Impact of Firm Heterogeneity on Direct and Spillover Effects of FDI: Micro Evidence from Ten Transition Countries

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Abstract

This paper provides a comparative study on the importance of direct technology transfer and spillovers through FDI on a set of ten transition countries by using a common methodology and appropriate methods to account for the selection and simultaneity correction. We use by far the largest firm level dataset (more than 90,000 firms) so far used by any study on spillover effects of FDI. The main novelty of the paper is that we explicitly control for various sources of firm heterogeneity when accounting for different effects of FDI on firm performance. By doing so, we find some contrasting results to the previous empirical work in the field. We find that horizontal spillovers have become increasingly important over the last decade and might become even more important than the vertical spillovers. Furthermore, our exercise shows that it is the heterogeneity of firms in terms of absorptive capacity, size, productivity and technology levels that importantly affects the results. Our findings suggest that both direct effects from foreign ownership as well as the spillovers from foreign firms do substantially depend on the absorptive capacity and productivity level of individual firms. Only more productive firms and firms with higher absorptive capacity are able both to compete with foreign affiliates in the same sector as well as benefit from the increased upstream demand for intermediates generated by foreign affiliates. In addition, our results show that foreign presence may also affect smaller firms in a larger extent than larger firms, but this impact may go in either direction.

Keywords: Foreign direct investment, technology transfer, spillovers, transition economies, firm heterogeneity
JEL Classification: D24, F14

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

1. Introduction

Foreign investors can transfer technology in two ways: directly to the affiliates under their ownership and control, and indirectly to other firms in the host economy through spillovers. There is ample empirical evidence on positive direct technology transfer from a multinational company (MNC) to its foreign affiliates in terms of higher productivity levels and growth. On the other hand, despite the theoretical justification of potential spillovers, the evidence on technology spillovers from a foreign affiliate to its host country horizontal competitors and/or vertically linked suppliers and customers is weak or even negative. According to the literature, there is a number of potential reasons for empirical failure to find significant spillovers. They range from MNCs being effective in protecting their technology advantages and thus in preventing potential spillovers, lack of host countries' firms absorption capacity and non-differentiation between vertical and horizontal spillovers, to the fact that most of the studies have been carried out at the aggregate or sectoral level while, in fact, only some categories of domestic firms are able to absorb FDI spillovers. This puts forward the issue of firm heterogeneity. In addition to these, there are several other, data and methodology related reasons for failing to find evidence of spillovers.

Recently, there is also growing literature on FDI spillovers in transition countries. Most of these analyses is based on firm level panel data and suggest only few intra-industry spillovers from FDI, if at all. Some of the more recent studies provide more optimistic results about FDI spillovers in some transition countries, at least in some sectors or categories of FDI. These studies provide a useful insight into the effects of international R&D spillovers to transition economies at the firm level, but due to heterogeneous methodology used, they remain merely case studies.

This paper has two primary objectives. The first objective is to provide a comparative study on the importance of direct technology transfer and spillovers through FDI by using an exhaustive firm-level dataset on a group of comparable countries by using a common methodology and appropriate methods to account for the selection and simultaneity problems. This is the way to achieve comparability of the results and to provide a credible insight into the importance of FDI as a channel of international technology transfer for firms in transition countries. The second objective of the paper is to account for inherent heterogeneity of firms. Most of the empirical work so far dealing with the issue of spillover effects from FDI on firm performance widely neglected the fact that local firms in competition with foreign affiliates in the same sector or in cooperation with upstream foreign affiliates are not homogeneous in terms of size, absorptive capacity, productivity and technology gap. Some recent studies, however, demonstrate that firm heterogeneity in terms of absorptive capacity might explain a lot of differential impact of FDI on firm performance. In this paper we account explicitly for different aspects of firm heterogeneity, including size, absorptive capacity, productivity and technology gap relative to foreign affiliates.

We differentiate between direct effects of FDI from the parent firm to foreign affiliates as well as horizontal and vertical spillovers from these affiliates to domestically owned local firms. To calculate horizontal and vertical spillovers and to differentiate between backward and forward vertical linkages, we use the methodology developed by Blalock (2001) and Damijan et al (2003a, 2003b). The importance of these different channels of technology transfer is then estimated in the framework of the growth-accounting approach using the unique firm-level database consisting of the panel of some 91,500 firms for 10 transition countries in the period 1995-2005 - eight new EU member states (Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania and Slovenia), plus Croatia and Ukraine.[1] We use several correction methods to account for possible biases in the data. We deal with the simultaneity problem that typically arises in the growth-accounting approach in the panel data framework by using the Olley - Pakes method. In addition, we correct for potential selection bias that arises due to possibly endogenous foreign investment decisions using a generalized Heckman two-step procedure.

In the course of estimations we then slice our datasets by countries to smaller subsamples according to size classes, productivity quintiles and technology gaps as well as control for firm absorptive capacity. Our empirical exercise reveals several interesting findings. First, direct effects of foreign ownership on firm (foreign affiliate) performance are rather rarely present in our exhaustive dataset on ten transition countries (in three countries only), but, if present, they are strictly positive. Second, horizontal spillovers are mostly negative if not controlled for absorptive capacity of firms. When accounting for firms' absorptive capacity, in most of the countries (in six to seven out of ten countries) firms do benefit from the increased competition of foreign affiliates in the same sectors. Third, positive horizontal spillovers are equally distributed across size classes of firms, while negative horizontal spillovers seem to accrue more likely to smaller firms. Fourth, positive horizontal spillovers seem more likely to be present in medium or high productivity firms with higher absorptive capacities, while negative spillovers are more likely to affect low to medium productivity firms. Fifth, vertical spillovers are less frequent than horizontal spillovers from FDI. However, if present, then smaller and more productive firms are more likely to benefit from positive vertical spillovers, while larger and less productive firms are more likely to suffer from negative vertical spillovers.

The paper is organized as follows. Section 2 discusses channels of technology transfer through FDI and section 3 develops a theoretical model that allows for accounting different measures of spillovers at the firm level. Section 4 describes the data and econometric approach employed. Section 5 presents the results, and the final section concludes.

2. Channels of technology transfer through FDI

There are many ways that a firm can acquire new technology besides its own investments into R&D capital. Despite trade, FDI is potentially the most important international vehicle of technology transfer for firms. Foreign investors can transfer technology in two ways: directly to the affiliates under their ownership and control and indirectly to other firms in the host economy through spillovers. The empirical evidence on positive direct technology transfer from MNCs to their foreign affiliates in terms of higher productivity levels and growth is ample. Empirical studies, using firm-level panel data, include developed as well as developing countries (for example,

[1] The choice of countries has been determined by the data availability and quality.

Haddad and Harrison, 1993; Blomström and Wolff, 1994; Blomström and Sjöholm, 1999; Aitken and Harrison, 1999; Girma et al, 2001; Barry, Görg and Strobl, 2002; Alverez et al, 2002; Blalock, 2001; Damijan et al, 2003b; Arnold and Smarzynska-Javorcik, 2005; Girma and Görg, 2006). 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 Romeo, 1980), and has the most direct effect on the efficiency of firms. 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 (Blanchard, 1997).

The extent and scope of technology transfer from MNCs to their foreign affiliates heavily depend on the position of foreign affiliates in the MNCs' international production network (see, for instance, White and Poynter 1984, Bartlet and Ghoshal 1989, Young, Birkinshaw and Hood 1998).[2] This points to the importance of including parameters of foreign affiliates' heterogeneity in the analysis of technology transfer from their parent companies.

The other way of technology transfer through FDI is spillovers from foreign affiliates to domestic firms. They take place when the entry or presence of foreign affiliates, which have typically better technologies and organizational skills than domestic firms, increases knowledge of domestic firms, and foreign investors do not fully internalize the value of these benefits (Griliches 1979, 1992). FDI spillovers can occur between firms that are vertically integrated with the MNC (vertical, inter-industry spillovers) or in direct competition with it (horizontal, intra-industry spillovers). Kokko (1992) identifies at least four ways that technology might be diffused from foreign affiliates to other firms in the host economy: demonstration-imitation effect, competition effect, foreign linkage effect and training effect. Not all spillovers are positive, as FDI can generate negative externalities when foreign firms with superior technology force domestic firms to exit. These negative externalities are also often called the competition effect, crowding-out effect or business-stealing effect. The substantial body of empirical literature on FDI spillovers, which has developed in the last nearly 30 years, has produced mixed empirical results. The econometric analyses have found positive, neutral, as well as negative spillovers from foreign subsidiaries to domestic firms. The discussion on FDI spillovers mainly focuses on estimates of the magnitude of intra-industry FDI spillovers in terms of domestic productivity, which constitutes the largest and the most influential literature (Keller and Yeaple, 2003: 3-5). There is also no strong consensus on the associated magnitudes of FDI spillovers (Blomström et al, 2000), or on the causality (Lim, 2001; Rodrik, 1999).

Overviews of literature on FDI spillovers (see, for instance, Görg and Strobl, 2001; Görg and Greenaway, 2004; Hanson, 2001; Smarzynska-Javorcik, 2004; Keller and Yeaple, 2003; Keller, 2004) mostly identify three types of analysis, i.e. case studies,

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[2] One of the first and still frequently used classifications of this kind is the one by White and Poynter (1984), who differentiate among five types of foreign affiliates - marketing satellite, miniature replica, rationalized manufacturer, product specialist and strategic independent unit - with obivously very different extent and scope of technology transfer.

sectoral studies and lately primarily firm level data based studies. Traditionally, FDI spillovers were assessed by sectoral and case studies. They mostly demonstrated positive FDI spillovers. Lately, it si firm level, preferably panel data based studies, which dominate (Görg and Strobl, 2001; Görg and Greenaway, 2004; Keller and Yeaple, 2003; Keller, 2004; Knell and Rojec, 2007). The main reason that empirical analysis of FDI spillovers moved towards using firm level data was a heterogeneity problem (Keller, 2004). Firm-level panel data analysis uses regressions of productivity on FDI and a number of control variables. Most firm level studies cast doubt on the existence of FDI spillovers in developing countries (Haddad and Harrison, 1993; Aitken and Harrison, 1999; Harrison, 1996; Blomström and Sjöholm, 1999; Lim, 2001 etc.); if positive they have been found to be limited to certain (types of) industries (Haddad and Harrison, 1993; Blomström and Sjöholm, 1999; Blomström et al, 1994). The picture is slightly more optimistic for industrialized countries (Girma, Greenaway and Wakelin, 2001; Haskel et al, 2001; Barry, Gőrg and Strobl, 2002; Alverez et al, 2002, etc.).

Recently, one witnesses a growing literature on FDI spillovers in transition countries; the evidence from firm-level panel data analysis suggests only few intra-industry spillovers from FDI. Konings (2001) shows that FDI may be important for transferring technology to an affiliate, but provides no evidence of horizontal spillovers to local firms in Bulgaria, Poland and Romania from 1993 to 1997. Instead, there is significant evidence of negative spillovers in Poland. Djankov and Hoekman (2000) also provide evidence of negative spillovers and suggest that there may not even have been much technology transfer to foreign affiliates in the Czech Republic from 1992 to 1996. Kinoshita (2000) provides evidence of spillovers in the Czech Republic from 1995 to 1998, but they are limited to firms engaged in R&D or in the production of electrical equipment. Tytell and Yudaeva (2005) demonstrate positive FDI spillover effects on domestic firms in Poland, Romania, Russia and Ukraine, but only in the case of export-oriented FDI. Damijan et al (2003b, for 10 transition countries), Gorodnichenko et al (2007, for 17 emerging market economies), Schoors and van der Tool (2001), and Smarzynska-Javorcik (2004) all find some evidence of (backward) vertical spillovers from FDI but much less evidence, if at all, for horizontal spillovers. Nicolini and Resmini (2006) find evidence of both horizontal and vertical-backward and vertical-forward spillovers on domestic firms generated by foreign firms in Bulgaria, Romania and Poland.

