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DO EXTERNAL KNOWLEDGE SPILLOVERS INDUCE FIRMS' INNOVATIONS? EVIDENCE FROM SLOVENIA

DRAFT

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Abstract

The paper analyses whether, and to what extent, firm's ability to innovate is induced by firm's own R&D activity and to what extent by factors external to firm. It first estimates the impact of firms' internal R&D capital and external R&D spillovers on firms' innovation activity within an integrated dynamic model. In the second step, we then estimate the impact of firms' innovations on firms' productivity growth. Using the firm level data on innovation activity combined with firms' financial data for a large sample of Slovenian firms in the period 1996-2002, the paper produces three main findings. First, firm's own R&D expenditures as well as external knowledge spillovers, such as national and international public R&D subsidies, foreign ownership and intra-sector innovation spillovers do enhance firm's ability to innovate. Second, innovations as a result of firm's R&D do contribute substantially to firm's total factor productivity growth. And third, foreign ownership has a double impact on firm's TFP growth - it first enhances firm's ability to innovate and then it additionally contributes to firm's TFP growth via superior organization techniques and other channels of knowledge diffusion.

Keywords: innovation, external knowledge spillovers, FDI, Slovenia

JEL Classification: D24, F14, F21

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1. Introduction

According to endogenous growth theory, technological progress is endogenous, it is driven by an intentional investment of resources by profit-seeking firms (Smolny 2000). To successfully undertake innovation activity, a firm normally needs to combine several different types of knowledge, capabilities, skills and resources. Critical seems to be the abilities and incentives of those managers who exercise strategic control, the size of the funds that are generated by the firm itself and the organizational integration of the firm (Lazonick 2005). Still, as claimed by Fagerberg (2005), the central finding in the literature on innovation is that, in most cases, innovation activities in firms depend heavily on external sources. The pattern of worldwide technical change is determined in large part by international technology diffusion because only a handful of rich countries account for most of the world's creation of new technology (Keller 2004). Eaton and Kortum (1999) and Keller (2002a) find that for most countries foreign sources of technology are of dominant importance - 90% or more - for productivity growth.

Along these lines, economic analysis of innovation identifies international knowledge flows (through FDI, trade, licensing and international technological collaborations) as important determinants of the development and the diffusion of innovations. Here, the notion of technology and knowledge spillovers is central. It is based in theories of endogenous technical change of the early 1990s (see, for instance, Aghion and Howitt 1998, Grossman and Helpman 1991, Romer 1990), claiming that the return to technological investments is partly private and partly public (Keller 2004). Because of the non-rival character of technology an innovation, which is produced by one firm, may and can also be used by another firm, without incurring very much additional cost (Smolny 2000). These are technology or knowledge spillovers.

The central objective of this paper is to test whether, and to what extent, firm's ability to innovate is induced by firm's own R&D activity as well as factors external to firm and what are the most important channels of external knowledge spillovers. These can be in the form of direct technology transfer (through FDI, trade, licensing, importing etc.), learning effects (innovation spillovers and learning-by-exporting) as well as in the form of public R&D subsidies. So far, most of these channels have been studied

separately[1]. Here, we analyse the impact and determine the relative importance of direct and indirect knowledge transfer through inward FDI and trade versus the impact of R&D subsidies and firms' own R&D activity for innovation activity of firms within an integrated dynamic model. We pay particular attention to firms' absorption capacity and other determinants of firms' innovation activity and external knowledge spillovers identified in the literature.

In building the conceptual approach for testing the relevance of external knowledge spillovers, the channels of external knowledge spillovers occupy the central place. However, since we test the relevance of external knowledge spillovers in an integrated framework, we are also interested in the endogenous factors of firms' innovation activity, firms' own R&D in the first place. Firms' endogenous factors co-determine their absorption capacity for external knowledge spillovers as well.

Most of the existing empirical studies estimate either the rate of return to firms' own R&D expenditures or the impact of external knowledge spillovers on firms' productivity growth. Instead, we estimate the impact of firms' internal R&D capital and external R&D spillovers on firms' productivity growth in a two step procedure. In the first step we determine the impact of firm own R&D capital and external R&D spillovers on firm's innovation activity. In the second step, we then estimate the efficiency of firms' innovation activity, i.e. we estimate the impact of firm's innovations on firms' productivity growth.

Using the firm level data on innovation activity (based on innovation surveys) combined with firm financial data for a large sample of Slovenian firms in the period 1996-2002, we find several interesting findings. First, firm's own R&D expenditures as well as external knowledge spillovers, such as national and international public R&D subsidies, foreign ownership and intra-sector innovation spillovers do enhance firm's ability to innovate. Second, innovations as a result of firm's R&D do contribute substantially to firm's total factor productivity growth. And third, foreign ownership

[1] A notable exception is Ornaghi (2004), who modelled knowledge capital as a function of own investment in R&D and spillovers. She explicitely claims that in examining the role of external knowledge spillovers for firms' innovation, one must do that in the framework of an integrated framework of explaining firms' innovatory activcity, i.e. one should take into account endogenous factors of firms' innovatory activity, as well as external knowledge spillovers.

has a double impact on firm's TFP growth - it first enhances firm's ability to innovate and then it additionally contributes to firm's TFP growth via superior organization techniques and other channels of knowledge diffusion.

The role of firms' innovation activity in productivity growth discussed in the next section arguments the conceptual framework and the chosen two step procedure. Section three reviews literature on R&D as a determinant of firm's innovation capacity and of the absorbtion capacity for external knowledge spillovers, while channels of external knowledge spillovers are reviewed in greater detail in the fourth section. Section five provides empirical evidence; after brief descriptive analysis, the determinants of innovation activity are identified, followed by the estimations of the effect of the innovation activity on firms' productivity growth. Section six concludes.

2. Firms' innovation activity and productivity growth

In our model we regress firstly innovation activity on external knowledge spillovers and factors, which are endogenous to firms. In the second step, we regress productivity (total factor productivity – TFP) growth on firms' innovation activity. This is in contrast to usually applied approach, which is to regress productivity growth on external knowledge spillovers. Let us explain the advantages of our approach.

The main objective of our exercise is to analyse whether and, if yes, to what extent external knowledge spillovers impact on firms' innovation activity. Based on the generally accepted premise that technology plays a key role in determining productivity (see section 3), and due to the non-availability of explicit data on firms' innovation activity, empirical studies of the impact of external knowledge spillovers on firms' innovation activity as a rule regress productivity growth on external knowledge spillovers, most often those via FDI. The result is then interpreted as the impact of external knowledge spillovers on firms' innovation activity. This, however, is only an indirect measure, only the second best solution, which bears certain problems. The problem of measuring technological externalities with productivity spillovers is recognised by several authors. Alvarez and Robertson (2004) point that by using indicators of technological innovation they avoid the use of productivity

measures that have been controversial in previous studies. Chen (1997) suggests that one of the problems with studies that link trade to productivity is that productivity is often measured as a residual, where anything not included in the estimation equation could contribute to productivity. Smarzynska (2003) indirectly points to the same problem by recognizing that while the knowledge spillovers present a rationale for governments to susbsidize FDI inflows, this is not the case when improved productivity of local firms is due to increased competition, as inducing greater competition may be achived by other means (import liberalization, anti-trust policies etc.).

