), we first have to take into account the nature of available data: research investment and hence research capital are truncated variables, while innovative outcome is binomial. Furthermore, there are possible selectivity and simultaneity biases stemming from the endogeneity of research capital in the innovation equation, while innovation output is endogenous in the productivity equations.

---

[14] CDM estimate their two innovation equations with pseudo maximum likelihood and ordered probit, respectively.

The setup of the model and the endogeneity issues argue for the use of a simultaneous equations system estimator. CDM find that the joint distribution of observable variables does not have a closed form, while numerical integration seems intractable due to the number of integrals involved and the size of the sample. Although a generalized method of moments estimator (GMM) could have been used, CDM propose using an asymptotic least squares (ALS) estimator[15]. ALS has been shown (Lee, 1982), firstly, to be more efficient than GMM in large samples. Secondly, there is a smaller computational cost (in terms of lost observations) of the estimator. Thirdly, ALS can be easily generalized to more complicated systems, which helps provide a unified and tractable framework for estimating limited dependent variables systems.

4.3. The results

We estimate the CDM approach on Slovenian dataset by estimating the above system of equations (1)-(4) for a single period of observation as well as for the whole period. As results are fairly similar both for all single periods as well as for the whole period 1996-2002, in Table 3 we present only the latter results. In the presentation of results, first two columns of the table show estimates of the two research equations, followed by estimates of the innovation equation and, in the last column, the productivity equation. Although a direct comparison between these results and the findings of CDM is not possible as different specifications were employed, we find that our results are broadly consistent with those in French manufacturing firms. Our results for the whole period are also consistent with those for individual years. We find no statistically significant effect of market share or firm size on the probability to engage in research, but the size of R&D expenditures is found to be positively affected by both variables. The innovation equation reveals that firms with larger R&D investment per employee tend to be more successful at innovating, which is line with the conclusions of CDM. On the other hand, we find that firm size has a beneficial effect on innovative activity, which contradicts the CDM finding that size has no impact on innovation intensity (which they measure by patents or share of innovative sales). The effect of innovation on productivity is again positive and significant. A novelty of our approach is the inclusion of firm age in the analysis. Where in most instances different estimations do not yield conclusive results with respect to the effects of age on either research or innovation, we find that younger firms, other things considered, are more productive than older ones.

---

15 For more on asymptotic least squares, see CDM and Gourieroux and Monfort (1989).

Table 3: Impact of R&D spending and innovation on productivity in Slovenia for the whole sample 1996-2002 [asymptotic least squares estimations]

Model	Research equations		Innovation and productivity equations	
	Probit[a]	Tobit[b]	Innovation[c]	Productivity[d]
R&D investment per employee (k_i)			0.168*** (0.018)	
Probability to innovate (p_i)				0.930*** (0.337)
Market share (s_i)	1.844 (1.283)	4.352*** (2.728)		
Number of employees (l_i)	0.299*** (0.030)	1.829*** (0.106)	0.028*** (0.005)	-0.219*** (0.039)
Export share (exp_i)	0.489*** (0.091)	3.777*** (0.395)	-0.049 (0.027)	0.039 (0.089)
Foreign direct investment (fdi_i)	0.196*** (0.061)	1.183*** (0.314)	0.005 (0.018)	0.231*** (0.052)
Horizontal spillovers (HS_inov_i)	0.034*** (0.010)	0.061*** (0.009)	0.0002 (0.0004)	-0.001 (0.001)
Vertical spillovers (VS_inov_i)	0.143*** (0.016)	0.013 (0.020)	-0.001 (0.001)	0.007*** (0.002)
Physical capital per employee (c_i)				0.231*** (0.008)
Sectoral dummies (S_i)	YES	YES	YES	YES
Time dummies (T_i)	YES	YES	YES	YES
Number of observations (N)	4947	4947	4947	4947

Notes: [a] dependent variable is an indicator variable taking on value 1 if firm *i* invests in research and 0 if it does not
[b] dependent variable is the logarithm of investment in research and development per employee
[c] dependent variable is an indicator variable taking on value 1 if firm *i* has innovated and 0 if it has not (we include both product and process innovation)
[d] dependent variable is logarithm of value added per employee
Robust standard errors in parentheses. *,** and *** denote statistical significance at 10%, 5% and 1% level.

In the next section, we use the probabilities of innovation estimated using the CDM approach as our major explanatory variable of firm performance. We use this variable interchangeably with the CIS variable of innovation activity in order to check for the robustness of results.

5. The impact of innovation activity on firms' productivity growth

With some notable exceptions (see for instance Parisi et al. 2006, Hall et al. 2007) most of the relevant empirical work focuses on the link between innovation and firm productivity levels. We believe that in order to explore the causal relationship between innovative activity and productivity one should instead focus on the impact of successful innovation on firm-level productivity growth.

This section is therefore aimed at exploring the efficiency of innovations regarding firms' total factor productivity (TFP) growth. We apply several empirical specifications and econometric approaches in order to verify the robustness of the link between firms' innovation and productivity growth. First, we estimate the growth accounting model by applying the OLS approach to the data in first differences. We estimate several specification of the empirical model, by including as explanatory variable of particular interest either the R&D capital, innovation variable from the CIS or the estimated probability to innovate as obtained from the CDM approach in the previous section. Second, we refine our empirical model by splitting the sample of firms to the sample of manufacturing and a sample of services firms and continue with splitting both samples into the quintiles of firms by the productivity measure (value added per employee), size (employment) and propensity to research (R&D expenditures relative to sales). We then estimate impact of innovation on TFP growth for each subsample in order to check the robustness of results to the sample of data. Finally, in the third approach we check the robustness of results to the econometric method by using the matching techniques and propensity score to discriminate between innovating and non-innovating firms and to explore whether innovation activity is the decisive factor driving firm productivity growth.

5.1. The effect of innovation on productivity growth using OLS estimations

In the OLS estimations we follow a great body of literature on the contribution of R&D to firms' TFP growth. Typically, a growth accounting approach in the form of a standard Cobb–Douglas production function is used in this type of analysis. We start from the following production function:

(5) $$Y_{it} = Ae^{\lambda t} K_{it}^{\alpha} L_{it}^{\beta} R_{it}^{\gamma} e^{\varepsilon_{it}} ,$$

where Y_{it} is value added in firm i at time t, and K, L, and R represent the capital stock, employment, and research capital used in production, respectively. A is a constant and λ represents the rate of disembodied technical change; e is the error term capturing all firm specific disturbances as well as measurement errors, etc. The production function is homogenous of degree r in K, L, and R, such that $g = \alpha+\beta+\gamma \neq 1$, which implies that Y may have non-constant returns to scale. α, β, and γ are the elasticities of production with respect to capital, labor, and R&D capital. Our main focus is placed on the estimated elasticity γ, which reflects the marginal productivity or rate of return of output to R&D capital.

By log-linearizing we can rewrite (5) in the form of first differences:

(6) $$\Delta y_{it} = \lambda + \alpha \Delta k_{it} + \beta \Delta l_{it} + \gamma \Delta r_{it} + \Delta \varepsilon_{it} .$$

Note that after controlling for standard inputs (labor and capital), the estimate of γ returns the contribution of R&D capital to total factor productivity (TFP) growth. We assume that R&D capital contains a set of factors that enhance innovation activity and are either internal or external to the firm. Hence, one can write *R* as a function of a firm's internal R&D capital $\mathbf{F}_{it}$ and of various spillover effects $\mathbf{Z}_{it}$:

(7) $$R_{it} = f^{i}(\mathrm{F}_{it}, \mathrm{Z}_{it})$$

where $\mathbf{F}_{it}$ contains the firm's own R&D expenditures, measured as a share of R&D expenditures relative to the firm's total sales. $\mathbf{Z}_{it}$ captures spillover effects that enhance the firm's ability to innovate, such as foreign ownership (*IFDI*), learning by exporting (exports to sales ratio, *exp*) as well as innovation spillovers received from other firms within the same sector (*HS_inov*) or from other sectors (*VS_inov*). We basically employ the same formulation of the research capital function (7), i.e. elements of F_{it} and Z_{it}, the same determinants of firms' innovation activity as in the CDM model in the previous section. A dummy variable for services firms is included in our model specification in order to control for differences in TFP growth pattern between manufacturing and services firms. The model also includes time dummies and dummy variables for technology intensity sectors (low tech, medium-low tech, medium-high tech and high tech).