The overall impression of the lack of evidence on FDI spillovers is predominantly due to the results of the firm-level panel data analysis. This is important because it is panels, using firm-level data that are the most appropriate estimation method of FDI spillovers. Gőrg and Greenaway (2001, 2004) list a number of reasons for the failure to find unambiguously positive spillover effects in econometric work. This is supported by the work of other authors:

a/ In a number of cases there may really be no (or even negative) spillovers. Foreign investors may be effective at ensuring that their technology advantages and other firm specific assets do not spill over, or may even reduce the productivity of domestic firms through competition effects (Aitken and Harrison, 1999; Caves, 1996; Konings, 2001; Sgard, 2001; Gőrg and Strobl, 2001).

b/ Spillovers may not occur horizontally (intra-industry) but through vertical relationships, which are missed in conventional spillover studies (Blalock, 2001;

Schoors and van der Tool, 2001; Kugler, 2006; Smarzynska-Javorcik, 2004; Damijan et al, 2003a, 2003b; Halpern and Murakozy, 2007, etc.).

c/ Positive spillovers may only affect a sub-set of firms and aggregate studies, therefore, underestimate the true significance of such effects. This is the firm heterogeneity problem. Studies that further disaggregate data into more homogenous groups of firms and plants, find more encouraging results as far as FDI spillovers is concerned (Gőrg and Greenaway, 2004). Firm heterogeneity has many aspects which act in different directions; it relates to: (i) geographical distance between foreign affiliates and domestic firms, (ii) time/dynamic dimension of FDI spillovers, (iii) heterogeneity of foreign affiliates, (iv) heterogeneity of foreign investors and, (v) heterogeneity of domestic firms related to the absorption capacity issue. The introduction of firm heterogeneity in the analysis proves to be a very important development in empirical studies of FDI spillovers.[3]

d/ Lack of absorption capacity in host countries. Empirical evidence (Kokko, 1994; Borensztein et al, 1998; and Kinoshita, 2000) 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.

e/ In addition to these, there are several other, data and methodology related reasons for failing to find evidence of spillovers. One reason is poor data quality, limited samples and short panels of firms studied. The second reason might be in hypothesizing a linear relationship between spillovers and local firms' productivity growth, and in the incorrect specification of the model.[4] Yet another reason might lie in using inappropriate econometric techniques such as simple pooled OLS or static panel data techniques (Gőrg and Greenaway, 2001, 2004; Knell and Rojec, 2007).

By applying the firm-level panel data analysis, in this paper we specifically tackle some of the above problems of FDI spillovers analysis, i.e. we distinguish between vertical and horizontal spillovers, and introduce the following sources of firm heterogeneity: geographical distance between foreign subsidiaries and domestic firms, time/dynamic dimension of technology transfer through FDI, heterogeneity of domestic firms as far as technological capacities, productivity and human capital is concerned. Let us briefly overview the evidence of existing literature on the above-mentioned aspects.

Vertical and horizontal FDI spillovers. The fact that entry of a MNC may stimulate the development of host country upstream industries supplying parts or components has been recognised long ago (Markusen and Venables, 1999). However, only relatively recently, empirical studies of FDI spillovers take explicit account of the differentiation between vertical and horizontal spillovers. The overwhelming conclusion of these studies is that horizontal intra-industry spillovers are less likely to take place than vertical spillovers. With rare exceptions - Smarzynska and Spatareanu

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[3] For an overview of the literature on the importance of different sources of heterogeneity for FDI spillovers see Knell and Rojec, 2007.

[4] Castellani and Zanfei (2007) claim that modelling MNCs' presence as the share of total activities should control for the size of the industry; if not estimates of externalities tend to be biased to zero. Keller and Yeaple (2003) and Gőrg and Strobl (2001) also put high importance on the accurate measuring of foreign presence.

(2002) for Romania - these studies mostly suggest positive vertical spillovers for host countries. Thus, Blalock (2001) finds positive productivity spillovers from FDI in upstream industries in Indonesia; Schoors and van der Tool (2001) find positive vertical spillovers in Hungary; Kugler (2006) finds FDI knowledge spillovers between but not within industries of the Colombian manufacturing sector; Smarzynska-Javorcik (2004) finds positive backward FDI spillovers but no horizontal spillovers in Lithuania; for ten advanced transition countries, Damijan et al (2003b) for 10 transition countries find that vertical spillovers are much more important than horizontal spillovers; Gorodnichenko et al (2007) for 17 emerging market economies find that backward spillovers are consistently positive, that forward spillovers are positive only for old and service sector firms, while horizontal spillovers are insignificant but positive; Halpern and Murakozy (2007) find positive vertical and negative horizontal FDI spillovers in Hungary.[5] The message of the above research is more than clear; empirical studies on technology spillovers should differentiate between horizontal and vertical spillovers, while the analysis of vertical spillovers should further differentiate between backward and forward linkages induced by foreign affiliates.

Geographical distance between foreign subsidiaries and domestic firms is probably the oldest recognised firm heterogeneity determinant of knowledge spillovers; it has been brought in the analysis already by Griliches (1979, 1992). Domestic firms that are located near to MNCs and their subsidiaries may be more likely to benefit than other firms (Gőrg and Greenaway, 2004). Geographical proximity is necessary to facilitate knowledge spillovers (Audretsch, 1998), because for transmitting knowledge face-to-face communication and other kinds of personal interaction are important, especially as far as tacit knowledge transfer is concerned (Jacobs, 1993). With the exception of Sjőholm (1999), and Aitken and Harrison (1999) who fail to find evidence for a regional component of FDI spillovers in Indonesia and Venezuela, empirical evidence confirms that technological spillovers are limited by distance. Branstetter (1996) claims that spillovers are primarily intra-national in scope, Girma and Wakelin (2002) find positive spillovers in domestic UK firms located in the same region as foreign subsidiaries, while Sgard (2001) in domestic Hungarian firms located in the most developed region, closer to the EU borders. Halpern and Murakozy (2007) also find that distance matters for backward linkages in the Hungarian case.

Time/dynamic dimension of FDI spillovers has only exceptionally been present in the analysis of FDI spillovers but offers another possibility to improve the accuracy of the empirical research. Kosova (2006) tackles the problem by analyzing the effect of foreign firm presence on the growth and survival of domestic firms in the Czech Republic. She finds both negative crowding out effect and positive technology spillover effect. Crowding out appears to be a short-term or static phenomenon: initial foreign entry increases the exit rate of domestic firms. Subsequently, however, the growth of the foreign industry segment is accompanied by increases in both the growth rate and survival of domestic firms. This seems to confirm that foreign subsidiaries tend, with the passage of time, to intensify their vertical relations with

[5] Other sources dealing with vertical versus horizontal FDI spillovers include Kugler (2001, 2002), Blalock and Gertler (2003), Damijan et al (2003a), Driffield et al (2002), Harris and Robinson (2002), Girma et al (2003).

local firms and to establish more stable linkages with the local environment (Cantwell, 1989).

Heterogeneity of domestic firms as a determinant of technology spillovers through FDI relates primarily to their productivity, technological capacity and human capital. These factors determine domestic firms' absorption capacity for spillovers (For an overview of relevant literature see Knell and Rojec, 2007). Absorption capacity for knowledge spillovers is most frequently directly 'measured' by firm's *level of technological capacity*. Any technology gap signals something about absorptive capacity (Glass and Saggi, 1998). Given that MNCs tend to tap into local lines of technological development and/or to import more technology to productive locations in which local competition is strongest, existing centers of excellence in the development of a certain technology will benefit most from possible technological spillovers. In these productive areas the importing of technology by foreign subsidiaries, and the absorption of foreign technology by local firms, will interact to generate virtuous circles of technological development (Cantwell, 1987, 1989). The empirical literature – Perez (1998) for UK and Italy, Halpern and Murakozy (2007) for Hungary, Ben Hamida and Gugler (2007) for Switzerland, Abraham et al (2006) for Chinese manufacturing sector, Girma et al (2006) for Chinese state-owned enterprises - predominantly confirms that knowledge spillovers occur more frequently if technology gap between domestic and foreign firms is not too large and thus a sufficient absorptive capacity is available in domestic firms. In contrast, Findlay (1978) claims that bigger technological gap offers more room for technological spillovers.

Differences in technological capacity of domestic firms are frequently proxied by *differences in their productivity levels*.[6] According to Keller and Yeaple (2003: 28), the U.S case shows that a relatively high productivity is required for a firm to acquire FDI related spillovers. In the case of Bulgaria, Romania and Poland, only more productive firms have been able to reap technological externalities emanating from FDI (Nicolini and Resmini, 2006). Quite the opposite, Haskel et al (2001) estimate that less productive (and smaller) UK plants receive on average stronger FDI spillovers than more productive (and larger) ones. Castellani and Zanfei (2003), on the case of France, Italy and Spain, find that high productivity gaps tend to favour positive effects of FDI.

Human capital capacity is probably the most frequently used measure of firm's absorption capacity for FDI spillovers. It is argued that human capital capacity increases the ability of domestic firms to benefit from positive spillovers (Borensztein et al, 1998; Meyer and Sinani, 2001). Thus, Ben Hamida and Gugler (2007) find positive FDI spillovers only in the sub-sample of domestic Swiss firms, which substantially invest in upgrading their human capital. Spillovers, however, affect negatively the productivity of domestic firms which do not actively engage in investment and learning. Girma et al (2006) similarly claim that there is a positive effect of FDI on Chinese state-owned enterprises that invest in human capital. Gorodnichenko et al (2007), however, find that firms with a larger share of university

6 Thus, Ben Hamida and Gugler (2007) define technological gaps of domestic firms as the ratio of the average labour productivity of foreign-owned firms in the relevant four-digit industry to domestic firm's own labour productivity.

educated workforce do not enjoy greater FDI spillovers than firms with less educated workers.

Yet another determinant of domestic firms' absorption capacity and knowledge spillovers via FDI, identified in the literature, is *company size* (Knell and Rojec, 2007). Company size seems to have a positive influence on domestic firms' absorption capacity. It is generally recognised that size has a positive influence on firms' innovation activity (Veugelers and Cassiman, 1999) and absorption capacity (Ornaghi, 2004).[7]

3. Modeling direct and spillover effects of FDI

As indicated by the above discussion, empirical studies on technology spillovers have to differentiate between direct effects of FDI as well as horizontal and vertical spillovers. In the search for horizontal spillovers, one should account for the technology gap between foreign affiliates and local firms, while the analysis of vertical spillovers should differentiate between backward and forward linkages induced by foreign affiliates.

Recent studies on technology transfer and spillovers through FDI are typically carried out using firm-level panel data. The impact of external technology spillovers can be measured indirectly in a production function approach by considering the Sollow residual of output growth as the rate of technological change after subtracting off the growth rates of labor and capital. But this residual may be more a measure of ignorance than a measure of technological accumulation, as Abramovitz (1956) pointed out. An alternative way is to include the technology variables directly in the production function, a method more reminiscent of the endogenous growth models developed since the late 1980s. This approach provides a way to study the various factors that affect productivity growth, including the technological accumulation. This is done by using the growth-accounting approach and decomposing total factor productivity (TFP) into factors internal and external to the firm, such as R&D activity, human capital and channels of technology transfer.

We assume each firm has a production function for gross output:

$$Y_{it} = Q^i(K_{it}^{\alpha} L_{it}^{\beta} T_{it}) \qquad i=1,...,n, \tag{1}$$

where Y_{it} is value added in firm i at time t, which is a firm specific Q^i function of $K_{it,}$ L_{it}, and T_{it} (capital stock, number of employees, and technology parameters, respectively). The production function (1) is homogenous of degree r in K and L, such that $r=\alpha+\beta \neq 1$, which implies that Q^i may have non-constant returns to scale.