The problem of measuring the impact of external knowledge spillovers (or technological externalities) with productivity spillovers arises from the fact that there are other factors, apart from technological externalities, which have an impact on productivity spillovers and which are not controlled for in the models. In other words, technological externalities may be the most important factor of productivity spillovers, but not the only one. To the extent that productivity spillovers are also a result of other factors apart from technological externalities, the productivity spillovers are not really a good indicator of technological externalities[2]. There are also factors that may prevent the transformation of technological externalities into productivity spillovers, like the bankruptcy of domestic firms due to strong foreign competition, insufficient absorption capacity of domestic enterprises for technological externalities, system/institutional deficiencies etc.[3] To eliminate these problems our proposition is to measure the impact of external knowledge spillovers directly by their impact on firms' innovation activity. Therefore, we regress innovation activity on external knowledge spillovers and public R&D subsidies, on own R&D in the firms, on firms' absorption capacity and a number of control variables, which co-determine firms' innovation activity and the extent of external knowledge spillovers[4].

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[2] Ornaghi (2004) points exactly to this issue. His results in the Spanish case suggest that knowledge spillovers play an important role in improving the quality of products and, to a lesser extent, in increasing the productivity of the firm.

[3] The problem here is that much work remains to be done until the precise process of spilling-over will be described correctly; the exact channels of embodied and disembodied spillovers remain undetermined.

[4] Regressing of both productivity growth and innovation activity on external knowledge spillovers would enable to differentiate between the technological and competition externalities of external knowledge spillovers, which is of relevance for economic policy.

3. Own R&D as a determinant of firm's innovation activity and of firm's capacity to absorb external knowledge spillovers

Own R&D is the crucial determinant of firm's innovation activity/capacity and of firm's capacity to absorb external knowledge. For this reason, R&D can be thought of as having two complementary effects on a firm's innovation activity and productivity growth (Cohen and Levinthal 1989). First, R&D directly expands a firm's technology level by new innovations, which is called the innovation effect. On the other hand, it increases a firm's absorptive capacity – the ability to identify, assimilate and exploit outside knowledge, which is usually called the learning or the absorption effect. These two important effects are both included in our model.

Theoretical foundations for the innovation effect are supplied by the literature on endogenous innovation and growth (see, for instance, Aghion and Howitt 1992, 1998, Grossman and Helpman 1991, Romer 1990). Cameron, Proudman and Redding (2003) quote a body of empirical work in favour of positive influence of R&D on productivity growth. Important references include Griliches (1980), Griliches and Lichtenberg (1984), Mansfield (1980), Hall and Mairesse (1995), Griffith, Redding and Simpson (2004). The R&D capital model has been the ruling research paradigm to investigate the relationship between firms' innovation and productivity growth. This approach adds some measure of knowledge capital, computed from the data on R&D, to the list of inputs entering the production function. According to (Ornaghi 2004), a distinguishing feature of this type of capital is that it does not depend only on firms' own research effort, but also on the pool of general knowledge a firm has access to, i.e. a firm may learn from innovations of other firms. This is how technological externalities or spillovers are brought in the model.

Firm's capacity to absorb external knowledge spillovers, through FDI and other types of technology transfer, has been broadly analysed and emphasized in the literature. In general, empirical evidence demonstrate that FDI can contribute to overall domestic productivity growth only when the technology gap between domestic and foreign firms is not too large and when a sufficient absorptive capacity is available in domestic firms (Damijan, Knell, Majcen and Rojec 2003a, Kokko 1994, Kokko, Tansini and Zejan 1996, Borensztein, De Gregorio and Lee 1998, Kinoshita 2000). In

other words, technology spillovers from MNCs tend to occur more frequently when the technological and social capabilities of the host country and the absorptive capacity of firms in the economy are high. Keller and Yeapl (2003) find that spillovers are significantly higher in high technology industries.

Firm's own R&D activity is not the only determinant of its external knowledge spillovers absorption capacity. Also one should distinguish between firm's and country's abrsorption capacity; the former importantly depends on the latter. The capacity to adopt external knowledge spillovers, often referred to as "technological capabilities" (Wang 1989, Lall 1992) or "national absorbtive capacity" (Movery and Oxley 1995), depends on a number of factors. Domestic technological capabilities, R&D investments and human capital are the most obvious (Cameron, Proudman and Redding 2003). Borenzstein, De Gregorio and Lee (1998) and Hoppe (2005) stress the importance of human capital that exists and is used in the economy. They claim that the contribution of FDI to the transfer of technology and economic growth is greater the higher the level of human capital stock in the host economy. Other determinants of absorption capacity identified in the literature includes company size (Ornaghi 2004), trade, investment and business climate in a host country[5], and the extent of agglomeration of foreign subsidiaries in a host country (Sgard 2001)[6]. Yet another possible determinant of knowledge and FDI spillovers, which has not beeen mentioned or analysed in the literature, is the size of a host economy. It seems logical that a host economy should have a certain critical size to enable foreign subsidiaries to engage local suppliers and to influence local competitors. This seems especially relevant in the case of local suppliers, i.e. backward linkages. Small size of the Slovenian economy is certainly not an aspect in favour of knowledge and FDI spillovers.

[5] The better and the more liberal the investment and business climate the higher the spillover effects (Keller 2004, Balasubramanyam, Salisu and Sapsford 1996, Moran 1998).

[6] In order to have positive spillover effects, foreign firms must represent a substantial share of the economy.

4. Channels of external knowledge spillovers

The channels of international technology transfer and their importance for growth have been studied extensively in the 1990s. These studies identify three principal channels of international research and development (R&D) spillovers. The first is a direct transfer of technology via international licensing agreements (Eaton and Kortum 1996), though recently these provide a less important source, as the latest and most valuable technologies are not available on license (UNCTAD 2000). The second is FDI that provides probably the most important and the cheapest channel of direct technology transfer as well as of indirect knowledge spillovers to developing countries. The third channel of technology transfer is through international trade, in particular imports of intermediate products and capital equipment as well as through learning-by-exporting into industrial countries.

While there is quite an amount of literature on individual channels of international transfer of technology, in particular of FDI, the papers that compare various channels directly in a way that generates evidence about the relative importance of each of them, are few. Alvarez and Robertson (2004), who estimate the effect of exports, FDI and trade in intermediate inputs on the Mexican and Chilean plants' decision to innovate, find that exporting has the greatest effect but FDI also plays an important role. Keller and Yeaple (2003) estimate international technology spillovers to US manufacturing firms via imports and FDI between 1987 and 1996 and suggest that FDI leads to significant productivity gains for domestic firms. There is some evidence for imports related spillovers as well, but it is weaker than for FDI. Damijan, Knell, Majcen and Rojec (2003a) examine different channels of global technology transfer to eight transition countries and provide evidence that technology is being transferred primarily through direct foreign investment linkages. The spillovers from trade are only exceptionally present, while FDI spillovers are negative or insignificant. Apart from that, Keller (2004), who surveys the existing literature on the extent and the channels of international technology diffusion, finds evidence for imports being a significant channel of technology diffusion. At the same time, the evidence for benefits with exporting is weaker. The importance of FDI is mixed but recently micro-economic findings seem to show positive results.

4.1. Direct FDI effects (foreign vs domestic ownership)

In dealing with FDI as a source of foreign technology and productivity growth one should distinguish between direct effects of FDI and FDI spillovers. Direct effects of FDI relate to the impact of foreign ownership on the technology transfer to and productivity of foreign subsidiaries; they relate to the issue of why are foreign sisbsidiaries (or MNEs in general) more efficient than domestic companies (or non-MNEs in general). Thus, in measuring contribution of FDI to the technological upgrading of a host country one should first take into account the technological endowment of the local subsidiary of a foreign firm, which can be expected to be superior to that of local producers (Sgard 2001).