Note that in a panel data framework, equation (5) is typically subject to firm-specific time invariant disturbances, which one can control for by using one of the standard panel data estimation techniques (within or between estimators). Alternatively, one can get rid of firm-specific effects by estimating the equation as in (6), where, by first-differencing the time invariant, firm-specific effects are simply eliminated. Another problem with the time-series cross-section specification of (5) is a potential endogeneity between the inputs and the output, which may lead to a biased estimation of input coefficients. However, in such a short and unbalanced panel dataset with mostly two to three observations per firm, there is little one can do about it. Correcting for this endogeneity, by using either the Olley-Pakes method or general method of moments (GMM) requires longer time series of data.

In the first specification we follow other empirical studies and estimate (6) by including only R&D expenditures (relative to sales) as a measure of R&D capital. This estimate gives us the upper bound of the possible return of output on R&D capital. Indeed, as shown in Table 4 (see column 1), the estimated elasticity of R&D capital with respect to output growth for Slovenian firms in the period 1996-2002 is about 0.15 (but insignificant). This estimate is closer to the lower boundary of returns – which is between 0.04 and 0.56 - found by other empirical studies with a similar model specification.[16]

In our second specification (see column 2) we go one step further by estimating the impact of innovations which is the effective result of R&D on firm TFP growth. This specification returns a significant estimate of the rate of return on innovation (γ) of 0.083. It demonstrates that in an average Slovenian firm innovation results in a bi-annual TFP growth of 8.3%. In addition to this, foreign ownership enhances a firm's TFP growth by an additional 8.8%, but our results also demonstrate that innovations have the same impact on TFP growth both in foreign owned and domestic firms (no significant difference found for the interaction term *INOV*IFDI*). Nevertheless, foreign ownership has a double impact on a firm's TFP growth. As shown by the CDM model in previous section, it first enhances firm's ability to innovate, but then it also contributes additionally to a firm's TFP growth via superior organizational techniques, and so on. Export propensity is also shown to contribute significantly to TFP growth.

From other external spillover variables included in our model, horizontal innovation spillovers seem to have a slightly negative impact on firm TFP growth, while vertical spillovers do not seem to have any direct impact. It is likely that innovation spillovers enhance firm's R&D activity and its ability to innovate but do not affect a firm's TFP growth *per se*. Test of the CDM specification of the research capital creation (see research equation in Table 3,) confirms this only partly showing that both horizontal (intra-industry) and vertical (inter-industry) knowledge spillovers do enhance firm's research capital creation, but do not contribute separately to firm's ability to innovate.

Innovation, as well as export propensity and foreign ownership are, thus, shown to have a positive and significant impact on firm productivity growth. However, it is important to see, first, whether these results are uniform across sectors and, second, whether product and process innovation have a different impact on TFP growth.

[16] See, for instance, Mansfield (1980), Griliches and Mairesse (1983), Clark and Griliches (1984), Sassenou (1988), Lichtenberg and Siegel (19891), Fecher (19890), Griliches and Mairesse (1990), and Griliches (1998).

Table 4: Impact of R&D and innovation on firm's TFP growth of Slovenian firms, 1996-2002 [OLS on first differences]

Type of innovation	(1) R&D	(2) All Inov	(3) All Inov	(4) Product Inov	(5) Process Inov	(6) All	(7) Product Inov	(8) Process Inov
ΔCapital	0.153	0.112	0.144	0.144	0.145	0.154	0.152	0.153
	[8.80]***	[8.68]***	[8.26]***	[8.25]***	[8.30]***	[8.89]***	[8.70]***	[8.71]***
ΔLabor	0.490	0.65	0.475	0.474	0.477	0.489	0.482	0.482
	[14.62]***	[22.24]***	[14.13]***	[14.09]***	[14.19]***	[14.64]***	[14.26]***	[14.26]***
ΔR&D/Sales	0.148							
	[1.11]							
Services dummy	-0.118		-0.105	-0.102	-0.094	-0.144	-0.132	-0.123
	[5.09]***		[3.11]***	[3.05]***	[2.84]***	[5.18]***	[4.49]***	[4.25]***
INOV [a]		0.083	0.053	0.049	0.058			
		[3.34]***	[1.39]	[1.24]	[1.40]			
INOV * Services[a]			0.184	0.178	0.155			
			[2.77]***	[2.54]**	[1.93]*			
p[INOV][b]						0.077	0.079	0.083
						[2.00]**	[1.64]	[1.53]
p[INOV][b] * Services[c]						0.214	0.249	0.227
						[2.48]**	[2.25]**	[1.65]*
IFDI		0.088	0.090	0.081	0.094			
		[3.73]***	[2.80]***	[2.58]**	[3.08]***			
INOV * IFDI		-0.055	-0.051	-0.024	-0.070			
		[1.32]	[0.90]	[0.41]	[1.13]			
EX/Sales		0.139	0.081	0.080	0.086			
		[5.31]***	[2.07]**	[2.05]**	[2.22]**			
HS_INOV		-0.002	-0.002	-0.002	-0.002			
		[2.85]***	[2.17]**	[2.19]**	[2.21]**			
VS_INOV		0.002	0.001	0.001	0.001			
		[1.21]	[0.58]	[0.57]	[0.52]			
Medium low tech		0.025	0.065	0.067	0.064			
		[0.82]	[1.42]	[1.46]	[1.41]			
Medium high tech		0.102	0.136	0.137	0.140			
		[3.20]***	[3.04]***	[3.05]***	[3.13]***			
High tech		-0.069	-0.015	-0.014	-0.009			
		[1.92]*	[0.27]	[0.26]	[0.17]			
Const.	0.093	-0.016	0.011	0.012	0.016	0.075	0.075	0.077
	[6.02]***	[0.55]	[0.27]	[0.29]	[0.39]	[3.86]***	[3.64]***	[3.78]***
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs	4318	4146	4171	4171	4171	4171	4171	4171
Adj R-sq.	0.08	0.19	0.10	0.10	0.10	0.09	0.08	0.08

Dep.var.: ΔValue added. [a] Innovation variable taken from CIS. [b] Probabilities to innovate obtained by the CDM approach. [c] NACE codes 38-74. *, ** and *** denote significance of coefficients at the 10%, 5% and 1%, respectively.

In the third specification (see column 3) we introduce a dummy for services sectors, what produces two interesting results. First, after including a dummy for services sector the general impact of innovation (γ) drops considerably (to 0.053) and becomes insignificant. And second, while services firms are shown to increase TFP at a slower pace (by some 10 percentage points) than manufacturing firms, this changes dramatically when interacting services dummy with the innovation variable (*INOV*Services*). Results show that innovating services firms do increase TFP at some 18 percentage points faster than non-innovating services firms. Similar results are obtained when controlling for product or process innovation (see specifications 4 and 5). We find that both product as well as process innovations are shown to boost the productivity growth of services firms (by 17.8 and 15.5 per cent, respectively), while neither of the two seems to have a significant impact on TFP growth of manufacturing firms.

As a robustness check we replicate above estimation by using the estimated probabilities to innovate from the CDM model (instead of innovation indicators from the CIS) where the research capital equation and innovation equation are estimated simultaneously. Note that explanatory variables in this system of equations are the same as those used as additional covariates in the above OLS estimations of the impact of innovation on TFP growth. Results including the estimated probabilities to innovate from the CDM model (see columns 6 - 8 in Table 4) show a statistically significant and larger estimate of the return on innovation (the estimate of γ increases to 0.077) as compared to 0.053 in the specification (3). Separate estimations for impact of product and process innovation on firm TFP growth gives (both marginally insignificant) slightly higher coefficients of γ (0.079 and 0.083 for product and process innovations, respectively). Again, product and process innovations in the services firms are found to have substantial impact on individual firm's TFP growth. Innovating services firms increase their TFP by 23% (process innovations) to 25% (product innovations) as compared to non-innovating services firms. Innovations apparently pay off considerably for services firms.