Differentiating equation (1) with respect to time, we get:

$$y_{it} = \alpha k_{it} + \beta l_{it} + t_{it} \tag{2}$$

where small letter variables indicate logarithmic growth rates of K, L and T, and α and β represent the elasticity of output with respect to k and l. We assume that technology

[7] One of rare exceptions is Aitken and Harrison (1999) who find that productivity in small Venezuelan firms has increased following the presence of MNCs, while there does not appear to be similar effect on large domestic firms.

shock T is a function of internal technology variables $\mathbf{G}_{it}$ and of various spillover effects $\mathbf{Z}_{it}$:

(3) $$T_{it} = f^{i}(\mathrm{G}_{it}, \mathrm{Z}_{kt})$$

where

$$(F_{it}, H_{it}) \in \mathrm{G}_{it}$$
$$(ES_{kt}, HS_{kt}, VSb_{kt}) \in \mathrm{Z}_{kt}$$

where the elements of G_{it} are foreign ownership F_{it}, and firm human capital H_{it} measured with the firm average wage bill. Z_{kt} consists of potential home market spillovers ES_{kt} (external economies of scale at the industry level k), horizontal spillovers HS_{kt} and of vertical backward spillovers VSb_{kt}, both measured at the industry level k.

The basic idea underlying equation (3) is that an individual firm can boost its technology level either internally through appropriate ownership structure and own investments into human capital and/or by relying on external sources of knowledge spillovers, such as home market spillovers as well as horizontal and vertical spillovers from affiliates of MNCs.

Regarding the impact of FDI, MNCs can transfer newer technology and organizational skills both directly to the affiliate and indirectly to other firms in the host economy. On the one hand, direct effects generally appear to affiliates as changes in productivity (shown in Q^{i}) and in potential better utilization of existing inputs. The presence of an affiliate, on the other hand, can also increase the rate of technical change and technological learning in the economy indirectly through knowledge spillovers to local firms. Knowledge spillovers occur as a consequence of an affiliate introducing new technologies and organizational skills that are typically better than at local firms. The innovation system and social capabilities of the host economy, together with the absorptive capacity of other firms in the host economy measured by own investments into human capital (H_{it}), will then determine the pace of technological progress in the economy as a whole.

Knowledge spillovers can occur either between all firms in the industry (external spillovers) or are related to foreign owned firms. Knowledge spillovers stemming from foreign owned firms arise between firms that are vertically integrated with the foreign affiliate (inter-industry spillovers) or in direct competition with it (intra-industry spillovers). Kokko (1992) and Perez (1998) describe at least five ways of how knowledge spillovers from foreign affiliates can increase technical change and technological learning. First, competition with the foreign affiliate can increase intra-industry spillovers by stimulating technical change and technological learning. Greater competitive pressure faced by local firms induces them to introduce new products to defend their market share and adopt new management methods to increase productivity. This sort of spillover, known as the competition effect, is the most important in industries with relatively low actual and potential competition and high barriers to entry. Second, cooperation between foreign affiliates and upstream suppliers and downstream customers increases knowledge spillovers (vertical spillovers). To improve the quality standards of their suppliers, foreign affiliates often provide resources to improve the technological capabilities of both vertically and horizontally linked firms. Third, human capital can spill over from foreign affiliates to other firms as skilled labor moves between companies. These spillovers are especially important for firms that lack the technological capabilities and managerial skills to compete in world markets. Fourth, the proximity of local firms to foreign affiliates can sometimes lead to demonstration or imitation spillovers. When foreign affiliates introduce new products, processes and organizational forms, they provide a demonstration of increased efficiency to other local firms. Local firms may also imitate foreign affiliates through reverse engineering, personal contact and industrial espionage. Finally, a concentration of related industrial activities may also encourage the formation of industrial clusters, which further encourage FDI and local spillovers.

Although there are clear differences between these types of knowledge spillovers, 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. Studies that estimate spillover effects using the production function approach similar to the one specified in equation (2) subject to (3), unintentionally pick up inter-industry effects contained in the variable Y. But with the exception of Blalock (2001), Schoors and van der Tool (2001) and Smarzynska (2002, 2004), Damijan et al (2003b), Kugler (2006), Halpern and Murakozy (2007), and Gorodnichenko et al (2007), all of the panel data analyses on the effect of knowledge spillovers on productivity growth consider only intra-industry effects. In the present study, we draw on Blalock (2001) and Damijan et al (2003b) in order to capture these inter-industry effects by incorporating direct requirement coefficients derived from the input-output accounts from each country into the empirical model.

To disentangle the two spillover effects, we define the scope for intra-industry spillovers, or horizontal spillovers, as the share of an industry's output produced by the foreign affiliates:

$$(4) \qquad HS_{kt} = \frac{\sum_{i=1}^{n} FA_{ikt}}{\sum_{i=1}^{n}\left(FA_{ikt} + DF_{jkt}\right)}, \qquad i=1,\ldots,n,$$

where HS_{kt} is horizontal spillovers in industry k in period t, FA_{ikt} and DF_{ikt} is value added of foreign affiliate i and domestic owned firm i in industry k and period t, respectively. These spillovers reflect mainly the competitive pressures that encourage local firms to introduce new products to defend their market share and adopt new management methods to increase productivity. Imitation, reverse engineering, personal contact and industrial espionage may also be captured by this variable. However, exports often comprise a large proportion of the output of foreign affiliates, reducing the impact they might have had on the domestic market. To compensate for this reduction of competitive pressures in the domestic market, we correct the measure of horizontal spillovers in (4) by the share of exports of foreign affiliates EX_{ikt} in their value added Y_{ikt}:

(5) $$\overline{HS}_{kt} = \frac{\sum_{i=1}^{n} FA_{ikt}}{\sum_{i=1}^{n}\left(FA_{ikt} + DF_{jkt}\right)} * \left(1 - \sum_{i=1}^{n}\frac{EX_{ikt}}{Y_{ikt}}\right),$$

In the next step, we account for potential vertical spillovers of foreign affiliates, i.e. for the impact of foreign affiliates on their upstream suppliers.[8] Foreign affiliates often provide resources to improve the technological capabilities and quality standards of their upstream suppliers. We account for these backward linkages VSb_{kt} as a sum of output of industries *r* purchased by firms in the industry *k* weighted by the share of total foreign output HS_{kt}:

(6) $$VSb_{kt} = \sum_{r,k=1}^{p}\left(\alpha_{krt} * HS_{kt}\right), \qquad r,k=1,...,p,$$

where α_{krt} ($0 \leq \alpha_{krt} \leq 1$) is the proportion of industry's *r* output consumed by industry *k*. These direct input requirements are obtained from the input-output accounts. Again, foreign affiliates tend to purchase a larger proportion of their inputs abroad than domestic firms, hence reducing the actual demand for home intermediate goods. Therefore, the measure of backward linkages in (6) should be corrected by foreign affiliates' import share:

(7) $$\overline{VSb}_{kt} = \sum_{r,k=1}^{p}\left(\left(\alpha_{krt} * HS_{kt}\right) * \left(1 - \sum_{i=1}^{n}\frac{IM_{ikt}}{MC_{ikt}}\right)\right), \qquad r,k=1,...,p,$$

where IM_{ikt} and MC_{ikt} are imports and material costs of foreign affiliate i.

It is important to note that not all spillovers are positive. The parent firm can also have a negative impact on the direct transfer of technology to its affiliate and reduce the knowledge spillovers to the local economy. For example, MNCs can provide their affiliates with too few, or the wrong kind of technological capabilities, or even limit access to the technology of the parent company. This type of behavior may restrict the production of its affiliate to low-value activities and can also reduce the scope for technical change and technological learning both within the affiliate and as spillovers to the domestic economy. Even if the parent firm transfers new technology to its affiliate, it can reduce the scope for knowledge spillovers by limiting downstream producers to low value-added activities or eliminate them altogether by relying on foreign suppliers (including itself) for higher value-added intermediate products. Domestic firms that do not have the capability to adapt can also be crowded out of the market. Bardham (1998) also suggests that the parent company can restrict domestic production when it sets up affiliates with the main purpose of protecting existing property rights and taking out patents in the host country.

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[8] In this paper, we account for backward linkages only, i.e. for the impact of foreign affiliates on their upstream suppliers. Similarly, foreign affiliates can also provide technical assistance to their downstream customers. However, as foreign affiliates are mainly engaged in end-user consumer goods, these forward linkages are found in empirical studies to be rather low or insignificant (Smarzynska-Javorcik (2004), Gorodnichenko et al (2007), Halpern and Murakozy (2007)). This is the reason why we neglect this issue in the present study.

Finally, one has to take account also of the external knowledge spillovers that are generated at the industry level and which can benefit all the firms in the industry. Ethier (1979), Markusen and Melvin (1981) and Helpman (1984) provide the strain of the literature emphasizing the importance of external spillovers among differentiated firms in an industry. The larger the industry, the larger the scope either for inter-firm exchange of components or for competition among differentiated firms. We capture these spillovers by the size of the industry, measured with the aggregate value added:

$$(8) \qquad ES_{kt} = \sum_{i=1}^{n} Y_{ikt}, \qquad i=1,...,n,$$

Castellani and Zanfei (2007) emphasize that in addition to the horizontal spillovers variable the size of sector (i.e. external spillovers) should also be included into the empirical model. The reasoning is straightforward, as horizontal spillovers are defined as a ratio of value added of foreign owned firms relative to the total industry value added, the elasticities of domestic firms' productivity to foreign and total industry activity are restricted to be equal in magnitude but with inverted signs. Clearly, when this restriction is not satisfied, the horizontal spillover coefficient may be downward biased. Using the case of Italian manufacturing firms, they demonstrate that a more accurate specification of externalities yields larger (positive and significant) spillover effects.

4. Data and econometric approach

4.1 Data

Data at the firm level provide the best way to test for FDI productivity spillovers. In order to analyze the importance of different channels of technology transfer via FDI in a comparative way, we gathered panel data for 10 transition economies: Bulgaria, Czech republic, Croatia, Estonia, Latvia, Lithuania, Poland, Romania, Slovenia and Ukraine. The data on balance sheets and financial statements were collected for the period 1995-2005 for most of the countries, with the exception of Estonia (1997-2005), Latvia (1996-2005), Slovenia (1995-2003) and Ukraine (1998-2005). The source of data is the Amadeus database (Bureau van Dijk), while for Slovenia, data were obtained from the local statistical office. We use the full Amadeus database, but limit our database to manufacturing firms only, where we put no limitations on the size threshold. Our data hence includes firms from all size classes, including micro and small firms. Our dataset consists of more than 90,000 firms with up to 11 annual observations, which would theoretically yield almost one million annual observations. However, the dataset is not balanced, while on the other side due to the requirements of the econometric methods used in this paper (Olley-Pakes corrections) we maintain in the empirical estimations only firms with 5 or more annual observations. These restrictions limit the size of our data in empirical estimations effectively to some 315,000 annual firm observations. This is by far the largest firm level dataset so far used by any study on spillover effects of FDI.[9]

[9] In our previous study (Damijan et al, 2003b) we have used data on some 8,000 firms in ten transition countries for the period 1994-1999. Note that Gorodnichenko et al (2007) use 2005 BEEPS (Business Environment and Enterprise Performance Survey, a joint initiative of the European Bank for Reconstruction and Development (EBRD) and the World Bank Group) data for

[Insert Table 1]

Some basic characteristics of the data are contained in the Table 1 which reveals that the best firm level data coverage is for Romania (48,500 firms), followed by Bulgaria (9,500 firms), Czech Republic (8,500 firms), Poland (6,000 firms), Ukraine (5,500 firms), while for Croatia, Estonia and Slovenia we have between 3,000 and 4,000 annual firm observations. On the other side, relatively poor coverage is for Lithuania (700 firms) and Latvia (1,500 firms).[10] Note, however, that the most reliable dataset in our country sample is data for Slovenia which is obtained from national statistical office and which covers virtually all manufacturing firms that were active in the period and that had at least one employee.