There is a lot of empirical evidence on positive direct technology transfer from a MNE to its local affiliates in terms of higher productivity levels and growth. These studies, using firm-level panel data, include developed as well as developing countries (e.g. Haddad and Harrison 1993, Blomström and Wolff 1994, Blomström and Sjöholm 1999, Aitken and Harrison 1999, Girma, Greenaway and Wakelin 2001, Barry, Görg and Strobl 2002, Alverez, Damijan and Knell 2002, Blalock 2001, Damijan, Knell, Majcen, Rojec 2003b etc.). FDI as a source of foreign technology and productivity growth has been particularly important for firms in transition economies because of the urgent need to restructure quickly. Foreign ownership often provides local firms with efficient corporate governance, as they - mainly privatized to insiders - do not have incentives and resources to restructure (Blanchard 1997). FDI may also be the cheapest means of technology transfer, as the recipient firm normally does not have to finance the acquisition of new technology. And it tends to transfer newer technology more quickly than licensing agreements and international trade (Mansfield and Romero 1980), and has the most direct effect on the efficiency of firms. Damijan, Knell, Majcen and Rojec (2003b), on a set of more than 8,000 firms for 10 advanced transition countries in the period 1995-1999, find that direct FDI provide by far the most important productivity effect for local firms.[7]

[7] Direct effects of FDI are found to provide on average an impact on a firm's productivity that is larger by factor 50 than the impact of backward spillovers and by factor 500 larger than the impact of horizontal spillovers.

4.2. FDI spillovers

The issue of FDI spillovers is the most extensively analysed channel of external knowledge spillovers in the literature. Knowledge spillovers from FDI take place when the entry or presence of foreign subsidiaries, which have typically better technologies and organizational skills than domestic firms, increases knowledge of domestic firms and MNEs do not fully internalize the value of these benefits (Smarzynska 2003). The presence of a foreign subsidiary can thus increase the rate of technical change and technological learning in the host economy indirectly through knowledge spillovers to domestic firms.

Kokko (1992) and Blomstrom and Kokko (1998) identify at least four ways how technology might be diffused from foreign subsidiaries to other firms in the economy: (i) demonstration-imitation effect, (ii) competition effect, (iii) foreign linkage effect and (iv) training effect. Demonstration effect occurs if domestic firms learn superior production technologies from arm's length relationships with foreign subsidiaries. Competition effect is when competition from foreign subsidiaries forces domestic rivals to update production technologies and techniques to become more productive (see, for instance, Griffith, Redding and Simpson 2004, Lim 2001 etc.). Foreign linkage effect goes through engaging of domestic suppliers for foreign subsidiaries (see, for instance, Markusen and Venables 1999, Görg and Strobl 2004, Griffith, Redding and Simpson 2004 etc.) and by foreign subsidiaries giving access to new specialized intermediate inputs also for domestic firms (Rodriguez-Clare 1996), or because domestic firms use local intermediate goods suppliers whose productivity has been raised through the know-how supplied by foreign subsidiaries (Keller and Yeaple 2003). Training effect is present if there are movements of highly skilled staff from MNEs to domestic firms; these employees may take with them knowledge which may be usefully applied in domestic firms (see, for instance, Görg and Strobl 2004, Griffith, Redding and Simpson 2004, Keller and Yeapl 2003, Lim 2001 etc.). Not all spillovers are positive as FDI can generate negative externalities when foreign firms with superior technology force domestic firms to exit, since they attract away demand from them. These negative externalities of the competition effect are also often called crowding-out effect or business-stealing effect (see, for instance, Aitken and Harrison 1999, Haddad and Harrison 1993, Djankov and Hoekman 2000 etc.).

In more recent studies, authors point to some other possible types of spillovers. These are basically derived from the above mentioned types of spillovers but stress some specific aspects, or introduce new subtypes. Thus, Ornaghi (2004) pleads for the differentiation between process and product innovation spillovers because the channels of technology spillovers are not the same, what may result in different magnitude of spillover effect[8]. From economic policy point of view, differentitation between knowledge (copying technologies of foreign subsidiaries, workers mobility) and competition (MNE entry leads to more competition and higher efficiency of domestic firms thereof) spillovers, based on Blomström and Kokko (1998), is relevant. Smarzynska (2003) claims that while the knowledge spillovers present a rationale for governments to susbsidize FDI inflows, this is not the case as far as competition spillovers is concerned, as inducing greater competition may be achived by other means (import liberalization, anti-trust policies etc.).

FDI spillovers' literature further distinguishes bettween technology spillovers through FDI that occur between firms that are vertically integrated with the MNE (vertical, inter-industry spillovers to domestic firms in upstream and downstream industries) or in direct competition with it (horizontal, intra-industry spillovers). Since MNEs have an incentive to prevent information leakages that would enhance the performance of their local competitors, but at the same time may want to transfer knowledge to their local suppliers, spillovers from FDI are more likely to be vertical than horizontal in nature[9] (Smarzynska 2003). The empirical literature captures mainly those occurring between firms within the industry. The reason is that competitive effects within an industry are much easier to measure than linkage effects across industries. The authors, who explicitely bring the notion of vertical and horizontal spillovers in the literature are Blalock (2001), Schoors and van der Tol (2001), Smarzynska (2001), Smarzynska (2003), Smarzynska and Spatareanu, (2002), and Damijan, Knell, Majcen

[8] Imitation of a product innovation can be achieved through reverse engineering while diffusion of process innovation may require more sophisticated channels, such as industrial espionage or recruitment of engineers and experts of rival firms. For the panel of Spanish manufacturing firms, Ornaghi (2004) finds that technological diffusion of product innovations is larger than the one of process innovations.

[9] For a theoretical justification of spillovers through backward linkages see Rodriguez-Clare (1996), Markusen and Venables (1999), and Saggi (2002), for case studies see Moran (2001).

and Rojec (2003), which all provide evidence of positive FDI spillovers through backward linkages[10].

The substantial body of literature on FDI spillovers, which has developed in the last nearly 30 years has produced mixed empirical results. Empirical analysis have found positive, neutral, as well as negative FDI spillover effects. The evidence suggests that there can be FDI spillovers, but they do not occur everywhere to the same degree (Keller 2004), there is also no strong consensus on the associated magnitudes of FDI spillovers (Blomström, Globerman and Kokko 2000), nor on the causality (Lim 2001). In contrast to the earlier literature (see, for instance, Haddad and Harrison 1993, Aitken and Harrison 1999, Harrison 1996, Djankov and Hoekman, 2000, Konings, 2001)[11], recent firm level based studies speak in favour of positive, and in some cases also economically large spillovers associated with FDI (see for instance, Keller and Yeaple 2003, Smarzynska 2003, Damijan, Knell, Majcen and Rojec 2003b etc.)[12].

The approach to FDI spillovers adopted in the empirical literature largely avoids the question how technology spillovers actually take place, and focuses on the simpler issue of whether the presence and magnitude of MNEs affect productivity in domestic firms (Gorg and Strobl 2001). The failure to better understand and to identify the exact mechanisms through which FDI facilitates knowledge spillovers is probably the main shortcoming of FDI spillovers' research (Griffith, Redding and Simpson 2004). Much work remains to be done until the precise process of spilling-over will be described correctly and the exact channels that enables knowledge to flow will be identified (Hoppe 2005, Ornaghi 2004). Only this will enable us to say who benefits most from spillovers and why.