5.2. Robustness check 1: OLS estimations on sub samples of firms

The results presented so far do not provide a conclusive evidence on the general impact of innovations on firm TFP growth. The evidence seems to point towards significant impact for services firms, but no significant impact for manufacturing firms. Let us explore further on this by splitting both samples of manufacturing and services firms to smaller sub samples of more homogenous firms. Estimating above empirical model on larger samples of quite heterogeneous firms – although controlling for their broader sectoral classification and technology intensity –hides a large portion of variation within the sample. Therefore, we split our samples of manufacturing and services firms to the quintiles of firms by the productivity measure (value added per employee), size (employment) and propensity to research (R&D expenditures relative to sales) and then estimate impact of innovation on TFP growth for each subsample. By doing so we try to uncover relationship between innovation and TFP growth for smaller and larger firms, for less productive and more productive firms, and for firms which have different propensity to R&D.

Table 5 reports the results obtained by estimating our empirical model on quintiles of firms by their key characteristics – productivity, size and R&D propensity. Note that we estimate the fully specified model (specification 3) with the CIS reported innovation (product or process) as our main explanatory variable. The results demonstrate, that – even after allowing for variation within the sample in terms of productivity, size and R&D propensity – neither product nor process innovations are shown to impact TFP growth of Slovenian manufacturing firms. The second quintile of R&D propensity is the only sub sample where manufacturing firms with product innovations are found to grow faster in terms of TFP relative to their non-innovating counterparts. In no other sub sample a significant relationship between either type of innovation activity and TFP growth has been detected.

Table 5: Impact of innovation on TFP growth of Slovenian firms, by sub samples of firms according to quintiles of productivity, size and R&D propensity, 1996-2002 [OLS on first differences]

Manufacturing firms (NACE 15-37)

	Productivity quintiles					
Innovation type[a]	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Product or process	0.034	-0.039	-0.031	-0.020	-0.008	0.043
	[1.25]	[0.35]	[0.64]	[0.39]	[0.20]	[0.74]
Product	0.031	-0.053	-0.023	-0.034	0.008	0.061
	[1.09]	[0.47]	[0.46]	[0.63]	[0.19]	[1.02]
Process	0.024	-0.091	-0.082	0.015	-0.010	0.048
	[0.82]	[0.76]	[1.54]	[0.28]	[0.24]	[0.80]

	Size quintiles					
Innovation type	All	Q1	Q2	Q3	Q4	Q5
Product or process	0.034	0.049	0.005	0.050	0.059	-0.023
	[1.25]	[0.31]	[0.05]	[0.89]	[1.30]	[0.45]
Product	0.031	0.004	0.026	0.044	0.053	-0.019
	[1.09]	[0.02]	[0.26]	[0.75]	[1.14]	[0.37]
Process	0.024	0.155	-0.046	0.051	0.053	-0.043
	[0.82]	[0.74]	[0.41]	[0.83]	[1.10]	[0.84]

	R&D/Sales quintiles					
Innovation type	All	Q1	Q2	Q3	Q4	Q5
Product or process	0.041	0.275	0.157	-0.323	-0.473	0.344
	[0.28]	[1.05]	[0.57]	[0.89]	[1.12]	[0.74]
Product	0.023	0.028	0.336	-0.228	-0.001	0.063
	[0.35]	[0.21]	[2.15]**	[1.50]	[0.01]	[0.34]
Process	-0.002	0.191	-0.080	0.012	-0.043	0.205
	[0.04]	[1.19]	[0.71]	[0.11]	[0.45]	[1.60]

Services firms (NACE 38-74)

	Productivity quintiles					
Innovation type[a]	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Product or process	0.161	0.102	0.033	-0.130	0.340	-0.027
	[2.96]***	[0.45]	[0.27]	[1.32]	[3.89]***	[0.27]
Product	0.140	0.168	0.062	-0.130	0.313	-0.102
	[2.40]**	[0.69]	[0.47]	[1.32]	[3.28]***	[0.96]
Process	0.206	-0.025	0.120	-0.118	0.363	0.081
	[3.06]***	[0.09]	[0.72]	[0.99]	[3.35]***	[0.69]

	Size quintiles					
Innovation type	All	Q1	Q2	Q3	Q4	Q5
Product or process	0.161	0.078	0.087	0.052	0.214	0.113
	[2.96]***	[0.45]	[0.39]	[0.55]	[2.15]**	[1.29]
Product	0.140	-0.068	0.084	0.011	0.268	0.103
	[2.40]**	[0.34]	[0.37]	[0.11]	[2.64]***	[1.06]
Process	0.206	0.046	0.220	0.077	0.224	0.141
	[3.06]***	[0.21]	[0.72]	[0.72]	[1.66]*	[1.28]

	RD/S quintiles					
Innovation type	All	Q1	Q2	Q3	Q4	Q5
Product or process	0.176	0.294	0.122	-0.236	0.901	
	[0.80]	[0.56]	[0.44]	[0.32]	[1.87]*	
Product	-0.064	0.111	-0.02	-0.314	0.059	-0.586
	[0.49]	[0.25]	[0.09]	[1.03]	[0.22]	[0.72]
Process	0.093	-0.711	0.208	-0.110	0.059	-0.048
	[0.82]	[0.44]	[1.12]	[0.33]	[0.32]	[0.17]

Dep.var.: Δ Value added. [a] Innovation variable taken from CIS. *, ** and *** denote significance of coefficients at the 10%, 5% and 1%, respectively.

The results in Table 5 indicate that the overall positive impact of innovation of Slovenian firms is driven by a very specific group of services firms. More specifically, we find that it is the services firms in the fourth quintile – measured either by the size, productivity or R&D propensity – that reveal higher TFP growth due to innovation activity. This is somehow at odds with our expectations as we would expect this to be a more general case in the sense that medium or large sized firms, most productive firms or firms with the highest R&D expenditures to sales would be the front runners in innovation and would experience the highest impact on productivity growth. It seems that firms just below the top have the highest potential in increasing productivity and are capable of using innovations most efficiently.

5.3. Robustness check 2: The effect of innovation on productivity growth using quantile regressions

Finally, we further explore the lack of a relationship between innovative activity and productivity growth in manufacturing firms by employing quantile regressions. This approach will give us a more comprehensive picture of the effects of firm characteristics (including innovative success) on productivity growth.

Standard linear regression models (such as OLS) rely heavily on the presumption of normality of the error distribution. In cases when the error distribution is not normal, i.e. has thicker tails, is asymmetric or multimodal, OLS does not provide robust results. In our case there are a number of other possible sources of firm heterogeneity impacting productivity growth that cannot be easily observed and accounted for[17]. These unobserved variables may cause the dependent variable and the error term to be independently but not identically distributed across firms, rendering ordinary least squares estimates inefficient. Furthermore, OLS regressions provide information only about the conditional mean of the explanatory variable disregarding higher moments of the distribution. Higher moments of the distribution may namely play an important role as the covariates may also affect the shape of the distribution not only its position or scale.

Quantile regression estimates, on the other hand, are more robust relative to OLS when the error distribution departs from the assumed normality. In addition, unlike OLS, quantile regressions place much less weight on outliers while also providing information on the shape of the distribution not only its position. Namely, while OLS only provides information on the conditional mean of the distribution, the quantile regressions give

[17] Such as managerial and entrepreneurial ability, idiosyncratic shocks, tehcnology uncertainties etc.

parameter estimates for different quantiles of the distribution. Following Koeneker and Basset (1978) and Yasar et al. (2006), quantile regressions can be described as follows

(8) $$\mathbf{y} = \mathbf{x}_{it}'\boldsymbol{\beta} + \mathbf{u}_{it} \text{ with } Q_\theta(\mathbf{y}_{it}/\mathbf{x}_{it}) = \mathbf{x}_{it}'\boldsymbol{\beta}$$

Where **y** is the output vector, **x** is a vector of all regressors, $\boldsymbol{\beta}$ is the vector of parameter estimates and **u** a vector of residuals. $Q_\theta(\mathbf{y}_{it}/\mathbf{x}_{it})$ denotes the θ^{th} conditional quantile of $\mathbf{y}_{it}$ given $\mathbf{x}_{it}$. The θ^{th} regression quantile solves the following minimization problem

(9) $$\min_\beta \frac{1}{n}\left\{\sum_{i,t:y_{it}\geq\beta x_{it}} \theta\,|y_{it} - x_{it}'\beta| + \sum_{i,t:y_{it}<\beta x_{it}} (1-\theta)\,|y_{it} - x_{it}'\beta|\right\}$$

Continuous changes of θ (0<θ<1) allow one to obtain any quantile of the distribution of $\mathbf{y}_{it}$ conditional on $\mathbf{x}_{it.}$ These changes relax the OLS assumption that parameter estimates are the same across the distribution. Linear programming methods are used to solve the above problem of minimizing the weighted sum of absolute deviations. This technique thus provides information on the variation of the impact of regressors on the dependent variable at different quantiles. The specific coefficient estimates can then be interpreted as marginal changes in *y* at θ^{th} quantile due to the marginal change in a particular regressor.