We dispose with the data on the share of foreign investors in total equity of domestic firms. According to other studies and our previous work, the foreign ownership variable is constructed as a dummy variable F_i equal to 1 when the share of foreign equity in total capital of a domestic firm exceeds 10%, and 0 if otherwise. Note that we are using Amadeus database of different vintages, which allows us to detect any changes in ownership that occurred between two consecutive years. This allows our foreign ownership variable to vary across time. Table 1 reveals that although a share of foreign firms in the total number of firms in the sample varies between 4 (Bulgaria) and 10 per cent (Poland), their contribution to the value added of the sample firms varies between 7 (Bulgaria) and 29 per cent (Poland). This shows that foreign owned firms are larger than domestic owned firms indicating possible selection problems, which we will deal with in the next subsection.

Data on labor enter our estimations as a number of employees, which is calculated from effective hours worked, while data on value added and capital are taken in local currencies. Capital data were deflated using GDP deflators, while data on sales were deflated using NACE 2-digit producer price indices for each country.[11]

Data on input-output accounts stem from local statistical offices. These data conducted at NACE 2-digit level refer mainly to individual years between 2000 and 2003. Unfortunately, these input-output tables are not available at a more disaggregated level and for all years in our sample. This, of course, may substantially limit our potential to discover possible vertical spillovers as these are normally taking place at a lower level of disaggregation as well as we are forced to exclude dynamic changes in the structure of studied economies. As a way of overcoming these limitations we have also applied the NACE 2-digit input-output coefficients to the

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17 transition countries. The BEEPS 2005 data, however, has two important limitations. First, it accounts only for 200-600 surveyed firms per country, of which the share of firms in services ranges from 50% to 65% and between two-thirds and three-quarters of the firms are small (less than 50 employees). And second, it provides only one single observation (growth from 2002 to 2005 in sales and the inputs) per firm.

[10] Note that we had to skip from our sample countries like Hungary and Slovakia, which are extremely poorly represented in the Amadeus database.

[11] GDP deflators and PPI data for individual countries is taken from the Eurostat, with the exception of Croatia and Ukraine where the source of the data are national statistical offices.

NACE 3-digit sectors when calculating the vertical spillovers. We report results with both levels of spillovers aggregation.

4.2. Correction for sample selection bias

The usual problem with empirical studies on firm level effects of FDI is an inherent selection bias. This is due to the fact that foreign investment decisions are not randomly distributed but are probably subject to firms' characteristics and their initial performances. Many studies report that foreign investors tend to acquire shares in the largest and most successful domestic firms (Hoekman and Djankov (2000), Evenett and Voicu (2001), Damijan et al (2003)). Hence, treating foreign and domestic firms as homogenous units of observation will likely produce biased results due to possible endogeneity of foreign investment decisions. We deal with this problem using the two-step method proposed by Heckman (1979).[12]

In the Heckman procedure, the bias that results from using non-randomly selected samples is dealt with as an ordinary specification bias arising due to the omitted variables problem. Heckman proposes to use estimated values of the omitted variables (which when omitted from the model give rise to the specification error) as regressors in the basic model. Hence, in the first step, we account for the probability p_i [0, 1] that a firm's selection for FDI is conditional on its initial structural characteristics before the takeover. We estimate the following probit model:

$$\Pr\left(p_{it_0} = 1 \mid \mathbf{X}_{i,jt_0}\right) = S\left(\mathbf{X}_{it_0} \neq \mathbf{X}_{jt_0}\right) \tag{9}$$

where i and j (i=1,...,n, j=1,...,m) are indicating individual foreign and domestic firms, respectively. The error terms are assumed to be IID and normally distributed, thus S(.) is a cumulative distribution function of the standard normal distribution. $\mathbf{X}_{i,jt_0}$ is a matrix of firms' structural characteristics in the initial year. These are firm size, capital intensity, labor productivity as well as industry characteristics, such as size of the industry and foreign penetration to the industry.[13] We estimate the probit model on the data for the initial period (i.e. the first year a firm has entered our sample). As already noted above, our foreign ownership variable is also time variant since we are able to track changes in ownership throughout the whole period. In order to avoid autocorrelation, the first year's observations are then excluded from the estimations of our main empirical model (see model (11) below). The results of the probit estimations (see Table A1 in Appendix) do in fact confirm the existence of selection bias for most of the countries in our database. The results, however, do not confirm the hypothesis that MNCs tend to acquire shares in the largest and most successful local firms as pointed out by Evenett and Voicu (2001). Our results suggest that size and labor productivity are not decisive characteristics of target firms considered by foreign investors. In two countries only (Czech Republic and Estonia) MNCs happened to acquire larger local firms, while in five countries (Bulgaria, Latvia, Lithuania, Romania and Ukraine) smaller firms were selected by MNCs. For the

[12] The problem of sample selection bias has been extensively dealt with in the econometric literature (see also Amemiya, 1984, and Wooldridge, 2002, for excellent surveys of the literature and correction methods).

[13] Foreign penetration to the industry is measured as the share of value added of foreign affiliates in total value added of the industry. Industry is defined at the NACE 2-digit level.

remaining three countries (Croatia, Poland and Slovenia), the coefficient on size is negative but marginally insignificant. Similarly, in only three out of ten countries (Estonia, Latvia and Romania) high initial labor productivity seems to be important in the selection process by MNCs, while in the other six countries initial labor productivity was seemingly not important. Instead, MNCs were found to tend to acquire more capital intensive firms, which is confirmed for 9 out of the 10 transition countries. The tendency of foreign investors to cluster in larger industries with established comparative advantage is rejected in 9 out of 10 countries. Finally, the evidence on clustering of foreign investments in industries with already high foreign penetration in terms of foreign ownership is mixed. Significant positive coefficients were found in only four countries, while in four countries these coefficients are negative and insignificant in the remaining two countries.

These results are in line with the descriptive statistics on foreign presence in individual countries (Table 1) showing relatively low penetration both in terms of the number as well as the share in value added of foreign affiliates. This may, on the one hand, increase the scope for horizontal spillovers as foreign penetration in industries is not too high. On the other hand, this may reduce the scope for backward spillovers as foreign firms may not be able to create a strong enough demand for intermediates of other vertically linked industries.

Based on these probit results, the so-called inverse Mill's ratios (λ_i) for all observations (for non-zero as well as zero observations regarding foreign investment choices) are calculated. A vector of λ_i (lambdas) is then included in our second step estimations as an additional independent variable, which controls for the unobserved impact of foreign investment decisions.

4.3 Econometric approach

To analyze the impact of different channels of technology transfer on a firm's TFP, we estimate growth model (2) augmented by a firm's technology structure (3). As discussed by Griliches and Mairesse (1995) and followed by a vast literature, using the OLS approach to estimate the firm's productivity, however, is inappropriate, as inputs k_i and l_i are probably determined simultaneously by the firm's past productivity. Present applications to estimating production functions have revealed significant problems of potential correlation between input levels and the unobserved firm-specific shocks. The idea is that firms that experience a large positive productivity shock may respond by using more inputs, which violates the OLS assumption of strict exogeneity of inputs and the error term. Another source of simultaneity between inputs and output in the production function approach is the selection issue. Olley and Pakes (1996) demonstrate that firm decisions are made at least to some extent on their perceptions of future productivity and those, in turn, are partially determined by the realizations of their current productivity. If one were to consider only those firms that survived over the entire period this would imply that a sample is being selected, in part, on the basis of the unobserved productivity realizations. This generates a selection bias in both the estimates of the production function parameters and in the subsequent analysis of productivity. Therefore they present an alternative solution that serves to deal with both the simultaneity and self-selection issues at the same time.

While there are many econometric methods to deal with this simultaneity problem (see Appendix 1 for discussion of the methods), in this paper we will use the Olley - Pakes (OP) method. The procedure to obtain unbiased estimates of total factor productivity (TFP) using the OP method relies on a three step approach. In the first step, we estimate the unobserved productivity shocks u_{it} in (A2) for each firm by employing the (firm-specific) investment equation and the dependence of investment on productivity shocks. These estimates can subsequently be used to control for the unobservable productivity shocks u_{it} in our estimations of (A1). We use a fourth order polynomial in capital and investment (with a full set of interaction terms) to approximate u_{it}. Using the estimates of productivity shocks, the primary production function is estimated to obtain unbiased estimates of the coefficient on labor as well as predicted values of the remaining (residual) part of the production function (A1). The second step of the estimation process involves the determination of the survival probability (the probability that a firm will survive in the local market), which depends on the firm's productivity remaining above the perceived cut-off level. In estimating the survival probability we use a fourth order polynomial in (k_i, i_t) with industry and time dummies (which serve as a proxy for differences in market conditions and time-specific factors that impact the survival probability). The third and final step of the estimation procedure utilizes the preceding two steps (whereby the first step estimation results are used to control for simultaneity, while the results of the second step serve to mitigate the selection bias) to estimate an expanded production function and obtain unbiased estimates of the coefficient on capital. We estimate the third step of the estimation algorithm using nonlinear least squares with bootstrapped regression coefficients (in line with Pavcnik, 2002). These three steps enable us to obtain consistent and unbiased estimates of coefficients on capital ($\overline{\alpha}$) and labor ($\overline{\beta}$), which are then used to obtain unbiased estimates of total factor productivity (TFP) as a residual in the consistently estimated production function (1):

$$\overline{TFP}_{it} = y_{it} - \overline{\alpha} K_{it} - \overline{\beta} L_{it} \tag{10}$$

Note that as a dependent variable in our empirical model the estimates of TFP from (10) will be used in place of the value added measures. The specification of the empirical model now differs slightly from (2) since capital and labor are no longer included in the estimation. Hence, our empirical model (2) subject to (3) and with both the Heckman and Olley-Pakes corrections can now be written as:

$$\begin{aligned} tfp_{itk} = {} & \delta F_{ikt} + \gamma w_{ikt} + \varphi hs_{kt} + \phi hs_{kt} * w_{ikt} + \eta vs_{kt} + \kappa vs_{kt} * w_{ikt} + \\ & + \omega es_{kt} + \varpi es_{kt} * w_{ikt} + \upsilon \lambda_{ikt} + \tau t + \sigma R + \varepsilon_{ikt} \end{aligned} \tag{11}$$

where *tfp* is logarithmic growth rate of $\overline{TFP}$. F_{ikt} is a dummy for foreign ownership, w_{ikt} denotes the stock of human capital in the firm (proxied by the average wage bill), hs_{ikt} and vs_{ikt} stand for horizontal and vertical spilovers from FDI at sectoral level, while es_{ikt} denote the impact of sector economies of scale (proxied by the sector size). In line with the recent research (Girma et al, 2006; Ben Hamida and Gugler, 2007), we include interaction terms of the spillover variables with the human capital variable (w_{ikt}) in order to control for the impact of firm absorption capacity on firm ability to reap the benefits of spillover effects from the foreign as well as the domestic firms in the sector. The variable λ_{ikt} is inverse Mill's ratio from the Heckman correction for sample selection. Variables T and R denote the year and regional dummies, and ε_{ikt} is the remaining error term.

Note that we measure spillovers (horizontal and vertical spillovers form FDI as well as the general sector spillovers) both at the level of NACE 2-digit (21 sectors) as well as NACE 3-digit (129 sectors) in order to check for the robustness of results on spillovers to the aggregation of the industries. Regarding the vertical spillovers from FDI, this is not entirely correct procedure as the input-output tables for the countries in our sample can be obtained only at the NACE 2-digit level. We are forced here to apply the common NACE 2-digit technical coefficients to all NACE 3-digit subsectors within the 2-digit sectors indicating that the major additional variation in the 3-digit vertical spillover variable is stemming from the NACE 3-digit relative to NACE 2-digit horizontal spillovers. Nevertheless, we believe that in this way we are able to grasp more accurately the backward linkage effects across the vertical cooperation links among industries.