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[10] Lall (1980) identifies the following MNE/supplier interactions that can help increase the productivity and efficiency of local firms: (i) helping prospective suppliers set up production facilities; (ii) demanding from suppliers reliable, high quality products that are delivered on time, while also helping the suppliers to improve the products or facilitate innovations; (iii) providing training and help in management and organization; and (iv) assisting suppliers to find additional costumers including subsidiaries in other countries.

[11] Earlier studies reveal that positive FDI spillovers in developing countries were limited to certain industries, such as those with relatively simple technology in Morocco (Haddad and Harrison, 1993), those that are export oriented as in Indonesia (Blomström and Sjöholm, 1999), or have sufficient human capital as in Uruguay (Blomström, Kokko and Zejan 1994).

[12] Girma, Greenaway and Wakelin (2001) as well as Haskel, Pereira and Slaughter (2001), who have studied inward FDI in the UK, also find evidence for positive FDI spillovers in the UK.

4.3. Imports and learning-by exporting

International trade works as a channel of technology transfer either through imports of intermediate products and capital equipment (Feenstra, Markusen and Zeile 1992) or through learning-by-exporting into industrial countries (Clerides, Lach and Tybout 1998)[13]. Several authors have recently examined the issue of technological externalities associated with trade. A first set of papers has looked for international R&D spillovers driven by imports. According to Keller (2004), overall evidence supports the notion that importing is associated with technology spillovers, but we do not know how strong diffusion through embodied technology in intermediate goods versus other technology diffusion associated with imports are. Keller and Yeapl (2003) and Keller (2004) provide a survey of literature on technology spillovers via imports: Eaton and Kortum (2001) claim that differences in relative price of equipment account for 25% of the cross-country productivity differences in a sample of 34 countries; Coe and Helpman (1995) for a sample of 22 OECD countries find that country's productivity is increasing in the extent to which it imports from high- as opposed to low-R&D countries[14]; Coe, Helpman and Hoffmesister (1997) find similar effects for technology diffusion from highly industrialized to less developed countries; Xu and Wang (1999) emphasize that it is imports of differentiated capital goods (machinery), which have a positive impact on productivity[15], while Keller (2000) came to the same results for specialized machinery imports; Lumenga-Neso, Olarreaga and Schiff (2001) also demonstrate positive spillovers from imports. More recent research has sought to provide a more powerful empirical framework by employing more disaggregated data and allowing for alternative spillover channels in addition to imports. This has produced mixed results so far; for instance, Keller's (2002b) industry-level analysis of technology spillovers among the G-7 countries finds evidence in support of imports-related effects, while Kraay, Isoalaga and Tybout

[13] Hoppe (2005) distinguishes three types of effects that trade has on technology transfer. First, direct effects resulting from import of capital goods, including modern technology, and intermediate goods of increasing variety and quality. Second, dynamic gains from trade resulting from an integrated world market that leads to higher production, mastering of better techniques and increase of productivity. Third, trade increases the set of technologies that are available in a country.

[14] They also show that these benefits are larger the more open an economy is to trade.

[15] Keller (1998) generates almost as strong results with counterfactual instead of observed imports data. This undrelines that the evidence for imports-related technology spillovers on the basis of these regressions is not very strong.

(2001) in their study of firm productivity dynamics in three less developed countries do not.

Comparing to imports there is much less evidence for knowledge spillovers via learning-by-exporting. Conventional wisdom is that learning-by-exporting effects are non-existent and this is consistent with current evidence. According to Keller (2004), learning-by-exporting effects have been found in the case study literature, whereas authors of econometric studies take a much more sceptical view. Thus, case studies of Rhee, Ross-Larson and Pursell (1984) for East Asian countries confirm learning-by-exporting-effect, while Clerides, Lach and Tybout (1998), for manufacturing plants in Columbia, Morocco and Mexico, Bernard and Jensen (1999) for US firms, and Hallward-Driemeier, Iarossi and Sokoloff (2002) for Southeast Asian countries find no econometric evidence for strong learning-by-exporting effect.

4.4. R&D subsidies

In the context of the research questions which we tackle in the present paper, the crucial issue of R&D subsidies is whether there are any positive spillovers from public to private R&D expenditures, i.e. from R&D subsidies given by the government to firms' own R&D expenditures (David, Hall and Toole 1999). In other words, in evaluating the effect of the R&D subsidy, the government should know, or at least have an idea, how much the firm would have spent on R&D had it not received the subsidy (Lach 2000). Are R&D subsidies stimulating or displacing company-financed R&D? Is public spending complementary and thus »additional« to private R&D spending, or does it substitute for and tend to »crowd out« private R&D? The standard rationale for government support of R&D is rooted in the beleif that some form of market failure exists that leads the private sector to underinvest in R&D (Arrow 1962, Nelson 1959). Underinvestment in R&D occurs because the social benefits from new technologies are difficult to appropriate by the private firms bearing the costs of their discovery, and because imperfect capital markets may inhibit firms from investing in socially valuable R&D projects (Griliches 1998, Romer 1990). The output of R&D is characterised by its public good nature, which implies that benefits are not fully appropriable by the investor but generate domestic

and international spillovers that might be captured by competitors. Economic incentives therefore do not generally lead firms to undertake the first best level of R&D spending. The aim of government intervention in R&D activity is to estabilh efficiency.

Therefore, publicly supported R&D is suppose to augment or complement private R&D expenditures. Yet the empirical evidence suggests that there is some subsitution between private and government funded R&D. Wallsten (2000) showed that a subset of publicly traded, young, technologicaly intensive US firms, reduced their R&D spending in the years following the award R&D subsidieis, while in about 30% of the Spanish firms analysed by Busom (2000) public funding fully crowds out privately financed R&D. On the other hand, Klette and Moen (1997) claim that the R&D susbsidies significantly expanded R&D expenditures of a sample of high-technology Norwegian firms and there was little tendency for crowding out. Lach (2000) concludes that R&D susbsidies to Israeli manufacturing firms stimulated long-run company-financed R&D expenditures; an extra dollar of R&D subsidies increases long-run company-financed R&D expenditures by 41 cents. The principal reasons for the substitution effect of R&D subsidies on private R&D expenditures are: (i) subsidizing of projects that firms would undertake even in the absence of subsidies, (ii) firms adjust their portfolio of R&D projects by closing or slowing-down non-subsidized projects, (iii) increased prices of R&D inputs due to increased demand arising from R&D subsidies (Lach 2000, David, Hall and Toole 1999).

David, Hall and Toole (1999) survey the body of available econometric evidence and also find ambivalent results. The survey does not offer a definite empirical conclusion regarding the sign and magnitude of the relationship between public and private R&D. One third of the studies they analysed report that R&D funding behaves as a substitute for private R&D investment. The substitution effect result is far more prevalent among the studies conducted at the line-of-business and firm level, than among those carried out at the industry and higher aggregation levels[16]. Of 19 analysis at the firm level 9 report substitution, however, this is mostly due to the USA: of 12

[16] The similarity with the empirical findings on FDI spillovers is more than obivous. The methodology – sectoral versus firm level econometrics – obviously has an important impact on the results.

studies based on US data 7 report susbstitution, while of 7 studies on other countries' data only 2 report substitution. Complementarity is thus much stronger in the case of non-US studies and vice versa in the case of US studies. These results point to the methodological problems which influence the results of econometric studies. They are related to (i) possible mutual interdependence of public and private R&D expenditures because of simultaneity and selection bias in the funding process, or because of omitted latent variables that are correlated with both the public and private R&D investment decisions, (ii) unobserved inter-industry differences in the technological opportunity set, which are likely to induce positive covariation in the public and private components of total industry level R&D expenditures, (iii) at the aggregate level the likely positive effect on R&D input prices of expanded government funding contributes to the appearance of complementarity movemements in the private and public components of nominal R&D expenditures.