We estimate an analogue of equation 6 for manufacturing firms only using quantile regressions and present the parameter estimates in Table 6. In contrast with (6) we forego measures of spillovers and add measures of geographical concentration of exports (share of exports to former Yugoslav republics and share of exports to EU markets). Share of exports to the markets of former Yugoslavia and the share of exports to the European Union countries serves to illustrate exposure to different competitive pressures. On one hand, markets of the former Yugoslav republics represent the first (and easiest) option for Slovenian manufacturing exports with low competitive pressures and relatively high markups. On the other hand, markets of EU countries are characterized by much stiffer competition and subsequently lower markups on average. Each of the deciles of the productivity growth distribution is estimated separately, with OLS estimates serving as a benchmark.

Table 6: Effect of innovation on growth in value added per employee using quantile regressions (manufacturing firms only)

	OLS	1st decile	2nd decile	3rd decile	4th decile	5th decile	6th decile	7th decile	8th decile	9th decile
Δln(employment)	-0.169***	-0.292***	-0.258***	-0.25***	-0.205***	-0.222***	-0.193***	-0.203***	-0.13**	-0.109
	[0.039]	[0.079]	[0.039]	[0.026]	[0.022]	[0.019]	[0.026]	[0.032]	[0.054]	[0.083]
Δln(capital per emp)	0.328***	0.257***	0.243***	0.248***	0.268***	0.258***	0.249***	0.249***	0.294***	0.299***
	[0.033]	[0.064]	[0.034]	[0.023]	[0.019]	[0.017]	[0.022]	[0.026]	[0.044]	[0.065]
ln(R&D expenditure per emp)	0	-0.007	-0.005	-0.004	-0.004	-0.003	0	0	-0.002	0.005
	[0.006]	[0.009]	[0.005]	[0.004]	[0.003]	[0.003]	[0.004]	[0.004]	[0.006]	[0.008]
$Inov_t$	0.007	0.113**	0.065**	0.048**	0.027	0.016	-0.009	-0.016	-0.027	-0.115***
	[0.030]	[0.046]	[0.027]	[0.019]	[0.017]	[0.015]	[0.019]	[0.022]	[0.032]	[0.044]
Exp_t	0.014	0.139*	0.079*	0.016	-0.03	-0.041	-0.019	-0.013	-0.075	-0.073
	[0.052]	[0.079]	[0.046]	[0.033]	[0.030]	[0.026]	[0.033]	[0.039]	[0.059]	[0.075]
Ex share (form YU)	-0.072*	-0.04	-0.101***	-0.065**	-0.054**	-0.042**	-0.051*	-0.028	-0.035	-0.091
	[0.040]	[0.064]	[0.038]	[0.027]	[0.023]	[0.020]	[0.026]	[0.031]	[0.047]	[0.061]
Ex share (EU)	-0.045	0.008	-0.038	-0.008	-0.004	-0.012	-0.026	-0.021	-0.046	-0.103*
	[0.039]	[0.062]	[0.037]	[0.026]	[0.023]	[0.020]	[0.026]	[0.030]	[0.045]	[0.057]
Foreign ownership	0.055**	0.059*	0.045**	0.034**	0.03**	0.035***	0.032**	0.042**	0.073***	0.054*
	[0.022]	[0.032]	[0.019]	[0.014]	[0.012]	[0.011]	[0.014]	[0.016]	[0.024]	[0.030]
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	3020	3020	3020	3020	3020	3020	3020	3020	3020	3020
Pseudo R-sq	0.122^{+}	0.0887	0.0727	0.068	0.067	0.063	0.0664	0.0663	0.0707	0.0883

Dependant variable: Δln (value added per employee)
Notes: robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%
$^{+}$ adjusted R-square
The P-value for the joint skewness and kurtosis tests is <0.001 indicating that the errors are not normally distributed
A

Table 6 reveals that smaller and more capital intensive firms experience faster productivity growth regardless of where they are situated on the distribution of productivity growth. Perhaps surprisingly, the level of R&D expenditure per employee has no significant effect on productivity growth, while exporting status positively impacts productivity growth only for the first two deciles i.e. slowest growing firms. Crucially, successful innovation is found to have a significant positive impact on productivity growth for firms in the first three deciles of productivity growth. The remaining quantiles exhibit either no significant impact of innovation or, as is the case with the 9th decile, a significant negative effect of innovation on productivity growth. These results imply that only firms with below average productivity growth are likely to experience significant benefits from successful innovation, while faster growing firms do not extract any additional benefits from innovation. As we show in Appendix B, discriminating between product and process innovation fully confirms these findings as the slowest growing firms are shown to benefit both from product and process innovation in contrast to those that experienced faster productivity growth. Unsurprisingly, OLS estimates show no significant relationship between innovation and productivity growth as they only describe the effect of innovation on the sample mean of productivity growth. The other reason for the observed differences between quantile regressions and OLS lies in the fact that the lower decile estimates in quantile regressions give low weights to right-tail outliers, while OLS estimates depend more heavily on those outliers. As faster growing firms (in the right tail of the productivity growth distribution) exhibit no significant relationship between successful innovation and productivity growth OLS estimates subsequently also reveal no significant correlation. Additionaly, joint skewness and kurtosis tests on either productivity growth or OLS residuals reject normality at $P<0.001$, warranting the implementation of quantile regressions instead of OLS.

Higher shares of exports to former Yugoslav countries show a significant negative impact on productivity growth both in OLS and lower decile (first 6 deciles) estimates indicating that for all but the fastest growing firms increased involvement in former Yugoslavia relates to slower productivity growth. In contrast, no such evidence apart from the 9th decile is found for the share of exports to the EU.

6. Conclusions

The paper analyses the impact of innovation on firms' productivity growth using firm-level innovation (CIS) and accounting data for a large sample of Slovenian firms from 1996-2002. In addition to traditional regression approaches we also apply Crépon-Duguet-Mairesse (CDM) estimation algorithm to control for endogeneity. We also distinguish between product and process innovations.

OLS estimates seem to provide some empirical support to the thesis of positive impact of innovation on productivity growth. Both the innovation variables from CIS as well as probabilities to innovate estimated using the system of research capital equation and innovation equation indicate that more innovating firms increase productivity at a faster pace than non-innovating firms. Refinements of the empirical tests allowing for sectoral differences and within sector heterogeneity, however, reveal that above results are mainly due to the exceptional performance of a specific group of services firms. It is shown that it is medium sized, more (but not the most) productive firms and firms with high (but not the highest) R&D expenditures to sales in the services sectors which are the frontrunners in innovation, which demonstrate the highest potential in increasing productivity and are capable of using innovations the most efficiently. Separate estimations for product and process innovations show no significant differences.

The overall conclusion is that the results of the exercise are not robust to different econometric approaches. There are several possible reasons why our analysis has not yielded the expected positive relationship between innovative activity and productivity growth. In our opinion, the primary reason for these results lies in the quality of the survey data, primarily with regard to the definition of innovation. Simple indicator of conducting at least one (product or process) innovation in the past two years may not indicate firm's true innovativeness in a satisfactory way. An indicator pointing out number of innovations conducted would be more informative. Similarly, a longer series of information about the share of sales obtained through innovated products and services would be of extreme importance. Secondly, we do not have the information on the exact time of innovation, as innovative activity could happen in either of the two years between surveys. Finally, it may be the case that a longer time series is required to capture the full effects of innovation

References

Aghion, P. and Howitt, P., 1992. A Model of Growth through Creative Destruction. Econometrica. 60, 323-351.