The model (11) is estimated by OLS. Note that firm specific effects are wiped out as we estimate the model with the dependent variable defined in first differences. We also include year dummies to control for common external policy shocks and regional dummies for region specific shocks. Regions are defined at the NUTS 3-digit level. The estimations are performed and reported for each country separately. In order to grasp the variation in our data sets as much as possible, we run the estimations for different sub samples of data for each country. We first estimate our model on the whole sample of firms, and then proceed with separate estimations for each size class (micro, small, medium, large), for each quintile of productivity across sectors (Q1 through Q5) and lastly for each class of technology gap between domestic and foreign owned firms (Gap1 through Gap3).

Size classes are defined in the usual way with regard to the number of employees.[14] Regressions across the quintiles of firm productivity are applied as Bekes et al (2007) provide convincing evidence on the sample of Hungarian firms that larger and more productive firms (defined by the deciles of size and productivity) are more able to reap spillovers from multinational firms than smaller firms. In line with recent research (Girma et al, 2006), spillovers from FDI are most likely to occur when the technology gap between domestic and foreign owned firms is not too large. We therefore divide our sample of data (for each country separately) into three sub samples according to the technology gap between domestic and foreign owned firms. Measure of technology gap is defined as a ratio of average productivity of domestic firms relative to the average productivity of foreign owned firms within each sector (NACE 2- or 3-digit). This continuous gap variable is then sliced into three gap dummies. Gap1, Gap2 and Gap3 refer to domestic firms with productivity level below 80 per cent, between 80 and 120 per cent and more than 120 per cent of the average productivity of foreign owned firms within each sector, respectively. Gap1, hence, denotes that domestic firms are lagging behind the multinational firms in the sector in terms of technology, while Gap3 indicates that domestic firms have a technology advantage over foreign owned firms in the sector. In contrast, Gap2 indicates that domestic and foreign firms are at roughly similar technology levels. Of course, these

[14] Micro firms (< 10 empl.), small firms ($10 \leq$ empl. < 50), medium firms ($50 \leq$ empl. < 250), and large firms ($250 \leq$ empl.).

measures of technology gap refer to the overall absorptive capacity of sectors implying only that in sectors with lower technology gap the potential of positive spillovers from FDI is higher. The actual “utilization” of this potential, however, depends on individual firm’s productivity level (indicated by firms classification into specific quintile of productivity) and firm’s individual absorption capacity (indicated by its human capital stock).

Note that we maintain the balanced classes of firms according to all three criteria (size, productivity, technology gap) by referring to the mean number of employees and productivity levels over the whole period the firm is contained in the data set.

5. Results

In this section, we first present estimation results on direct effects as well as horizontal and vertical spillovers from FDI obtained from the sample of foreign affiliates and local firms. In addition to explicit control for individual firm’s productivity level and absorption capacity we also provide several robustness checks, including matching technique when accounting for direct effects and different aggregation of sectors when accounting for horizontal and vertical spillovers from FDI. Note that we estimate the fully specified empirical model (11), while – due to the dimensions of tables – the results are presented separately for direct effects, horizontal effects and vertical effects from FDI.[15]

5.1 Direct effects from FDI

5.1.1 Basic results

In line with the previous study (Damijan et al, 2003b) we refer direct effects of FDI to the impact of foreign ownership on firm TFP growth as foreign ownership is believed to enhance firm performance through direct technology transfer. In Table 2 we report the coefficients for F_{ikt} from the regression model (11). Note that we include both the time and region dummies in all specifications. As can be seen from the first three columns, the results do not change much, when time and region dummies are included. One exception being Romania, where the overall coefficient on direct effect from foreign ownership becomes marginally insignificant after the region dummies were included into the regression model. The results show that, on average, in only three out of ten countries under examination (in Czech Republic, Latvia and Slovenia) foreign owned firms grew faster in terms of TFP over the period 1995-2005. For other countries the growth rate of affiliates was also higher than that of domestic firms, but not significantly.[16] The average productivity growth premia of foreign affiliates in this period ranges between 2.4 per cent (Poland) and 9 per cent (Czech Republic). Note that these results are obtained by including the time and region dummies. As demonstrated by the Table 2, the results are in general robust to inclusion of dummies, the notable exception being only the results for Romania (turning the coefficient for direct effects from significant to insignificant when

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[15] Regression results are suppressed due to space limitations. Refer to Table A2 in Appendix for regression statistics.

[16] Note that in none of the countries direct effect of FDI is negative.

including region dummies) and Latvia (turning the coefficient for direct effects from insignificant to significant when including region dummies).

[Insert Table 2]

While most of the studies stop at this point, we analyze these direct effects further by taking into account various sources of heterogeneity of firms. By doing this, we can see that the productivity growth differential of foreign affiliates relative to domestic firms in the above three countries is driven by small (Czech Republic) and medium sized foreign affiliates (Latvia and Slovenia) as well as by affiliates of medium (Q3 quintile in the Czech Republic and Latvia) or high productivity (Q4 and Q5 quintiles in Slovenia). In addition, by allowing for the heterogeneity of firms, we can observe significantly higher productivity growth also for certain categories of foreign affiliates in five of the remaining seven countries. In Bulgaria we find significantly higher growth of affiliates only among the micro sized firms and the least productive firms (Q1). In Lithuania it is the medium sized firms and firms in the fourth quintile of productivity. In Poland it is only the least productive firms (Q1), while in Romania it is the large and the most productive firms (Q5). Finally, in Ukraine it is the micro firms only. In terms of the absorptive capacity, we find significantly higher TFP growth of foreign affiliates with the highest positive technology gap relative to domestic firms (in Czech Republic and Romania) and affiliates at a roughly similar technology level than domestic firms (in Slovenia and Ukraine).

5.1.2 Robustness check using the matching approach

Although the results on direct effects from FDI presented in the previous section do control for many aspects of firm heterogeneity including size and comparative productivity levels, there is still a lot of firm heterogeneity that is not controlled for. In this section, we apply additional robustness check for the above results by using the matching and the average treatment effect techniques.

In order to determine the actual effect of foreign ownership on firm productivity growth the effect of foreign ownership on firm performance has to be estimated by comparing otherwise similar firms. A way of doing this is to employ matching techniques to construct something akin to a controlled experiment. We use firm propensity to become foreign owned to match foreign owned firms with otherwise similar non-foreign owned firms in order to evaluate the importance of foreign ownership on productivity growth. Firms' probability to become foreign owned is estimated by running the following probit regression:

$$(12) \qquad \Pr(F_{\mathrm{ikt-1}} = 1) = \alpha + \beta_1 L_{\mathrm{ikt-1}} + \beta_2 \left(\frac{K}{L}\right)_{i\mathrm{ikt-1}} + \beta_3 \left(\frac{VA}{L}\right)_{i\mathrm{ikt-1}} + \delta Sector_k + \varepsilon_{ikt-1}$$

where *t-1* indicates the year before the firm's switch in the ownership from domestic to foreign. The probability of a firm to become foreign owned is determined by firm's past size (in terms of employment), capital intensity, productivity and sector (NACE 3-digit).

Conditional on satisfying the balancing property of the propensity score, the fitted values obtained from estimating the above equation (the probit estimation) are used to pair up foreign owned firms with domestically owned firms, and those matched pairs are subsequently used to estimate the average treatment effect of foreign ownership on firm subsequent productivity growth. The balancing property ensures that once the observations have been stratified into blocks according to the propensity score, the right hand side variables of (12) do not differ significantly between the groups of treated and non-treated observations within a block. The more closely the firms are matched with respect to regressors in (12), the more likely it is that the observed differences in productivity trajectories between foreign owned and domestically owned firms result purely from the fact that some firms have switched status from domestic to foreign ownership. We match foreign owned firms with their domestic owned counterparts using nearest neighbor matching (with random draws), which pairs up the treated with the closest non-treated observations with respect to the propensity score. Given that our sample size is very small in some instances, all the standard errors reported were generated by bootstrapping with 100 repetitions.

[Insert Table 3]

Table 3 reports the average treatment effect (ATT) of foreign ownership on firm subsequent TFP growth. We report results by referring to the technical time (*t*) after the change in ownership and by accounting for the cumulative change in TFP after the change in ownership. Results up to five years after the change in ownership are reported. Hence, results for the periods *t+1* through *t+5* indicate the differences in the accumulated change in the TFP levels between foreign (treated) and domestic owned (non-treated) firms over one to five years after the firms have switched their status from domestic to foreign ownership.[17]

The results are consistent with the findings in the previous section. When comparing the cohorts of fairly similar foreign and domestic owned firms over time, we find that foreign owned firms persistently outperform domestic firms in terms of TFP growth only in the Czech Republic and Slovenia. In both countries, firms are shown to permanently gain productivity improvements after the ownership change from the first to the last period under examination. In Estonia, Latvia and Poland these productivity gains are observed only in the first year after the change in ownership and seem to dissipate afterwards (in Latvia and Poland the TFP premia arises again in the fourth and fifth year, respectively). In Croatia and Romania benefits of foreign ownership become significant in the second, third and fourth year after the switch in ownership, respectively, but dissipate afterwards. On the other side, in Bulgaria productivity improvements from foreign ownership become visible in the fourth year after the ownership change and seem to become permanent. In contrast, when controlling for exact heterogeneity among firms, a switch to foreign ownership seems to have negative impact on firm cumulative TFP performance in Ukraine. These

[17] Note that we keep the samples of treated and non-treated firms for each country constant allowing us to track the comparative changes in TFP for the same cohorts of firms.

effects, however, are quite divergent over the period indicating possible significant turbulences in the economic environment in this country.[18]

These results confirm that direct productivity improvements from foreign ownership are far from being general but are subject to foreign affiliate heterogeneity. The productivity gains widely differ not only across size and productivity classes but also with regard to the time period after the ownership change. This indicates huge variation of direct productivity gains from foreign ownership, which may be attributable both to the firms' inherent heterogeneity as well as to quite differential *treatment effects* of foreign ownership when controlling for the exact firm heterogeneity.

5.2 Horizontal spillovers from FDI

As shown in the survey of empirical literature on spillovers, most of the early firm-level panel data empirical studies of spillovers from FDI so far find non-existent or even negative horizontal spillovers. More recent studies using either better firm level data or more accurate empirical approaches, however, find less evidence of non-existent or negative horizontal spillovers. The extensive research done so far seems to imply that the initial negative horizontal spillovers (i.e. crowding out effects) seem to dissipate with the local firms' catching up in terms of productivity. At the same time, negative horizontal spillovers seem to be compensated by positive vertical spillovers (Damijan et al, 2003b; Gorodnichenko et al, 2007; Halpern and Murakozy, 2007).

In this section we provide results on horizontal spillovers based on two different aggregation levels of sectors.[19] We first present results for NACE 2-digit sectors and as a robustness check we also show results for NACE 3-digit sectors. Table 4, showing results for NACE 2-digit sectors[20], demonstrates that in general, i.e. for all firms and without any control for either absorptive capacity or size, productivity level or technological gap, in none of the ten countries under examination positive and significant horizontal spillovers from foreign affiliates can be found. Moreover, in four out of ten countries (Estonia, Romania, Slovenia and Ukraine) significant negative horizontal spillovers are found. These results, however, are reverted when controlling for absorptive capacity of firms – we find positive horizontal spillovers in six out of ten countries once controlled for individual firm's wage level as a proxy for the level of human capital.[21] Negative horizontal spillovers after controlling for absorptive capacity are found in one country (Bulgaria) only. These results are quite robust to the level of sectoral aggregation as at the NACE 3-digit level positive overall horizontal spillovers after controlling for absorptive capacity are confirmed in seven countries.[22] On the other side, after controlling for absorptive capacity in none of the countries negative horizontal spillovers are found.

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[18] Due to small sample sizes after exact matching of foreign and domestic owned firms, here we don't provide additional results for subsamples of firms with regard to the size and productivity dimension.

[19] Note that we report results of the model (11) with included year and region dummies.