5. Determinants of firms' innovation and the impact of innovation on firms' productivity growth in Slovenia

5.1. Innovation activity of Slovenian firms

In this section we make use of the official Innovation surveys (based on OECD methodology) in order to reveal the determinants of the innovation activity by Slovenian firms. Innovation surveys in Slovenia are being conducted by the Slovenian Statistical office every second year, starting in 1996. Up to now there have been four such extensive innovation surveys carried out – in 1996, 1998, 2000 and 2002. These innovation surveys are being carried out among a wide sample of manufacturing and non-manufacturing firms with no conditions put on actual R&D activity by these firms. Hence, these surveys allow for a broad picture of determinants of the innovation activity and its impact on performance of Slovenian firms.

5.1.1. Descriptive statistics of innovation activity by Slovenian firms

In this sub-section we show some descriptive statistics of innovation activity by Slovenian firms. Innovation activity of individual firms has been analysed with regard to the type of ownership, firm's size as well as technological intensity of sectors. Table 1 reveals that the innovation activity, which captures both the innovation of products and services as well as innovation of processes,[17] is pretty low in Slovenia. Only about 20% of Slovenian firms are innovative, i.e. have claimed to have conduct at least one innovation of products and services or innovation of processes in the respective 2-year period. What is striking is the negative trend of innovation activity of Slovenian firms, showing that the share of innovative Slovenian firms is shrinking from 1998 to 2002.[18] This is predominantly due to the low innovation activity of indigenous firms (only 17% of firms with domestic owners 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 points toward more competitive and innovation friendly environment in foreign owned firms.

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

	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.

[17] Throughout this section we don't discriminate between innovation of products (services) and innovation of processes. The analysis of determinants of both types of innovation activity (see sub-section 5.1.2) shows no major differences between them, therefore we treat them together in one single variable.

[18] The share of innovative firms is shrinking in spite of the fact that total innovation expenditure is increasing.

Table 2: R&D expenditures and innovation activity of Slovenian firms by size and ownership type, 1996-2002 (in %)

	N		R&D/Sales (Innovative firms)		R&D/Sales (Non-Innovative firms)		Fraction of Innovative firms	
	Dom	For	Dom	For	Dom	For	Dom	For
Small								
1996	578	67	1.6	2.2	0.011	0.000	8.8	13.4
1998	790	121	1.0	2.2	0.000	0.000	10.5	11.6
2000	1,358	265	9.4	5.4	0.021	0.000	11.4	14.7
2002	1,424	281	9.0	16.1	0.000	0.016	12.4	11.7
Medium								
1996	438	146	1.4	1.9	0.017	0.011	22.6	27.4
1998	447	183	2.1	1.8	0.008	0.000	25.5	35.5
2000	445	215	5.5	4.5	0.030	0.005	26.3	40.9
2002	406	222	4.1	4.9	0.019	0.144	24.9	36.9
Large								
1996	132	93	1.2	1.8	0.198	0.087	48.5	57.0
1998	126	102	1.0	1.9	0.003	0.022	56.3	60.8
2000	120	115	4.7	2.9	0.025	0.092	54.2	60.0
2002	105	126	2.6	4.3	0.010	0.000	54.3	61.1

Source: Statistical office of Slovenia; own calculations.

Breakdown according to firms' size into small (less than 50 employees), medium (50 - 250 employees) and large firms (more than 250 employees) shows that there are on average three- to four-times more innovative firms among the medium-sized ones than among the small ones, while among large firms the share of innovative firms is five- to six-times higher than among small firms. Again, Table 2 reveals significant differences among indigenous and foreign owned firms in Slovenia. Foreign owned firms, especially if they are of medium or large size, are more likely to be innovative than firms with domestic owners. More precisely, 30% - 35% of foreign owned medium sized firms are on average innovative, while this ratio with domestic firms is only about 25%. With large firms this difference is narrower as 60% of foreign owned firms relative to 55% of domestic firms are innovative.

Let us now look into differences in innovation activity among firms in different technology intensity groups.[19] Table 3 demonstrates that, in Slovenia, the most innovative are firms in the medium high technology sectors, such as electrical appliances, automotive production, machinery and chemical production. But there again, foreign owned firms exhibit up to 20 percentage points higher figures of innovation activity. High technology sectors' firms also exhibit above average innovation activity, but substantially lower than firms in medium high technology

sectors (25% relative to 35%, respectively). For foreign owned firms these differences in innovation activity across sectors are less prominent, since with the exception of the medium low technology intensity sectors foreign owned firms seem to be equally inclined to innovation activity at a rate of about 40% - 50%.

Table 3: R&D expenditures and innovation activity of Slovenian firms by technology defined sectors and ownership type, 1996-2002 (in %)

	N		R&D/Sales (Innovative firms)		R&D/Sales (Non-Innovative firms)		Fraction of Innovative firms	
	Dom	For	Dom	For	Dom	For	Dom	For
Low tech								
1996	314	98	0.7	0.6	0.026	0.003	17.8	31.6
1998	333	110	0.8	0.9	0.004	0.000	20.1	39.1
2000	423	138	4.2	3.1	0.004	0.002	15.6	39.1
2002	413	147	3.5	4.8	0.004	0.015	14.8	40.1
Medium-low tech								
1996	451	96	0.7	0.5	0.005	0.015	12.0	18.8
1998	548	149	0.8	1.0	0.001	0.000	11.1	23.5
2000	867	256	5.4	3.7	0.007	0.020	11.0	20.7
2002	923	266	5.6	4.5	0.005	0.000	10.7	18.8
Medium-high tech								
1996	154	61	2.3	2.6	0.011	0.062	31.2	50.8
1998	203	71	2.0	2.3	0.000	0.025	35.0	49.3
2000	245	103	5.4	4.1	0.000	0.012	30.6	47.6
2002	243	101	4.1	3.4	0.000	0.101	34.2	39.6
High tech								
1996	229	51	2.0	3.6	0.087	0.047	24.5	43.1
1998	287	76	2.2	4.0	0.007	0.000	24.0	36.8
2000	339	90	9.6	5.9	0.117	0.000	25.4	42.2
2002	329	107	11.3	7.2	0.002	0.240	26.1	35.5

Source: Statistical office of Slovenia; own calculations.

What is especially striking in Tables 1 – 3 is that 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 last two innovation surveys (2000, 2002) foreign owned firms show proportionally less R&D expenditures comparative to indigenous firms. Hence, their higher ability to innovate must be driven by other factors, such as constant transfer of technology and other knowledge spillovers from their parent companies. Next sub-section explores further into this issue.

[19] Individual sectors are classified into four technology intensity groups (low technology, medium-low technology, medium high technology and high technology) according to OECD methodology.