Bartelsman, E.J., van Leeuwen, G., and Nieuwenhuijsen, H.R., 1998. Adoption of Advanced Manufacturing Technology and Firm Performance in the Netherlands. Economics of Innovation and New Technology, 6, 291-312.

Benavente, J. M., 2006. The role of research and innovation in promoting productivity in Chile. Economics of Innovation and New Technology. 15, 301-315.

Cincera, M., 1998. Technological and economic performances of international firms. PhD Thesis. Belgium: Universite ́Libre de Bruxelles. Available on: http://homepages.ulb.ac.be/~mcincera/.

Clark, B. and Griliches, Z., 1984. Productivity and R&D at the firm level in French manufacturing. In: Z. Griliches (ed.), R&D, patents, and productivity. University of Chicago Press, Chicago, pp. 393-416.

Cohen, W. and Levinthal, D., 1989. Innovation and learning: The two faces of R&D. Economic Journal. 99, 569-596.

Crépon, B., Duguet, E., and Mairesse, J., 1998. Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level. National Bureau of Economic Research. Working Paper 6696.

Criscuolo, C. and Haskel, J., 2002. Innovations and productivity growth in the UK, CeRiBa discussion paper.

Cunéo, P. and Mairesse, J., 1984. Productivity and R&D at the firm level in French manufacturing. In Z. Griliches (ed.), *R&D,* Patents and Productivity. University of Chicago Press, Chicago, pp. 375–392.

Damijan, J., Jaklič, A., and Rojec, M., 2006. Do External Knowledge Spillovers Induce Firms' Innovations? Evidence from Slovenia. In Tavares, A.T. and Teixeira, A. (eds.), Multinationals, Clusters and Innovation: Does Public Policy Matter? Palgrave, Basingstoke, pp. 27-47.

Duguet, E., 2000. Knowledge diffusion, technological innovation and TFP growth at the firm level: Evidence from French manufacturing. EUREQua 2000. 105.

Duguet, E. and Monjon, S., 2002. Creative Destruction and the Innovative Core: Is Innovation Persistent at the Firm Level? UCL Discussion Paper 02-07.

Fecher, F., 1990. Effects Directs et Indirects de la R&D sur la Productivité: une analyse de l'Industrie Manufacturière Belge. Cahiers Économiques de Bruxelles. 128, 459-83.

Gourieroux, C. and Monfort, A., 1989. Statistics and Econometric Models. Cambridge University Press, Cambridge.

Griffith, R., Huergo, E., Mairesse, J., and Peters, B., 2006. Innovation and productivity across four European Countries. Oxford Review of Economic Policy. 22, 483-498.

Griliches, Z., 1979. Issues in Assessing the Contribution of R&D to Productivity Growth. Bell Journal of Economics. 10, 92-116.

Griliches, Z., 1980. Returns to R&D expenditures in the private sector. In K. Kendrick and B. Vaccara (eds.), New Developments in Productivity Measurement. Chicago University Press, Chicago, pp. 419-454.

Griliches, Z., 1986. Productivity, R&D and basic research at the firm level in the 1970s. American Economic Review. 76, 141–154.

Griliches, Z., 1992. The Search for R&D spillovers. Scandinavian Journal of Economics, 94, 29-47.

Griliches, Z., 1998. R&D and Productivity. University of Chicago Press, Chicago.

Griliches, Z. and Mairesse, J., 1983. Comparing productivity growth: an exploration of French and US industrial and firm data. European Economic Review. 21, 89–119.

Griliches, Z. and Mairesse, J., 1984. Productivity and R&D at the firm level. In Griliches, Z. (ed.), R&D, Patents and Productivity. University of Chicago Press, Chicago, pp. 339–374.

Griliches, Z. and Mairesse, J., 1990. R&D and productivity growth: comparing Japanese and US manufacturing firms. In Hulten, C. (ed.), Productivity Growth in Japan and the United States. University of Chicago Press, Chicago, pp. 317–340.

Hall, B. and Mairesse, J., 1995. Exploring the relationship between R&D and productivity in French manufacturing firms. Journal of Econometrics. 65, 263-294.

Hall, B. and Mairesse, J., 2006. Empirical studies of innovation in the knowledge-driven economy. Economics of Innovation and New Technology. 15, 289-299.

Hall, B., Lotti, F., and Mairesse, J., 2007. Employment, Innovation, and Productivity: Evidence from Italian Microdata. National Bureau of Economic Research. Working Paper 13296.

Harrison, R., Jaumandreu, J., Mairesse, J., and Peters, B., 2005. Does Innovation Stimulate Employment? A Firm-Level analysis Using Comparable Micro Data from four European Countries. Mimeo, Department of Economics, University Carlos III, Madrid.

Janz, N., Lööf, H., and Peters, B., 2004. Firm level Innovation and Productivity: Is there a Common Story?, Problems and perspectives in management. 2, 184-204.

Jefferson, G., Huamao. B., Xioajing. G. and Xiaoyun. Y., 2002. Research and Development Performance in Chinese Industry. Economics of Innovation and New Technology. 15, 345-366.

Klomp, L. and van Leeuwen, G., 2001. Linking innovation and firm performance: A new approach. International Journal of the Economics of Business. 8, 343–364.

Koenecker, R. And Basset G., 1978. Regression Quantiles. Econometrics, 46, 33-50.

Lee, L.F., 1982. Simultaneous Equation Models with Discrete and Censored Dependent Variables. International Economic Review. 23, 199-221.

Levinsohn, J. and Petrin, A., 2003. Estimating Production Functions Using Inputs to Control for Unobservables. Review of Economic Studies. Blackwell Publishing, 70, 317-341.

Lichtenberg, F.R. and Siegel, D., 1991. The Impact of R&D Investment on Productivity – New Evidence Using Linked R&D-LRD Data. Economic Inquiry, 29, 203-229.

Link, A.N., 1981. Research and development activity in U.S. manufacturing. Preager, New York.

Link, A.N., 1983. Inter-firm technology flows and productivity growth. Economic Letters. 11, 179–184.

Lööf, H. and Heshmati, A., 2006. On the relationship between innovation and performance: A sensitivity analysis. Economics of Innovation and New Technology, 15, 317-344.

Lööf, H., Heshmati, Apslund, A., R., and Nås, S.O., 2002. Innovation and performance in manufacturing firms: A comparison of the Nordic countries. International Journal of Management Research. 5-36.

Mairesse, J. and Hall, B.H., 1996. Estimating the productivity of research and development: an exploration of GMM methods using data on French and United States manufacturing firms. NBER Working Paper No. 5501.

Mairesse, J. and Mohnen, P., 1995. R&D and productivity: a survey of the econometric literature. Institut National de la Statistique et des Etudes Economiques (INSEE). Paris, Mimeograph.

Malerba, F. and Orenigo, L., 1996. The dynamics and evolution of industries, Industrial and Corporate Change. 5, 51-87.

Manez Castillejo, J.A., Rochina Barrachina, M.E., Sanchis Llopis, A., and Sanchis Llopis, J.A., 2004. A Dynamic Approach to the Decision to Invest in R&D: The Role of Sunk Costs. mimeo.

Mansfield, E., 1980. Basic research and productivity increase in manufacturing. American Economic Review. 70, 863–873.

Mohnen, P., 2006. What drives productivity growth in Tanzania: Technology or institutions? Presented at the Blue Sky II Forum, Ottawa, Canada.

Mohnen, P., Mairesse, J., and Dagenais, M., 2006. Innovativity: A comparison across seven European countries. Economics of Innovation and New Technology. 15, 391-413.

Mohnen, P. and Therrien, P., 2003. Comparing the innovation performance of manufacturing firms in Canada and in selected European countries: An econometric analysis", in Gault, F., ed., *Understanding Innovation in Canadian Industry*, McGill-Queens University Press, Montreal, pp. 313-339.

Nadiri, M.I., 1991. *Innovation and technological spillovers*, Mimeo, New York University.