[20] Note that due to space limitations we present here only coefficients from model (11) related to horizontal spillovers.

[21] These countries are Czech Republic, Croatia, Estonia, Romania, Slovenia and Ukraine.

[22] These are as above Czech Republic, Croatia, Estonia, Romania, Slovenia, Ukraine, and Poland in addition.

[Insert Table 4]

Controlling for absorptive capacity, size heterogeneity of firms does not reveal a very clear picture as far as the significance of horizontal spillovers is concerned. There are only three countries (Croatia, Romania and Slovenia) where horizontal spillovers seem to accrue non-discriminatory to all firms despite their size. In all three countries positive horizontal spillover effects tend to increase with firms size. The pictures in other countries vary considerably.

Similar pattern appears as far as productivity and technology gap heterogeneity is concerned. In Croatia, Romania and Slovenia horizontal spillovers seem to accrue non-discriminatory to all firms regardless of their productivity levels, while in other countries positive horizontal spillovers tend to accrue in medium and/or high productivity quintiles. Horizontal spillovers in Slovenia appear in all technology levels of firms, while for other countries situations broadly vary. Still, the results show that the lower the technological gap, the more positive are horizontal spillovers. Interestingly, horizontal spillovers seem to be less frequent for foreign affiliates than for domestic firms, which may indicate that foreign affiliates are not fully integrated into local environment but may depend more on direct links with their parent companies.

These results are quite robust to sectoral aggregation as most of the results obtained by NACE 2-digit sectors are also replicated, both in terms of size as well as significance of coefficients, when estimating the model with the NACE 3-digit sectors.[23]

Main message obtained from the analysis so far is that horizontal spillovers are substantially dependent on the absorptive capacity of individual firms. Harsh competitive pressures within sectors brought about by enlarged presence of foreign affiliates can have severe negative effects for firms which are not ready for the competition. Only firms with significantly high absorptive capacity can accommodate to the competition and can enjoy positive learning effects from the competitive pressures.

5.3 Vertical spillovers from FDI

In this section we estimate the impact of vertical spillovers of foreign affiliates on domestic firms. Previous studies, which dealt with both the horizontal as well as vertical spillovers, so far revealed a larger relative importance of the latter (see Section 2). As discussed in the methodology section, here we focus on backward linkages only, i.e. on the impact of foreign affiliates on their upstream suppliers. Our preliminary results as well as other empirical studies demonstrated that forward linkages are rather low or insignificant in transition countries (Smarzynska-Javorcik (2004), Gorodnichenko et al (2007), Halpern and Murakozy (2007)). The reason for this lies primarily in the fact that foreign affiliates are mainly engaged in end-user consumer goods. While focusing on backward linkages, however, we take a full account of the firm heterogeneity in terms of size, absorptive capacity and

[23] See Table A3 in Appendix.

technological gap. We present our results both with the spillovers aggregated to the NACE 2-digit as well as to NACE 3-digit sectors. [24]

[Insert Table 5]

Unlike the horizontal spillovers, vertical spillovers seem to have more heterogeneous effects. Abstracting from the heterogeneity of firms, there are only two countries (Slovenia and Ukraine) that show some positive vertical spillovers from FDI at the NACE 2-digit sector level, while there are four countries (Bulgaria, Czech Republic, Poland and Romania) demonstrating significant negative vertical spillover effects (see Table 5). These results change a bit when allowing for absorptive capacity of firms as in Bulgaria, Czech Republic and Poland firms with higher human capital are shown to be able to reap positive spillovers from their upstream links with foreign firms. With NACE 3-digit sectors, [25] these negative backward spillovers are further reduced to two countries only (Lithuania and Romania), and to a single country (Lithuania) after controlling for firms' absorptive capacity.[26] On the other side, with this more precise sectoral aggregation of spillovers we find positive backward spillovers from foreign affiliates in four transition countries. In Croatia and Ukraine these backward spillovers are generally accruable to all domestic firms, while in the Czech Republic and Romania these are limited to firms with sufficient absorptive capacity only. Interestingly, we find some evidence of positive backward spillovers between foreign affiliates in two countries only (Poland and Slovenia), while in Romania foreign affiliates seem to be affected negatively by other upstream foreign firms. These results are consistent by using both levels of sector aggregation.

Allowing for further heterogeneity of firms in terms of size, productivity and technology gap, we can have a closer look into the characteristics of firms that may drive the above results. In general, one can hardly find any pattern across countries. Positive vertical spillovers appear in all size classes of firms, but most frequently in small and medium sized firms, at all productivity levels and at all technology gaps. Interestingly, in the Czech Republic, positive backward spillovers are limited to the least productive (Q1) and the least technologically advanced firms (Gap1). In Croatia, positive spillovers are consistently present for micro and small firms and firms with the highest productivity levels (Q4 or Q5) as well as with the medium or higher technology levels (Gap 2 and Gap3). In Poland, positive backward spillovers are accruable to medium sized firms and firms with lower to medium productivity levels (Q1 through Q4) and lower technology levels (Gap1). In Romania, mainly small domestic firms with higher absorptive capacity do benefit from upstream foreign affiliates. On the other side, either low productive (Q2) and low technology (Gap1) firms or high productivity Romanian firms (Q5) do benefit from backward spillovers. In Slovenia, vertical spillovers are not consistent for domestic firms across different aggregation levels of spillovers, but they are quite consistent for foreign affiliates. Mostly medium (Q2) or high productive (Q4 and Q5) foreign affiliates with high productivity levels do benefit from other upstream foreign affiliates. Finally, in Ukraine it is either micro or large firms that gain from upstream foreign affiliates,

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[24] Note that we report results of the model (11) with included year and region dummies.

[25] See Table A4 in Appendix.

[26] Note, however, that due to data unavailability we are unable to control for absorptive capacity for Lithuanian firms.

while larger positive spillovers seems to be accruable to firms with lowest technology levels and medium productivity levels.

5.4 Summary of results

In order to summarize our empirical findings on the direct and spillover effects of FDI, we have constructed a table summing up the number of countries with significant coefficients. This helps us to discern the pattern of results across firms' characteristics and countries. Indeed, Table 6 demonstrates several interesting facts. First, direct effects of foreign ownership on firm performance are rather rarely present in our exhaustive dataset on ten transition countries (in three countries only), but if present they are strictly positive. Second, horizontal spillovers are mostly negative if not controlled for absorptive capacity of firms. When accounting for firms' absorptive capacity, in most (six to seven out of ten) countries firms do benefit from the increased competition of foreign affiliates in the same sectors. Third, positive horizontal spillovers are equally distributed across size classes of firms, while negative horizontal spillovers seem to accrue more likely to smaller firms. Fourth, positive horizontal spillovers seem to be more likely present in medium or high productivity firms with higher absorptive capacities, while negative horizontal spillovers are more likely to affect low to medium productivity firms. Fifth, vertical spillovers are less frequent than horizontal spillovers from FDI. However, if present, then smaller and more productive firms are more likely to benefit from positive vertical spillovers, while larger and less productive firms are more likely to suffer from negative vertical spillovers.

[Insert Table 6]

These findings suggest that spillovers from foreign firms do substantially depend on the absorptive capacity and productivity level of individual firms. Only more productive firms and firms with higher absorptive capacity are able both to compete with foreign affiliates in the same sector as well as benefit from the increased upstream demand for intermediates created by foreign affiliates. Foreign presence may also affect smaller firms in a larger extent than larger firms, but this impact may go in either way.

6. Conclusions

This paper provides a comparative study on the importance of direct technology transfer and spillovers through FDI on a set of ten transition countries by using a common and by taking into account various sources of firm heterogeneity. In this way we achieve comparability of the results and provide a credible insight into the importance of different channels of technology transfer via FDI for firms in transition countries. We gathered firm level panel data for ten transition economies for the period 1995-2005. Our exhaustive dataset comprises some 90,000 manufacturing firms with up to 11 annual observations, which yields some 315,000 annual firm observations. In our study, we differentiate between direct effects of FDI from the parent firm to local affiliates as well as among horizontal and vertical spillovers from foreign affiliates to domestically owned local firms. The importance of these different channels of technology transfer via FDI on firm performance is estimated in the framework of a growth-accounting approach. We use several correction methods to account for possible biases in the data. Possible selection problem of domestic firms into foreign ownership has been accounted for by using the Heckman procedure, while we deal with the simultaneity problem that typically arises in the growth-accounting approach in the panel data framework by using the Olley-Pakes method.

The main novelty of our paper is that we explicitly control for firm heterogeneity when accounting for different effects of FDI on firm performance. By doing so we find some contrasting results to the previous empirical work in the field. We find that horizontal spillovers have become increasingly important over the last decade and might become even more important than the vertical spillovers. Furthermore, our exercise shows that it is the heterogeneity of firms in terms of absorptive capacity, size, productivity and technology levels that importantly affect the results. Our findings suggest that both direct effects from foreign ownership as well as the spillovers from foreign firms do substantially depend on the absorptive capacity and productivity level of individual firms. Only more productive firms and firms with higher absorptive capacity are able both to compete with foreign affiliates in the same sector as well as benefit from the increased upstream demand for intermediates generated by foreign affiliates. In addition, our results show that foreign presence may also affect smaller firms in a larger extent than larger firms, but this impact may go in either direction.

Another interesting results is that we find that both horizontal as well as vertical spillovers from FDI seem to be less frequent for foreign affiliates than for domestic firms. We argue that this may indicate that foreign affiliates are not fully integrated into local environment but may depend more on direct links with their parent companies. Our data, however, does not allow us to study this interesting feature in more depth. Such a study would require a detailed survey of demand – supply links of both domestic firms and foreign affiliates.

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Tables to be included into text