5.1.2. Determinants of firms' innovation in Slovenia

In this sub-section we explore the question what drives the innovation activity of Slovenian firms. Integrated approach to the analysis of the impact of external knowledge spillovers on firms' innovation activity (conceptualised in Figure 1) suggests the most important determinants of firms' innovation activity. The list of those available to empirical testing includes:

- Following the endogenous innovation and growth theory, firms' own R&D is crucial for their innovation activity, and also for their capacity to absorb external knowledge spillovers. The higher the own R&D expenditures, the higher the firm's innovation activity and the higher the absorption of external knowledge.
- External knowledge spillovers are becoming increasingly important for firms' overall innovation activity. However, the relevance of different channels of external knowledge spillovers varies considerably. Direct FDI effect, embodied in foreign technology and organizational knowledge transferred by foreign parent companies to their subsidiaries might be by far the most important channel of external knowledge spillovers. As regards knowledge spillovers via trade, learning-by-exporting effect is not obvious. [20]
- The spillover effect from public R&D subsidies in the form of additional funds to the private R&D expenditures of subsidy recipients is not conclusive. One may expect results in the range between weak complementarity and weak substitution.
- Firms' (and countries') absorption capacity is very important for the magnitude of external knowledge spillovers. External knowledge spillovers will increase with own R&D expenditures, foreign ownership, technological intensity of the industry (distinction among high tech, medium high tech, medium low tech and low tech), the level of of human capital, export propensity, and size of the firm. For vertical spillovers, their magnitude might be positively related to domestic market propensity of firms.

[20] Those from imports of capital equipment and intermediate inputs are likely to be positive (but were unfortunately unavailable in these research), while that is much less certain, if at all, for learning-by-exporting.

- External knowledge spillovers may have different impact on product and on process innovations due to different channels of spillovers in both cases. Ornaghi (2004) claims that product innovations are more easily to absorb.

Figure 1: INTERLINKAGES OF SOURCES AND DETERMINANTS OF FIRM'S INNOVATION ACTIVITY USED IN THE MODEL
Based on the findings of econometric literature and depending on data availability

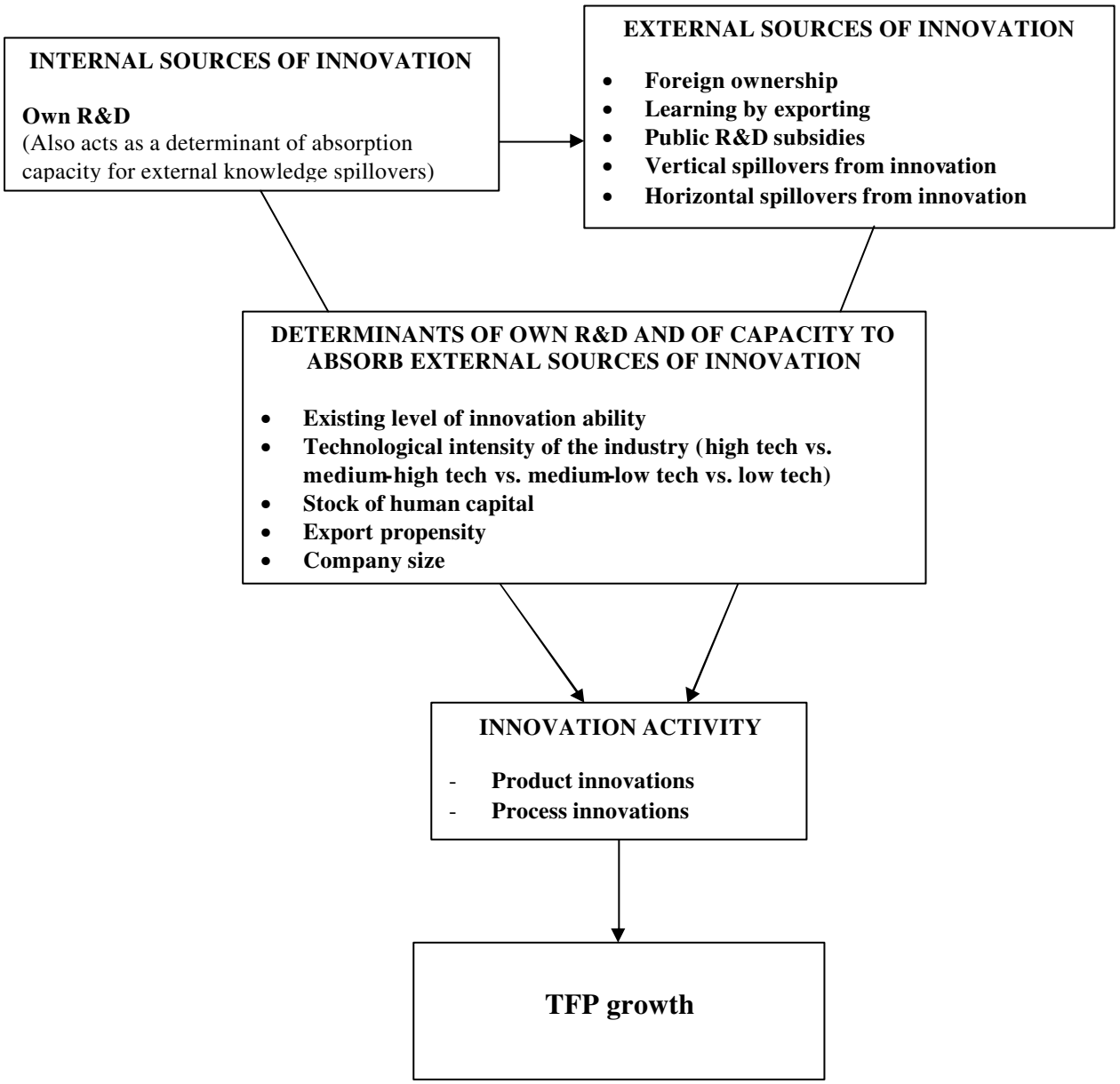

Table 4 shows the importance of above explained determinants of innovation activity by Slovenian firms. It demonstrates that innovation activity of firms is persistent over time, i.e. firms that have been innovative two years ago are more likely to innovate also presently. Table also shows innovative firms are likely to be larger in terms of employment, do invest much more into R&D and also attract higher proportion of subsidies, either public of foreign.[21] At the same time, innovative firms are also more inclined to exports and are more likely foreign owned. Surprisingly, innovative firms do not seem to be more productive in terms of value added per employee (measured to the individual sector average).

Table 4: Determinants of firms' innovation in Slovenia, 1996-2002 (in %)

	N	INOV_ t-2	rVA/ Emp	Emp	R&D/ Sales	R&D/ VA	Total sub./R& D	Public sub./ R&D	Foreign sub./ R&D	Ex/ Sales	IFDI
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: Statistical office of Slovenia; own calculations.

In order to reveal the importance of these individual factors on firms' innovation activity we estimate the probability $INOV_{it}$ [0, 1] of a firm *i* in period *t* to innovate:

$$\Pr(INOV_{it} = 1 | \mathbf{M}_{it}) = G(\omega \mathbf{M}_{it}), \quad (1)$$

where $\mathbf{M}_{it}$ is a matrix of operational characteristics of firms. We assume that errors are IID distributed and have an independent extreme-value distribution. The dependent variable $INOV_{it}$ is equal to 1 if a firm has made any innovation of products (services) or production processes in period *t*, and 0 otherwise. The control variables contained in $\mathbf{M}_{it}$ are those listed in table 4, i.e. a dummy for past innovation activity (lagged one period, i.e. two years), firm size (number of employees), firm relative

[21] However, R&D subsidies on average do not represent significant share of R&D expenditure. According to innovation survey innovation expenditure were mostly covered by own funds.

productivity (firm value added per employee relative to the average productivity of particular sector), share of R&D expenditures in total sales, export propensity and dummy for foreign ownership as well as three variables for the importance of R&D subsidies (total R&D subsidies, public R&D subsidies and R&D subsidies received from abroad, all calculated as a ratio to total firm's R&D expenditures). In the model we also include horizontal and vertical spillovers from innovation activity of other firms. Horizontal spillovers are being measured by the number of innovations done in the same sector. Vertical spillovers are calculated as the number of innovations conducted in a related sector multiplied by the respective input-output coefficient, where the latter reflects the strength of input – output relationship between the sectors. In other words, the more interlinked are both sectors through bilateral supply and demand links and the higher the innovation activity in both sectors the larger is the scope for positive vertical knowledge spillovers between the both sectors. The model also takes into account the technology intensity of the sectors in which firms are operating. It is expected that firms operating in technologically more sophisticated sectors will have higher probability to innovate in order to remain competitive or to build their technological competitive advantage over the competitors. Due to a short and non-balanced panel we do not include the time dummies.