O'Mahoney, M. and Vecchi, M., 2000. Tangible and intangible investment and economic performance: evidence from company accounts. In Buigues, P., Jacquemin, A., and Marchipont, J.-F., (eds.), Competitiveness and the Value of Intangible Assets. Edward Elgar, Cheltenham, pp. 199–227.

Pakes, A. and Griliches, Z., 1984. Patents and R&D at the firm level: A first look. In Griliches, Z. (ed.). R&D, Patents and Productivity, University of Chicago Press, Chicago, pp. 55-72.

Peters, B., 2005. Persistence of innovation: Stylised facts and panel data evidence, Discussion paper 05-81, ZEW.

Parisi, M.L., Schiantarelli, F., and Sembenelli, A., 2006. Productivity, innovation and R&D: Micro evidence for Italy. European Economic Review. 50, 2037-2061.

Raymond, W., Mohnen, P.A., Palm, F., Schim van der Loeff, S., 2006. Persistence of innovation in Dutch manufacturing: Is it spurious?, Cirano Scientific Series 2006s-04.

Romer, P., 1990. Endogenous Technological Change. Journal of Political Economy. 98, S71-S102.

Sassenou, M., 1988. Recherche-developpment et productivity dans les enterprizes Japonaises: Une etude econometrique sur donnees de panel, Doctoral Dissertation, Ecole des Hautes Etudes en Sciences Sociales, Paris.

Schankerman, M., 1981. The effects of double-counting and expensing on the measured returns to R&D. Review of Economics and Statistics. 63, 454–458.

Smolny, W., 2000. Endogenous Innovations and Knowledge Spillovers. Heidelberg: Physica-Verlag.

Solow, R. M., 1957. Technical change and the aggregate production function. Review of Economics and Statistics. 39, 312-320.

Van Leeuwen, G. and Klomp, L., 2006. On the contribution of innovation to multi- factor productivity growth., Economics of Innovation and New Technology. 15, 367-390.

Yasar M., Nelson C. H., and Rejesus R., 2006. Productivity and Exporting Status of Manufacturing Firms: Evidence from Quantile Regressions. Review of World Economics, 142, 675-694.

Wieser, R., 2005. Research and development productivity and spillovers: Empirical evidence at the firm level. Journal of Economic Surveys. 19, 587-621.

Appendix A

Table B1: Changes in employment in firms conducting product and process innovations in 1996 – 2002, by size classes*

		Product and process innov.				Process innovators only				Product innovators only			
		-1	0	1	2	-1	0	1	2	-1	0	1	2
0<x<10	change in employ.	1.0	0.4	0.1	-27.0	1.0	0.7	-10.4	-1.2	0.9	-4.1	-0.6	-8.5
	number of firms	38	82	7	10	5	3	5	5	41	23	12	16
10<x<50	change in employ.	2.5	2.0	-2.9	-6.3	1.4	0.3	1.7	-6.2	1.2	1.4	-2.4	0.2
	number of firms	216	204	99	121	45	43	22	28	176	173	105	126
50<x<250	change in employ.	2.8	1.1	-8.0	-0.8	-0.3	0.7	-25.0	-1.8	0.3	-1.9	0.9	-2.2
	number of firms	401	264	148	278	52	78	31	36	185	162	119	148
x>250	change in employ.	-8.5	-10.8	-12.9	-13.2	-5.4	-34.0	-6.2	-9.2	-1.3	-11.8	-1.2	-9.5
	number of firms	302	171	70	215	30	25	16	21	94	81	57	68

Notes: *Change in number of employees calculated as mean of changes at the firm level in respective size class.Source: SURS, own calculations.

Appendix B

Table B1: Effect of product innovation on growth in value added per employee using quantile regressions (manufacturing firms only)

	OLS	1st decile	2nd decile	3rd decile	4th decile	5th decile	6th decile	7th decile	8th decile	9th decile
Δln(employment)	-0.169***	-0.295***	-0.254***	-0.251***	-0.205***	-0.224***	-0.201***	-0.205***	-0.119**	-0.106
	[0.039]	[0.085]	[0.040]	[0.026]	[0.023]	[0.020]	[0.024]	[0.030]	[0.052]	[0.093]
Δln(capital per emp)	0.329***	0.254***	0.249***	0.253***	0.269***	0.256***	0.247***	0.248***	0.29***	0.289***
	[0.033]	[0.070]	[0.034]	[0.023]	[0.020]	[0.017]	[0.020]	[0.025]	[0.042]	[0.073]
ln(R&D exp per	0	-0.003	-0.005	-0.005*	-0.003	-0.002	0	-0.001	-0.005	0
	[0.005]	[0.008]	[0.005]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.005]	[0.008]
Product $Inov_t$	0.01	0.099**	0.067***	0.056***	0.028*	0.011	-0.01	-0.013	-0.014	-0.095**
	[0.027]	[0.041]	[0.025]	[0.018]	[0.016]	[0.014]	[0.016]	[0.019]	[0.028]	[0.043]
Exp_t	0.014	0.143*	0.1**	0.015	-0.03	-0.038	-0.014	-0.016	-0.084	-0.076
	[0.052]	[0.085]	[0.044]	[0.033]	[0.031]	[0.027]	[0.031]	[0.036]	[0.056]	[0.083]
Ex share (form YU)	-0.072*	-0.05	-0.108***	-0.067**	-0.051**	-0.041*	-0.05**	-0.027	-0.045	-0.074
	[0.040]	[0.069]	[0.039]	[0.027]	[0.024]	[0.021]	[0.024]	[0.029]	[0.045]	[0.069]
Ex share (EU)	-0.044	0.003	-0.045	-0.011	-0.003	-0.01	-0.026	-0.019	-0.056	-0.095
	[0.039]	[0.067]	[0.038]	[0.026]	[0.023]	[0.021]	[0.023]	[0.028]	[0.043]	[0.065]
Foreign ownership	0.055**	0.056*	0.045**	0.039***	0.03**	0.033***	0.033***	0.041***	0.07***	0.062*
	[0.021]	[0.034]	[0.019]	[0.014]	[0.013]	[0.011]	[0.013]	[0.015]	[0.023]	[0.033]
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	3020	3020	3020	3020	3020	3020	3020	3020	3020	3020
Pseudo R-sq	0.1230+	0.0883	0.0734	0.0685	0.067	0.0672	0.0664	0.0663	0.0705	0.0877

Dependant variable: Δln (value added per employee)

Notes: robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

+ adjusted R-square

The P-value for the joint skewness and kurtosis tests is <0.001 indicating that the errors are not normally distributed

Table B2: Effect of process innovation on growth in value added per employee using quantile regressions (manufacturing firms only

	OLS	1st decile	2nd decile	3rd decile	4th decile	5th decile	6th decile	7th decile	8th decile	9th decile
Δln(employment)	-0.169***	-0.266	-0.258	-0.262	-0.206	-0.224	-0.194	-0.203	-0.133	-0.098
	[0.039]	[0.079]**	[0.041]**	[0.031]**	[0.023]**	[0.021]**	[0.025]**	[0.033]**	[0.051]**	[0.097]
Δln(capital per emp)	0.328***	0.249	0.243	0.243	0.269	0.256	0.247	0.247	0.295	0.305
	[0.033]	[0.065]**	[0.035]**	[0.027]**	[0.020]**	[0.018]**	[0.021]**	[0.027]**	[0.041]**	[0.076]**
ln(R&D exp per	-0.001	0	-0.002	-0.001	-0.002	-0.002	-0.001	-0.002	-0.002	-0.005
	[0.004]	[0.006]	[0.004]	[0.003]	[0.002]	[0.002]	[0.003]	[0.003]	[0.004]	[0.006]
Process $Inov_t$	0.021	0.087	0.048	0.035	0.023	0.011	-0.004	-0.008	-0.034	-0.07
	[0.023]	[0.034]**	[0.021]**	[0.017]**	[0.014]*	[0.012]	[0.014]	[0.017]	[0.024]	[0.036]**
Exp_t	0.013	0.166	0.069	0.022	-0.044	-0.038	-0.014	-0.015	-0.079	-0.091
	[0.052]	[0.074]**	[0.049]	[0.038]	[0.030]	[0.027]	[0.032]	[0.040]	[0.056]	[0.087]
Ex share (form YU)	-0.071*	-0.048	-0.1	-0.065	-0.043	-0.041	-0.051	-0.03	-0.048	-0.082
	[0.040]	[0.063]	[0.039]**	[0.031]**	[0.024]*	[0.021]*	[0.025]**	[0.031]	[0.044]	[0.073]
Ex share (EU)	-0.044	0.018	-0.037	-0.003	-0.002	-0.012	-0.025	-0.025	-0.06	-0.095
	[0.039]	[0.061]	[0.038]	[0.030]	[0.023]	[0.021]	[0.024]	[0.030]	[0.042]	[0.069]
Foreign ownership	0.055***	0.059	0.044	0.038	0.034	0.035	0.033	0.04	0.067	0.072
	[0.021]	[0.032]*	[0.020]**	[0.016]**	[0.013]**	[0.011]**	[0.013]**	[0.017]**	[0.023]**	[0.035]**
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	3020	3020	3020	3020	3020	3020	3020	3020	3020	3020
Pseudo R-sq	0.1232^{+}	0.0885	0.0722	0.0676	0.067	0.0672	0.0664	0.0663	0.0711	0.0883