Table 1: Basic characteristics of the dataset

country		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	#Firms	#Effective obs.
BG	**N(for)**	31	94	48	59	284	325	387	151	148	100	76	**9,549**	**24,809**
	N(dom)	1,301	2,958	1,483	1,482	7,025	8,032	9,162	3,252	3,156	2,624	2,019		
	N(f)/N(d)	0.024	0.032	0.032	0.040	0.040	0.040	0.042	0.046	0.047	0.038	0.038		
	VA(f)/VA(d)	0.015	0.022	0.036	0.042	0.045	0.047	0.053	0.054	0.063	0.050	0.072		
CZ	**N(for)**	87	95	100	140	161	200	217	239	244	238	137	**8,496**	**19,940**
	N(dom)	933	996	1,052	1,543	1,877	2,374	3,022	5,074	7,075	8,258	3,367		
	N(f)/N(d)	0.093	0.095	0.095	0.091	0.086	0.084	0.072	0.047	0.034	0.029	0.041		
	VA(f)/VA(d)	0.171	0.183	0.188	0.201	0.239	0.248	0.244	0.236	0.211	0.219	0.223		
EE	**N(for)**			71	89	110	133	139	156	145	153	148	**4,145**	**13,935**
	N(dom)			1,086	1,433	2,753	3,100	3,109	3,519	3,833	3,992	2,484		
	N(f)/N(d)			0.065	0.062	0.040	0.043	0.045	0.044	0.038	0.038	0.060		
	VA(f)/VA(d)			0.190	0.211	0.200	0.197	0.192	0.198	0.177	0.197	0.190		
HR	**N(for)**	0	8	15	59	64	78	80	84	88	91	95	**3,179**	**18,817**
	N(dom)	3	112	246	2,711	2,856	2,934	2,989	3,004	3,102	3,088	3,004		
	N(f)/N(d)	0.000	0.071	0.061	0.022	0.022	0.027	0.027	0.028	0.028	0.029	0.032		
	VA(f)/VA(d)	0.000	0.127	0.092	0.067	0.072	0.088	0.094	0.095	0.105	0.114	0.118		
LT	**N(for)**		3	5	7	8	16	15	36	49	48	23	**1,567**	**4,080**
	N(dom)		112	192	226	293	350	398	984	1,518	1,278	661		
	N(f)/N(d)		0.027	0.026	0.031	0.027	0.046	0.038	0.037	0.032	0.038	0.035		
	VA(f)/VA(d)		0.066	0.051	0.054	0.050	0.055	0.055	0.080	0.074	0.075	0.076		
LV	**N(for)**	0	6	13	21	24	28	37	43	47	49	25	**723**	**3,176**
	N(dom)	20	137	219	283	314	350	454	552	676	641	374		
	N(f)/N(d)	0.000	0.044	0.059	0.074	0.076	0.080	0.081	0.078	0.070	0.076	0.067		
	VA(f)/VA(d)	0.000	0.077	0.062	0.087	0.095	0.103	0.115	0.106	0.120	0.123	0.156		
PL	**N(for)**	97	442	497	601	688	701	770	868	809	576	144	**6,074**	**12,059**
	N(dom)	478	2,265	2,386	3,129	3,966	4,197	4,780	5,311	5,629	5,498	1,470		
	N(f)/N(d)	0.203	0.195	0.208	0.192	0.173	0.167	0.161	0.163	0.144	0.105	0.098		
	VA(f)/VA(d)	0.269	0.297	0.289	0.303	0.320	0.331	0.316	0.314	0.315	0.267	0.288		
RO	**N(for)**	131	926	1,094	1,368	1,667	2,070	2,318	2,542	3,170	3,696	3,554	**48,495**	**171,270**
	N(dom)	1,920	16,053	18,272	20,378	22,273	24,965	25,637	27,207	34,578	42,103	44,941		
	N(f)/N(d)	0.068	0.058	0.060	0.067	0.075	0.083	0.090	0.093	0.092	0.088	0.079		
	VA(f)/VA(d)	0.128	0.094	0.099	0.124	0.138	0.152	0.171	0.188	0.205	0.205	0.211		
SI	**N(for)**	121	200	217	230	239	252	268	264	285			**3,829**	**27,908**
	N(dom)	2,756	2,964	3,090	3,311	3,464	3,536	3,406	3,539	3,544				
	N(f)/N(d)	0.044	0.067	0.070	0.069	0.069	0.071	0.079	0.075	0.080				
	VA(f)/VA(d)	0.060	0.097	0.128	0.134	0.170	0.196	0.214	0.224	0.236				
UA	**N(for)**				0	10	17	44	50	53	55	56	**5,446**	**18,750**
	N(dom)				1	1,131	2,920	5,158	5,275	5,393	5,198	5,010		
	N(f)/N(d)				0.000	0.009	0.006	0.009	0.009	0.010	0.011	0.011		
	VA(f)/VA(d)				0.000	0.015	0.015	0.013	0.016	0.018	0.018	0.020		
Total													**91,503**	**314,744**

Notes: N(for) and N(dom) is number of foreign and domestic owned firms in the dataset, respectively. N(f)/N(d) and VA(f)/VA(d) are shares of foreign firms in the total number of firms and in the total value added of the whole sample of firms.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Source: Amadeus database (Bureau van Dijk), except for Slovenia (SORS).

Table 2: Direct effects from FDI – Impact of foreign ownership on firm TFP growth [OLS on first differenced log TFP]

				Firms by size classes				Firms by quintiles of productivity					Gap of domestic vs. foreign firms in productivity			
	No dum.	Year dum.	Year & Region dum.	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	Gap1	Gap2	Gap3	No. obs.
BG	0,067	0,046	0,046	0,231	0,062	-0,094	-0,041	0,399	0,013	0,041	0,083	0,011	0,077	-0,058	0,056	24.809
	[1.26]	[0.86]	[0.87]	[1.83]*	[0.70]	[0.87]	[0.23]	[1.66]*	[0.09]	[0.40]	[0.82]	[0.09]	[0.65]	[0.45]	[0.71]	
CZ	0,090	0,089	0,090	0,171	0,137	0,037		0,002	0,076	0,139	0,047	0,04	0,111	0,108	0,03	19.940
	[2.73]***	[2.72]***	[2.74]***	[1.39]	[2.72]***	[0.84]		[0.02]	[1.10]	[2.09]**	[0.70]	[0.55]	[2.32]**	[1.42]	[0.45]	
HR	0,049	0,051	0,055	-0,022	0,066	0,02	0,111	-0,021	0,091	0,033	0,005	0,09	0,046	0,019	0,009	13.935
	[1.15]	[1.18]	[1.28]	[0.23]	[0.83]	[0.27]	[0.80]	[0.18]	[0.96]	[0.17]	[0.05]	[0.93]	[0.53]	[0.26]	[0.09]	
EE	0,082	0,081	0,083	0,228	0,085	-0,087	0,027	-0,414	0,439	-0,026	0,104	0,075	0,062	-0,003	0,252	18.817
	[1.18]	[1.18]	[1.19]	[0.98]	[0.88]	[0.94]	[0.08]	[0.99]	[1.37]	[0.16]	[0.70]	[0.76]	[0.76]	[0.01]	[1.20]	
LT	0,009	0,004	0,004	0,44	0,042	0,078	0,063	-0,055	-0,173	0,048	0,262	-0,095	-0,035	-0,309	0,166	4.080
	[0.13]	[0.05]	[0.05]	[0.45]	[0.22]	[0.89]	[0.46]	[0.05]	[0.17]	[0.18]	[1.34]	[0.71]	[0.38]	[0.35]	[0.86]	
LV	0,067	0,071	0,072	0,072	-0,147	-0,122	0,094	-0,043	-0,022	-0,033	0,327	0,025	0,048	0,096	0,029	3.176
	[1.50]	[1.60]*	[1.61]*	[1.61]*	[0.16]	[0.93]	[1.65]*	[0.33]	[0.17]	[0.22]	[1.82]*	[0.16]	[0.62]	[1.37]	[0.11]	
PL	-0,015	-0,005	-0,009	-0,072	-0,002	-0,019	-0,015	0,146	0,02	0,017	-0,163	0,051	-0,008	-0,169	0,088	12.059
	[0.38]	[0.14]	[0.25]	[0.20]	[0.02]	[0.33]	[0.27]	[1.31]	[0.20]	[0.22]	[2.09]**	[0.66]	[0.14]	[1.93]*	[1.04]	
RO	0,033	0,025	0,024	-0,009	0,018	0,025	0,093	0,04	0,03	0,017	-0,004	0,044	0,033	0,002	0,07	171.270
	[1.95]*	[1.58]*	[1.51]	[0.29]	[0.75]	[0.77]	[1.84]*	[0.55]	[0.69]	[0.47]	[0.14]	[1.65]*	[1.53]	[0.08]	[1.19]	
SI	0,068	0,066	0,066	0,064	0,057	0,113	0,068	-0,037	0,101	0,039	0,106	0,088	0,053	0,073	0,035	27.908
	[2.16]**	[2.12]**	[2.12]**	[0.84]	[1.18]	[2.44]**	[1.13]	[0.31]	[1.43]	[0.57]	[1.67]*	[1.68]*	[1.02]	[1.59]*	[0.29]	
UA	0,061	0,06	0,06	0,704	0,134	0,027	0,003	-0,545	0,017	0,003	-0,029	0,158	0,11	0,141	-0,034	18.750
	[0.46]	[0.45]	[0.45]	[0.58]	[0.43]	[0.11]	[0.01]	[0.12]	[0.03]	[0.01]	[0.08]	[0.72]	[0.45]	[0.31]	[0.18]	
sig	3	4	3	2	1	3	1	2	0	2	2	2	2	2	0	314.744

Notes: Results from the full specification of the model (11). See Table A2 in Appendix for regression statistics. t-statistics in brackets. ***,** and * indicate significance at 1, 5 and 10 per cent, respectively.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table 3: Direct effects from FDI – Impact of foreign ownership on firm TFP growth [ATT effects with nearest neighbor matching]

	year after the change in ownership	*t+1*	*t+2*	*t+3*	*t+4*	*t+5*	No. obs. Treated/non-treated
BG	**ATT**	-0.008	-0.028	0.118	0.272	0.424	248/38
	t	*-0.07*	*-0.24*	*0.88*	*1.55**	*1.81**	
CZ	**ATT**	0.205	0.287	0.270	0.373	0.453	267/77
	t	*2.79****	*3.40****	*2.84****	*3.37****	*3.33****	
EE	**ATT**	0.181	0.197	0.108	0.082	-0.104	134/54
	t	*1.59**	*1.49*	*0.78*	*0.52*	*-0.59*	
HR	**ATT**	0.041	0.108	0.185	0.044	0.113	77/55
	t	*0.45*	*1.75**	*2.86****	*0.60*	*1.27*	
LT	**ATT**	0.053	0.082	0.049	-0.034	-0.026	193/13
	t	*0.62*	*1.43*	*0.96*	*-0.52*	*-0.32*	
LV	**ATT**	0.147	0.064	-0.015	0.059	0.223	283/73
	t	*2.44***	*1.27*	*-0.32*	*1.13*	*4.25****	
PL	**ATT**	0.121	0.028	0.050	0.272	0.222	391/70
	t	*1.56**	*0.28*	*0.38*	*1.57**	*0.96*	
RO	**ATT**	-0.009	-0.017	-0.052	0.332	0.016	1951/944
	t	*-0.19*	*-0.43*	*-1.26*	*5.76****	*0.45*	
SI	**ATT**	0.286	0.440	0.403	0.389	0.489	150/95
	t	*3.05****	*4.09****	*3.72****	*3.24****	*4.31****	
UA	**ATT**	0.167	-0.496	0.067	0.028	-0.353	47/11
	t	*0.72*	*-2.52****	*0.35*	*0.10*	*-1.89**	

Notes: t-statistics in italics. ***,** and * indicate significance at 1, 5 and 10 per cent, respectively.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table 4: Horizontal spillover effects from FDI with NACE-2 digit sectors
[OLS on first differences after Olley-Pakes]