We estimate a probit model using the bi-annual data for a set of manufacturing as well as non-manufacturing firms in Slovenia in the period 1996 – 2002. Results for two separate probit estimations are given in Table 5. Both estimations show that firms present innovation activity is heavily dependent on its previous innovation activity. More specifically, there is a 82% probability that a firm will innovate either a product or process if it was innovative in the previous period. Firm size positively affects firm's ability to innovate, most likely due to the scale effect, i.e. large scale of sales allows for raising enough funds for substantial R&D expenditures. This is confirmed by highly significant and positive sign of the firm own R&D expenditures. While literature is inconclusive regarding the importance of R&D subsidies, our results show that both public R&D subsidies as well as R&D subsidies received from abroad (both measured as a share of firm's total R&D subsidies) help significantly Slovenian firms to increase their ability to innovate.

Table 5: Firms' probability to innovate* in Slovenia, 1996-2002 (Results of a probit model)

	Model 1		Model 2	
	Coef.	z-stat	Coef.	z-stat
$INOV_{t-2}$	0.821	***11.5	0.822	***11.5
Size	0.495	***10.0	0.497	***10.0
rVA/Emp	0.003	0.4	0.003	0.4
R&D/Sales	117.259	***25.2	118.173	***25.2
Total sub./R&D	7.217	***5.1		
Public sub./R&D			8.497	***4.3
Foreign sub./R&D			17.678	*1.7
IFDI	0.119	*1.7	0.117	*1.7
EX/Sales	0.112	1.1	0.103	1.0
HS_INOV	0.008	***3.3	0.009	***3.4
VS_INOV	-0.003	-0.4	-0.002	-0.4
ML tech	-0.043	-0.4	-0.056	-0.5
MH tech	-0.035	-0.3	-0.045	-0.4
H tech	-0.133	-1.0	-0.162	-1.2
Const.	-2.602	***-18.7	-2.603	***-18.7
Number of obs	4167		4167	
LR chi2(12)	2888.5		2897.6	
Prob > chi2	0.00		0.00	
Pseudo R2	0.616		0.618	

Dep.var.: $INOV_t$

* Product and process innovation are treated equally.

Foreign ownership does stimulate firms to innovate while exporting is not shown to have a significant impact of firm's innovation activity. Horizontal knowledge spillovers seem to drive firms innovation activity, while vertical knowledge spillovers are shown not to be important. This can be interpreted in the sense that highly competitive environment in terms of high innovation activity of competitors pushes individual firm to engage in R&D and innovation activity. On the other hand, technological linkages to other sectors seem to be rather weak.

Interestingly and highly striking are the facts that firm's individual productivity and technology intensity of sectors in which it operates do not dominate their innovation activity. One would expect that firms would build their productivity growth upon persistent innovation activity. Accordingly, it is somehow wird that firms engaged in medium-high and high technology intensive sectors are not more likely to be innovative than their counterparts from less technologically sophisticated sectors. Especially since the share of innovation expenditure in sales was also considerably higher in high technology class.[22]

In addition to the above estimations where we treat product innovations equally to process innovations, we also run a separate estimation for each of these types of innovation activity. However, results (see Table A1 in Appendix) are almost identical for both types of innovation activity, which justifies our decision to treat both types of innovation in one common variable. There are only some minor differences in both separate estimations in the sense that process innovations require a slightly larger firms size, while product innovations seem to be more pronounced in foreign owned firms and seem to give slightly higher return to public subsidies.

5.2. Impact of innovation on firms' productivity growth in Slovenia

While the previous sub-section has shown quite an efficiency of firms' own R&D expenditures and R&D subsidies in stimulating firms' innovation activity, this sub-section is aimed at exploring the efficiency of innovations for firms total factor productivity (TFP) growth.

In empirical work we are following the great body of literature on 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 (see Griliches, 1991; and Mairesse and Sassenou, 1991 for comprehensive overview of the empirical studies on R&D contribution to growth). We start from the following production function:

$$Y_{it} = Ae^{\lambda t} K_{it}^{\alpha} L_{it}^{\beta} R_{it}^{\gamma} e^{\varepsilon_{it}} , \tag{2}$$

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

[22] 8,5% compared to 2,5% for medium-high, 2,7% for medium low and 1,4% for low technology sectors for total sample.

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 toward the estimated elasticity γ, which reflects the marginal productivity or rate of return of output to R&D capital.

By log-linearizing one can easily rewrite (2) in the form of first differences:

$$\Delta y_{it} = \lambda + \alpha \Delta k_{it} + \beta \Delta l_{it} + \gamma \Delta r_{it} + \Delta \varepsilon_{it} . \quad (3)$$

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 firm's internal R&D capital $\mathbf{F}_{it}$ and of various spillover effects $\mathbf{Z}_{it}$:

$$R_{it} = f^{i}(\mathbf{F}_{it}, \mathbf{Z}_{it}) , \quad (4)$$

where $\mathbf{F}_{it}$ contains firm own R&D expenditures, measured as a share of R&D expenditures relative to firm's total sales. $\mathbf{Z}_{it}$ captures all spillover effects that enhance firm's ability to innovate, such as foreign ownership, learning by exporting (exports to sales ratio), public R&D subsidies received either from national or international sources as well as innovation spillovers received from other firms within the same sector or from other sectors.

Note that in a panel data framework equation (2) is typically subject to firm specific time invariant disturbances, which one can take control of by using one of the standard panel data econometric techniques (within or between estimators). Alternatively, one can get rid of firm specific effects by estimating the equation as in (3), where by first-differencing the time invariant firm specific effects are simply wiped out. Another problem with the time-series cross-section specification of (2) is a potential endogeneity between the inputs and the output, which may lead to 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 both by using the Olley-

Pakes method or general method of moments (GMM) requires longer time series of input and output data in order to be efficiently used as lagged instruments for firm's present performance.

Table 6: Impact of R&D and innovation on firm's TFP growth of Slovenian firms, 1996-2002

	Model 1		Model 2		Model 3	
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Δ Capital	0.029	***4.5	0.025	*3.4	0.021	***3.0
Δ Labor	0.446	***13.4	0.446	***13.2	0.451	***13.4
Δ R&D/Sales	0.238	*1.9				
INOV			0.069	*1.8		
p[INOV]					0.083	**2.2
IFDI			0.062	*1.8	0.051	*1.8
INOV * IFDI			-0.051	-0.8		
EX/Sales			0.052	1.3		
HS_INOV			0.001	1.5		
VS_INOV			0.002	1.4		
ML tech			-0.055	-1.2		
MH tech			0.036	0.7		
H tech			0.054	0.5		
Const.	-0.205	***-3.0	-0.302	***-3.6	-0.185	***-2.6
Time dummies	No		Yes		Yes	
Number of obs	3144		3073		3073	
F-test	72.81		21.63		45.65	
Adj R-sq.	0.064		0.069		0.068	

Dep.var.: Δ VA
*, ** and *** denote significance of coefficients at the 10%, 5% and 1%, respectively.