Dependant variable: Δln (value added per employee)

Notes: robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

$^{+}$ adjusted R-square

The P-value for the joint skewness and kurtosis tests is <0.001 indicating that the errors are not normally distributed

PUBLISHED PAPERS IN THE SERIES

1. Lado Rupnik: **THE NEW TAX SYSTEM IN SLOVENIA**, IER, Ljubljana, 1993, 16 p.
2. Franc Kuzmin: **SOME DILEMMAS IN THE THEORY OF COST-PUSH INFLATION – SLOVENIAN CASE**, IER, Ljubljana, 1993, 17 p.
3. Miroslav Glas: **SLOVENE SMALL BUSINESS**, IER, Ljubljana, 1993, 26 p.
4. Tine Stanovnik: **SOCIAL SECURITY IN SLOVENIA**, IER, Ljubljana, 1993, 14 p.
5. Peter Stanovnik, Ivo Banič: **THE ROLE OF FDIs IN SLOVENIA'S ECONOMIC DEVELOPMENT**, IER, Ljubljana, 1993, 13 p.
6. Vladimir Lavrač: **THE ADJUSTMENT OF THE SLOVENIAN MONETARY SYSTEM TO THE EUROPEAN MONETARY INTEGRATION PROCESS**, IER, Ljubljana, 1993, 14 p.
7. Andrej Kumar: **EUROPEAN INTEGRATION – REALITY OR A DREAM?**, IER, Ljubljana, 1994, 20 p.
8. Frančiška Logar, Danica Zorko: **UPSWING OF TOURISM IN SLOVENIA**, IER, Ljubljana, 1994, 23 p.
9. Milena Bevc: **EDUCATIONAL CAPITAL IN SLOVENIA IN THE EARLY 90s**, IER, Ljubljana, 1994, 28 p.
10. Franc Kuzmin: **THE MAIN CHARACTERISTICS OF SLOVENE LABOUR MARKET DURING TRANSITION PERIOD – THE PROBLEM OF UNEMPLOYMENT**, IER, Ljubljana, 1994, 9 p.
11. Emil Erjavec, Miroslav Rednak, Jernej Turk: **THE MAIN ISSUES INVOLVED IN THE ECONOMIC TRANSITION OF SLOVENE AGRICULTURE**, IER, Ljubljana, 1994, 16 p.
12. Stanka Kukar: **THE HIDDEN ECONOMY AND THE LABOUR MARKET IN SLOVENIA IN THE PERIOD OF TRANSITION**, IER, Ljubljana, 1994, 16 p.
13. Milan Lapornik, Peter Stanovnik: **INDUSTRIAL AND ENTERPRISE RESTRUCTURING IN SLOVENIA**, IER, Ljubljana, 1995, 24 p.
14. Vladimir Lavrač: **COMMON CAPITAL MARKET OF CEFTA COUNTRIES – A POSSIBLE WAY OF DEEPENING CEFTA**, IER, Ljubljana, 1997, 15 p.
15. Valentina Prevolnik: **HEALTH CARE REFORM IN SLOVENIA**, IER, Ljubljana, 1997, 17 p.
16. Tine Stanovnik: **THE TAX SYSTEM AND TAX REFORM IN SLOVENIA**, IER, Ljubljana, 1997, 16 p.

WORKING PAPERS

1. Vladimir Lavrač: **EXCHANGE RATE OF THE SLOVENIAN TOLAR IN THE CONTEXT OF SLOVENIA'S INCLUSION IN THE EU AND IN THE EMU**, IER, Ljubljana, 1999, 18 p.
2. Tine Stanovnik, Nada Stropnik: **ECONOMIC WELL-BEING OF THE ELDERLY AND PENSION REFORM IN SLOVENIA**, IER, Ljubljana, 1999, 34 p.
3. Marjan Simončič, Franc Kuzmin: **MACROECONOMIC EFFECTS OF THE PENSION REFORM IN SLOVENIA**, IER, Ljubljana, 1999, 26 p.
4. Jože Pavlič Damijan: **EFFICIENCY OF FREE TRADE AGREEMENTS: DID THE REDUCTION OF TRADE BARRIERS HAVE ANY EFFECT ON INCREASING TRADE BETWEEN SLOVENIA AND THE CEFTA COUNTRIES?**, IER, Ljubljana, 1999, 18 p.
5. Boris Majcen: **SECTOR PERFORMANCE IN THE SLOVENE ECONOMY: WINNERS AND LOSERS OF EU INTEGRATION**, IER, Ljubljana, 2000, 37 p. + appendix
6. Peter Stanovnik, Art Kovačič: **SOME QUESTIONS OF THE INTERNATIONAL COMPETITIVENESS OF NATIONAL ECONOMIES WITH EMPHASIS ON SLOVENIA**, IER, Ljubljana, 2000, 24 p.
7. Janez Bešter: **TAKEOVER THEORIES AND PREDICTION MODELS – THE CASE OF SLOVENIAN PRIVATISED COMPANIES**, IER, Ljubljana, 2000, 16 p.
8. Jeffrey David Turk, Hedvika Usenik: **BUYER SUPPLIER RELATIONSHIPS IN THE ENGINEERING INDUSTRIES IN SLOVENIA AND COMPARISONS WITH HUNGARY**, IER, Ljubljana, 2000, 22 p.
9. Jože Pavlič Damijan, Boris Majcen: **TRADE REORIENTATION, FIRM PERFORMANCE AND RESTRUCTURING OF SLOVENIAN MANUFACTURING SECTOR**, IER, Ljubljana, 2001, 16 p.
10. Jože Pavlič Damijan, Boris Majcen, Matija Rojec, Mark Knell: **THE ROLE OF FDI, R&D ACCUMULATION AND TRADE IN TRANSFERRING TECHNOLOGY TO TRANSITION COUNTRIES: EVIDENCE FROM FIRM PANEL DATA FOR EIGHT TRANSITION COUNTRIES**, IER, Ljubljana, 2001, 26 p.
11. Matija Rojec, Jože Pavlič Damijan, Boris Majcen: **EXPORT PROPENSITY OF ESTONIAN AND SLOVENIAN MANUFACTURING FIRMS: DOES FOREIGN OWNERSHIP MATTER?**, IER, Ljubljana 2001, 22 p.
12. Nevenka Hrovatin, Sonja Uršič: **THE DETERMINANTS OF FIRM PERFORMANCE AFTER OWNERSHIP TRANSFORMATION IN SLOVENIA**, IER, Ljubljana, 2001, 21 p.
13. Vladimir Lavrač, Tina Žumer: **EXCHANGE RATE ARRANGEMENTS OF ACCESSION COUNTRIES IN THEIR RUN-UP TO EMU: NOMINAL CONVERGENCE, REAL CONVERGENCE AND OPTIMUM CURRENCY AREA CRITERIA**, IER, Ljubljana, 2002, 35 p.
14. Vladimir Lavrač: **MONETARY, FISCAL AND EXCHANGE RATE POLICIES FROM THE VIEWPOINT OF THE ENLARGEMENT OF THE EUROZONE: SURVEY OF THE LITERATURE**, IER, Ljubljana, 2002, 21 p.
15. Jože Pavlič Damijan, Črt Kostevc: **THE EMERGING ECONOMIC GEOGRAPHY IN SLOVENIA**, IER, Ljubljana 2002, 30 p.
16. Boris Majcen: **THE EFFECTS OF FOREIGN TRADE LIBERALIZATION AND FINANCIAL FLOWS BETWEEN SLOVENIA AND EU AFTER THE ACCESSION**, IER, Ljubljana 2002, 33 p.
17. Jože Pavlič Damijan, Mark Knell, Boris Majcen, Matija Rojec: **TECHNOLOGY TRANSFER THROUGH FDI IN TOP-10 TRANSITION COUNTRIES: HOW IMPORTANT ARE DIRECT**

EFFECTS, HORIZONTAL AND VERTICAL SPILLOVERS?, IER, Ljubljana, 2003, 23 p + appendix

18. Jože Pavlič Damijan, Črt Kostevc: **THE IMPACT OF EUROPEAN INTEGRATION ON ADJUSTMENT PATTERN OF REGIONAL WAGES IN TRANSITION COUNTRIES: TESTING COMPETITIVE ECONOMIC GEOGRAPHY MODELS**, IER, Ljubljana, 2003, 27 p.
19. Vladimir Lavrač: **ERM 2 STRATEGY FOR ACCESSION COUNTRIES,** IER, Ljubljana, 2003, 21 p.
20. Renata Slabe Erker: **ENVIRONMENTAL SUSTAINABILITY IN SLOVENIA,** IER, Ljubljana, 2003, 25 p.
21. Tine Stanovnik, Miroslav Verbič: **PERCEPTION OF INCOME SATISFACTION AND SATISFACTION WITH THE QUALITY OF LIVING; AN ANALYSIS OF SLOVENIAN HOUSEHOLDS,** IER, Ljubljana, 2003, 18 p.
22. Vladimir Lavrač: **FULFILLMENT OF MAASTRICHT CONVERGENCE CRITERIA FOR SLOVENIA AND OTHER ACCEDING COUNTRIES**. IER, Ljubljana, 2004, 15 p.
23. Janez Bešter: **ANATOMY OF A POST-MERGER INTEGRATION: THE CASE OF SLOVENIA.** IER, Ljubljana, 2004, 21 p.
24. Miroslav Verbič: **ECONOMETRIC ESTIMATION OF PARAMETERS OF PRESERVATION OF PERISHABLE GOODS IN COLD LOGISTIC CHAINS.** IER, Ljubljana, 2004, 33 p.
25. Egbert L. W. Jongen: **AN ANALYSIS OF PAST AND FUTURE GDP GROWTH IN SLOVENIA.** IER, Ljubljana, 2004, 42 p.
26. Egbert L. W. Jongen: **FUTURE GDP GROWTH IN SLOVENIA: LOOKING FOR ROOM FOR IMPROVEMENT.** IER, Ljubljana, 2004, 37 p.
27. Peter Stanovnik, Marko Kos: **TECHNOLOGY FORESIGHT IN SLOVENIA.** IER, Ljubljana, 2005, 22 p.
28. Art Kovačič: **COMPETITIVENESS AS A SOURCE OF DEVELOPMENT.** IER, Ljubljana, 2005, 25 p.
29. Miroslav Verbič, Boris Majcen, Renger van Nieuwkoop: **SUSTAINABILITY OF THE SLOVENIAN PENSION SYSTEM: An ayalysis with an overlapping-generations General Equilibrium Model.** IER, Ljubljana, 2005. 24 p.
30. Miroslav Verbič: **AN ANALYSIS OF THE SLOVENIAN ECONOMY WITH A QUARTERLY ECONOMETRIC MODEL.** IER, Ljubljana, 2006. 26 p.
31. Vladimir Lavrač, Boris Majcen: **ECONOMIC ISSUES OF SLOVENIA'S ACCESSION TO THE EU.** IER, Ljubljana, 2006. 37 p.
32. Miroslav Verbič, Renata Slabe Erker: **ECONOMIC VALUATION OF ENVIRONMENTAL VALUES OF THE LANDSCAPE DEVELOPMENT AND PROTECTION AREA OF VOLČJI POTOK**. IER, Ljubljana, 2007. 28.p.
33. Boris Majcen, Miroslav Verbič. **MODELLING THE PENSION SYSTEM IN AN OVERLAPING-GENERATIONS GENERAL EQUILIBRIUM FRAMEWORK.** IER, Ljubljana, 2007. 37 p.
34. *Boris Majcen, Miroslav Verbič (corresponding author), Ali Bayar and Mitja Čok.* **THE INCOME TAX REFORM IN SLOVENIA: SHOULD THE FLAT TAX HAVE PREVAILED?** IER, Ljubljana, 2007. 29 p.

35. Miroslav Verbič. **VARYING THE PARAMETERS OF THE SLOVENIAN PENSION SYSTEM: AN ANALYSIS WITH AN OVERLAPPING-GENERATIONS GENERAL EQUILIBRIUM MODEL.** IER, Ljubljana, 2007. 28 p.
36. Miroslav Verbič, **SUPPLEMENTARY PENSION INSURANCE IN SLOVENIA: AN ANALYSIS WITH AN OVERLAPPING-GENERATIONS GENERAL EQUILIBRIUM MODEL.** IER, Ljubljana, 2007. 32 p.
37. Matjaž Črnigoj: **RISK AVERSE INSIDERS WITH SPECIFIC OBJECTIVE FUNCTION AND CAPITAL STRUCTURE.** IER, Ljubljana, 2007. 13 p.
38. Renata Slabe Erker, Janez Filiplič: **MONITORING SUSTAINABILITY FOR SLOVENIA'S REGIONS.** IER, Ljubljana, 2007, 22 p.
39. Jože P. Damijan, Črt Kostevc: **TRADE LIBERALIZATION AND ECONOMIC GEOGRAPHY IN TRANSITION COUNTRIES: CAN FDI EXPLAIN THE ADJUSTMENT PATTERN OF REGINAL WAGES?** IER, Ljubljana, 2008, 40 p.
40. Jože P. Damijan, Matija Rojec, Boris Majcen, Mark Knell: **IMPACT OF FORM HETEROGENEITY ON DIRECT AND SPILLOVER EFFECTS OF FDI: MICRO EVIDENCE FROM TEN TRANSITION COUNTRIES.** IER, Ljubljana, 2008, 25 p.

OCCASIONAL PAPERS

1. Helen O'Neill: **IRELAND'S ECONOMIC TRANSITION: THE ROLE OF EU REGIONAL FUNDS – AND OTHER FACTORS**, IER, Ljubljana, 2000, 16 p.
2. Sanja Maleković: **CROATIAN EXPERIENCE IN REGIONAL POLICY**, IER, Ljubljana 2000, 13 p.
3. Peter Backé, Cezary Wójcik: **ALTERNATIVE OPTIONS FOR THE MONETARY INTEGRATION OF CENTRAL AND EASTERN EUROPEAN EU ACCESSION COUNTRIES**, IER, Ljubljana, 2002, 17 p.
4. Andreas Freytag: **CENTAL BANK INDEPENDENCE IN CENTRAL AND EASTERN EUROPE ON THE EVE OF EU-ENLARGEMENT,** IER, Ljubljana, 2003, 29 p.
5. Jasmina Osmanković: **REGIONALIZATION AND REGIONAL DEVELOPMENT IN BOSNIA AND HERZEGOVINA IN THE POST-WAR PERIOD**, IER, Ljubljana, 2004, 16 p.
6. Carlos Vieira, Isabel Vieira, Sofia Costa: **MONETARY AND FISCAL POLICIES IN EMU: SOME RELEVANT ISSUES,** IER, Ljubljana, 2004, 36 p.
7. Bojan Radej. **THE FOUR CAPITAL MODEL, MATRIX AND ACCOUNTS.** IER, Ljubljana, 2007.
   25 p.