In the first specification we follow other empirical studies and estimate (3) by including only R&D expenditures (relative to sales) as a measure of R&D capital. This estimate gives us the upper bound of possible return of output to R&D capital. Indeed, as shown in Table 6 (see Model 1) the estimated elasticity of R&D capital with respect to output growth for Slovenian firms in the period 1996-2002 is about 0.24. This estimate is within the bounds of returns – between 0.04 and 0.56 - found by other empirical studies with similar model specification (see Table 7).

Table 7: Estimates of rate of return to R&D capital in some previous studies

	Sample of firms	Rate of return to R&D
Mansfield (1980)	US chemicals and petroleum firms (1960-76)	0.27
Griliches and Mairesse (1983)	US and French firms (1973-78)	0.28
Clark and Griliches (1984)	US business units (1971-80)	0.20
Sassenou (1988)	Japanese firms (1973-81)	0.22
Lichtenberg and Siegel (1989)	US firms (1972-85)	0.13
Fecher (1989)	Belgian firms (1981-83)	0.04
Griliches and Mairesse (1990)	US firms (1973-80)	0.41
	Japanese firms (1973-80)	0.56

Source: Griliches 1998.

However, in our second specification (see Model 2 in Table 6) we go one step further by estimating the impact of innovations, which is the effective result of R&D, on firm TFP growth. This is our preferable estimation returning the estimate of the rate of return to innovation of 0.069. It demonstrates that in an average Slovenian firm innovation results in TFP growth by 6.9%. In addition to it, foreign ownership enhances firm's TFP growth by additional 6.2%, but our results also show that innovations have the same impact on TFP growth both in foreign owned and indigenous firms (see interaction term INOV*IFDI). Hence, foreign ownership has a double impact on firm's TFP growth. It first enhances firm's ability to innovate that was demonstrated already in the previous sub-section, but then it also contributes additionally to firm's TFP growth via superior organization techniques, etc.

Other external spillover variables included in our specification of model 2, such as export propensity and vertical innovation spillovers, do not seem to have any further impact on firm's TFP growth. As it was demonstrated in the previous sub-section, it is very likely that these external knowledge spillovers only induce firm's ability to innovate but do not affect firm's TFP growth *per se*. We check for this by including the predicted value of innovation that we have estimated in the probit model of "innovation production" (we take predicted values of model 1 in Table 5). The results of including this predicted innovation variable (see model 3 in Table 6) returns a bit higher estimate of the return to innovation (estimate of γ increases to 0.83). But again, foreign ownership is shown to contribute additionally 5.1% to firm TFP growth.

According to the above findings, we can draw three important conclusions for Slovenian firms. First, firm's own R&D expenditures as well as external knowledge spillovers, such as national and international public R&D subsidies, foreign ownership and intra-sector innovation spillovers, do enhance firm's ability to innovate. Second, innovations as a result of firm's R&D do contribute substantially to firm's total factor productivity growth. And third, foreign ownership has a double impact on firm's TFP growth - it enhances firm's ability to innovate, but then it also contributes additionally to firm's TFP growth via superior organization techniques, etc.

6. Conclusions

In spite of rapidly increasing number of studies related to innovation, numerous question related to the process of innovation are still open. Empirical studies mostly explore multiple determinants and effects of innovation activity. Along with the increasing number and complexity of significant determinants of innovation activity and channels of knowledge diffusion identified, exploring their relative importance and simultaneousness effects remains an important research challenge.

Evidence from Slovenia is based on simultaneousness estimation of the importance of internal and external sources of innovation and evaluation of their impact on productivity growth. Own R&D expenditures and previous innovation activity (used as variables of internal sources) are consistently confirmed as significant determinants of innovation activity, however, much more efficient when accompanied by diffusion of knowledge from outside sources. External knowledge spillovers, either domestic or international are thus found as important and innovantion incentive. R&D subsidies, both domestic and from international sources and intra-sectoral innovation spillover complement internal sources and significantly increase the ability of Slovenian firms to innovate. Inward FDI as well significantly increase firms' ability to innovate. Compared to domestic firms, foreign owned firms even show lower average level of R&D expenditures, suggesting that innovation acivity must be driven by other factors such as knowledge and technology spillovers. Exporting, on the other hand has not been found to be an important chanell of knowledge diffusion, or an innovation inducement. Productivity and technological intensity as well do not confirm significant influence on innovation activity.

The importance of the external factors suggests that firms, though being productive, technologically intensive and innovative in the past and in spite of their own R&D activity, are less likely self-sufficient in their current and future innovation activity. As R&D activity is frequently a result of non-cooperative strategy and the character of technology and innovation is non-rival, spillovers are particularly important. External innovation incentives resulting from (foreign and domestic) R&D subsidies, foreign investment and competitive environment (horizontal innovation spillovers) should thus be taken into account as important complementary sources. Exploiting

external spillovers also complements the major effect of R&D sources, which reflects in considerable increase of total factor productivity. For Slovenia, the estimated rate of return to R&D capital by using growth accounting approach amounts to 0.24 and range within the boundaries find by other studies with similar model estimations. Foreign ownership thus has, similarly as R&D, a double impact on firm's TFP growth - it enhances firm's ability to absorb knowledge and innovate, but then it also contributes additionally to firm's TFP growth via superior organization techniques and other channels of knowledge difussion.

Future research of innovation activity might broaden the set of external determinants and examnine domestic and international spillovers in greater detail (vertical and horizontal FDI spillovers, spillovers through imports, more detailed technology spillovers through trade and asimetry of spillovers) which would additionally explain their relative weight. The eventual changes in importance of determinants and effects of innovation activity should also be explored in a dynamic context.

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Appendix

Table A1: Firms' probability to innovate products and processes in Slovenia, 1996-2002 (Results of a probit model)

	Product innovation				Process innovation			
	1		2		3		4	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
INOV_t-1	1.136	18.5	1.137	18.5	0.868	13.1	0.866	13.1
Size	0.438	9.9	0.442	10.0	0.532	12.1	0.531	12.0
rVA/Emp	0.003	0.4	0.003	0.4	0.007	1.0	0.007	1.0
R&D/Sales	18.842	18.0	19.217	18.4	18.489	17.4	18.504	17.5
Total sub./R&D	4.413	6.9			2.851	7.3		
Public sub./R&D			5.115	6.4			3.268	6.2
Foreign sub./R&D			4.771	2.5			2.273	3.5
IFDI	0.146	2.4	0.140	2.3	0.106	1.7	0.103	1.7
EX/Sales	0.241	2.8	0.228	2.6	0.175	2.0	0.171	1.9
HS_INOV	0.007	3.4	0.008	3.4	0.011	5.0	0.011	5.1
VS_INOV	-0.008	-1.5	-0.008	-1.5	0.002	0.3	0.001	0.3
ML tech	-0.030	-0.3	-0.035	-0.4	-0.206	-2.1	-0.214	-2.2
MH tech	0.144	1.5	0.135	1.4	-0.150	-1.5	-0.158	-1.6
H tech	0.188	1.6	0.177	1.5	-0.184	-1.6	-0.183	-1.6
Const.	-2.426	-19.8	-2.424	-19.8	-2.612	-21.2	-2.596	-21.2
Number of obs	4166		4166		4166		4166	
LR chi2(12)	1931.6		1938.3		1536.4		1527.5	
Prob > chi2	0.00		0.00		0.00		0.00	
Pseudo R2	0.438		0.440		0.382		0.380	

Dep.var.: $INOV_t$