		All	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	G1	G2	G3
BG	hs	0,012	-0,040	0,019	-0,033	-0,020	-0,047	-0,037	0,015	-0,078	0,036	-0,028	-0,049	0,018
	hsw	-0,021	0,264	0,089	-0,046	0,079	0,321	0,341	0,034	0,520	-0,019	0,351	0,827	-0,050
	hsf	-0,164	0,230	-0,187	-0,150	0,102	-0,118	-0,196	-0,153	-0,007	-0,198	-0,121	0,050	-0,146
	hsfw	0,073	-0,146	0,086	0,148	0,012	-0,182	0,172	0,071	0,036	0,057	0,032	0,067	0,084
CZ	hs	-0,003	-0,012	-0,024	-0,009	0,000	-0,032	-0,048	-0,005	-0,030	0,011	0,001	-0,035	0,010
	hsw	0,007	0,016	0,033	0,020		0,094	0,073	0,007	0,030	0,005	-0,001	0,047	0,003
	hsf	0,310	0,375	0,218	0,547		-0,256	0,472	-0,130	0,672	0,261	0,312	0,110	-0,526
	hsfw	-0,018	-0,025	-0,015	-0,046		0,209	-0,074	0,023	-0,050	-0,023	-0,010	-0,024	0,121
EE	hs	-0,014	-0,023	-0,032	-0,032	-0,035	0,039	-0,025	-0,032	-0,042	-0,014	-0,032	-0,019	-0,002
	hsw	0,035	0,017	0,076	0,076	-0,015	-0,193	0,105	0,085	0,077	0,025	0,076	0,026	0,008
	hsf	-0,006	0,022	0,005	-0,004	0,045	0,071	-0,143	0,522	0,088	-0,059	-0,006	-0,005	0,078
	hsfw	0,003	-0,030	-0,046	0,020	0,025	0,122	0,087	-0,078	-0,123	0,046	-0,019	-0,001	-0,172
HR	hs	-0,075	-0,083	-0,033	-0,050	-0,128	-0,038	-0,035	-0,041	-0,036	0,012	-0,063	0,052	0,233
	hsw	0,023	0,046	0,070	0,000	0,056	0,038	0,097	0,080	0,086	0,015	0,030	0,038	-0,004
	hsf	0,368	0,900	0,189	-0,029	-0,076	-0,073	0,059	0,042	0,043	0,071	-0,063	0,209	0,203
	hsfw	-0,025	0,109	-0,118	-0,017	-0,065	0,463	-0,159	0,086	-0,079	-0,012	-0,002	0,009	-0,047
LT	hs	0,007	0,203	0,043	-0,009	-0,036	-0,024	0,039	-0,010	0,016	0,012	0,100	-0,666	0,070
	hsw													
	hsf	-0,035	-1,597	-0,230	-0,019	0,066	-0,456	0,361	-0,748	0,099	-0,038	-0,080	0,106	-0,309
	hsfw													
LV	hs	0,006	-0,083	0,005	0,012	0,040	0,058	-0,003	0,008	0,003	0,007	0,033	0,000	-0,017
	hsw													
	hsf	-0,023	0,000	-0,042	-0,013	-0,084	-0,157	-0,421	-0,330	-0,030	-0,007	-0,028	-1,047	-0,045
	hsfw													
PL	hs	0,008	-0,941	-0,258	0,199	-0,001	-0,002	0,707	-0,055	0,091	-0,119	0,127	0,052	-0,012
	hsw	0,003	0,007	0,019	-0,020	0,008	0,020	-0,101	-0,004	-0,003	0,005	-0,009	0,006	0,002
	hsf	0,022	0,257	0,079	0,009	0,029	0,059	-0,160	-0,064	-0,034	0,020	-0,011	-0,039	0,099
	hsfw	-0,016	-0,059	-0,036	0,011	-0,041	-0,135	0,323	0,097	0,082	-0,017	-0,001	0,027	-0,087
RO	hs	-0,006	-0,010	-0,010	-0,009	-0,018	-0,032	-0,047	-0,040	-0,025	-0,005	0,001	-0,031	-0,004
	hsw	0,024	0,014	0,027	0,043	0,021	0,180	0,192	0,121	0,081	0,017	0,023	0,032	0,041
	hsf	0,061	0,016	0,051	0,007	0,117	-0,018	0,055	-0,101	-0,003	0,049	-0,038	0,158	0,082
	hsfw	-0,010	0,048	0,010	-0,015	-0,013	-0,008	0,026	0,191	0,059	-0,005	-0,011	-0,011	0,019
SI	hs	-0,023	-0,019	-0,035	-0,022	-0,054	-0,001	-0,050	-0,056	-0,050	-0,029	-0,004	-0,046	-0,074
	hsw	0,015	0,013	0,020	0,017	0,039	0,002	0,033	0,035	0,027	0,015	0,012	0,020	0,020
	hsf	0,042	0,025	0,053	0,019	0,044	-0,124	0,145	-0,016	0,120	0,057	0,021	0,052	0,263
	hsfw	-0,022	-0,027	-0,025	-0,013	-0,031	0,113	-0,094	0,012	-0,068	-0,026	-0,019	-0,024	-0,089
UA	hs	-0,161	-0,187	-0,104	-0,078	-0,205	-0,294	-0,085	-0,182	-0,051	-0,241	-0,206	0,177	-0,119
	hsw	0,116	0,892	0,124	0,113	0,116	0,776	0,135	0,212	0,210	0,076	0,220	0,072	0,115
	hsf	0,297	0,000	-0,173	0,161	0,576	-0,418	0,931	0,975	0,602	-0,133	0,241	-0,109	-0,650
	hsfw	-0,225	0,000	-0,688	-0,691	-0,075	0,126	-0,639	-0,150	-0,947	-0,204	-0,763	0,148	0,406
pos.	D	0	0	0	1	0	0	1	0	0	0	2	0	0
	Dw	6	5	7	3	5	4	4	4	7	5	5	6	2
neg.	D	4	4	4	1	3	4	4	3	5	1	2	3	1
	Dw	1	0	0	2	0	0	1	0	0	1	1	0	1

Notes: Results from the full specification of the model (11). See Table A2 in Appendix for regression statistics. t-statistics are omitted from the results due to space limitations. Shadowed results indicate that the coefficient is significant at 10 per cent at the least.
Full results are available from the authors at request.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table 5: Vertical spillover effects from FDI with NACE-2 digit sectors [OLS on first differences after Olley-Pakes]

		All	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	G1	G2	G3
BG	vs	-0,120	0,055	-0,237	-0,273	-0,157	-0,699	-0,221	-0,129	0,041	-0,130	0,058	-0,056	-0,349
BG	vsw	0,058	-0,014	0,103	0,109	0,046	0,509	0,115	0,042	-0,022	0,051	-0,048	-0,190	0,121
BG	vsf	-0,068	-1,652	0,084	-0,298	-0,780	-0,216	0,306	-0,523	0,592	-0,654	-0,734	-0,110	0,255
BG	vsfw	-0,036	0,400	-0,219	0,064	0,116	0,183	-0,090	0,138	-0,156	0,105	0,188	-0,404	-0,147
CZ	vs	-0,025	-0,013	0,005	-0,009		-0,084	0,042	0,006	0,044	-0,054	-0,039	0,046	-0,083
CZ	vsw	0,040	0,032	0,002	0,002		0,215	-0,046	-0,006	-0,039	0,032	0,055	-0,041	0,076
CZ	vsf	-0,040	-0,108	-0,011	-0,070		0,199	0,031	0,016	-0,201	-0,009	-0,005	-0,061	0,166
CZ	vsfw	0,002	0,059	-0,049	0,070		-0,606	-0,196	-0,049	0,162	0,014	-0,024	0,069	-0,363
EE	vs	0,027	0,048	0,063	-0,004	0,036	-0,044	0,069	0,057	0,035	-0,042	0,046	0,077	-0,023
EE	vsw	-0,048	-0,019	-0,149	-0,048	0,098	0,299	-0,215	-0,099	-0,051	0,000	-0,109	-0,077	0,023
EE	vsf	-0,091	-0,151	-0,171	0,124	-0,165	0,164	-0,248	-0,192	-0,297	0,181	-0,060	-0,135	-0,447
EE	vsfw	0,053	0,083	0,181	-0,108	-0,085	-0,297	0,616	0,268	0,314	-0,127	0,063	0,188	0,699
HR	vs	0,025	0,021	0,080	-0,067	0,096	-0,036	0,007	-0,004	0,078	0,063	-0,058	0,056	-0,034
HR	vsw	-0,022	0,030	-0,114	0,140	-0,140	0,243	-0,042	0,074	-0,089	-0,037	0,112	-0,068	0,176
HR	vsf	-0,163	0,198	-0,451	-0,110	-0,413	0,161	-0,396	-0,349	-0,257	-0,128	0,652	-0,205	-0,428
HR	vsfw	0,276	-0,127	0,452	0,124	0,904	-0,853	1,196	0,458	0,503	0,040	-0,201	0,306	1,255
LT	vs	-0,019	-0,969	-0,076	0,034	0,230	-0,087	-0,350	0,243	-0,042	0,118	-0,219	0,546	-0,259
LT	vsw													
LT	vsf	0,229	-4,384	0,421	0,038	-0,483	0,399	-0,525	0,135	-1,178	0,295	0,244	0,266	0,331
LT	vsfw													
LV	vs	-0,003	-0,034	-0,001	-0,019	-0,221	-0,329	0,010	-0,010	0,000	0,052	-0,046	0,000	-0,015
LV	vsw													
LV	vsf	-0,010	0,000	1,153	-0,023	0,312	0,121	0,262	0,208	0,355	-0,047	0,034	0,000	-0,079
LV	vsfw													
PL	vs	-0,031	0,168	-0,001	-0,078	-0,016	-0,031	-0,181	-0,092	-0,107	-0,018	-0,066	-0,038	-0,035
PL	vsw	0,013	0,003	-0,003	0,069	-0,002	0,096	0,237	0,158	0,068	0,002	0,054	0,010	0,004
PL	vsf	-0,009	-0,549	-0,095	0,026	-0,038	-0,171	0,314	0,253	0,112	-0,007	0,082	0,124	-0,142
PL	vsfw	0,031	0,147	0,061	-0,037	0,093	0,301	-0,604	-0,297	-0,091	0,039	-0,019	-0,043	0,135
RO	vs	-0,081	0,014	-0,239	-0,026	0,085	0,239	0,394	0,198	0,034	-0,053	-0,202	0,147	0,146
RO	vsw	0,067	0,029	0,429	-0,319	-0,018	-0,210	-0,187	-0,768	-0,347	0,113	0,364	-0,345	-0,369
RO	vsf	-0,197	-0,435	-0,371	-0,271	-0,371	-0,726	-0,116	-0,315	-0,124	-0,256	-0,067	-0,744	-0,148
RO	vsfw	-0,106	0,182	0,840	0,735	-0,094	0,527	0,505	0,975	-0,780	-0,172	-0,373	0,977	-0,477
SI	vs	0,026	0,019	0,033	0,041	0,054	-0,027	-0,065	0,032	0,031	0,039	0,014	0,045	0,104
SI	vsw	-0,013	-0,013	-0,015	-0,015	-0,028	0,229	0,054	-0,011	-0,013	-0,019	-0,021	-0,017	-0,025
SI	vsf	-0,080	-0,165	-0,008	-0,017	-0,090	0,916	-0,060	0,090	-0,245	-0,165	-0,037	-0,105	-0,348
SI	vsfw	0,046	0,096	0,014	0,028	0,019	-0,659	0,320	-0,061	0,154	0,070	0,054	0,049	0,212
UA	vs	0,100	0,091	0,110	0,059	0,115	-0,013	0,040	0,143	0,078	0,077	0,139	-0,033	0,057
UA	vsw	-0,325	-0,699	-0,336	-0,331	-0,287	-0,529	-0,152	-0,618	-0,072	-0,209	-0,836	0,081	-0,246
UA	vsf	-0,311	0,000	-0,403	-0,789	-0,235	0,443	-2,924	-0,125	-0,121	-0,214	-0,142	-0,281	0,090
UA	vsfw	0,104	0,000	0,304	0,293	-0,001	-0,138	0,196	0,198	0,140	0,111	0,361	0,188	-0,069
pos.	D	2	1	2	0	1	0	1	2	1	1	0	3	0
	Dw	3	0	2	3	0	4	1	1	1	2	3	0	3
neg.	D	4	0	2	3	0	2	2	0	1	0	4	0	1
	Dw	3	0	2	2	2	1	1	1	1	3	2	4	1

Notes: Results from the full specification of the model (11). See Table A2 in Appendix for regression statistics. t-statistics are omitted from the results due to space limitations. Shadowed results indicate that the coefficient is significant at 10 per cent at the least.
Full results are available from the authors at request.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table 6: Summary of results for domestic firms*
[Number of countries with significant spillovers]

		All	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	G1	G2	G3
Direct effects														
Positive		3	2	1	3	1	2	0	2	2	2	2	2	0
Negative		0	0	0	0	0	0	0	0	0	0	0	0	0
Horizontal spillovers														
Positive spill.														
Nace-2	D	0	0	0	1	0	0	1	0	0	0	2	0	0
	Dw	6	5	7	3	5	4	4	4	7	5	5	6	2
Nace-3	D	1	0	0	0	0	1	2	0	1	0	0	0	1
	Dw	7	6	5	2	5	3	4	4	4	6	6	4	1
Negative spill.														
Nace-2	D	4	4	4	1	3	4	4	3	5	1	2	3	1
	Dw	1	0	0	2	0	0	1	0	0	1	1	0	1
Nace-3	D	5	3	5	2	1	0	4	3	4	1	5	2	1
	Dw	0	0	0	1	0	0	1	0	0	0	0	0	1
Vertical spillovers														
Positive spill.														
Nace-2	D	2	1	2	0	1	0	1	2	1	1	0	3	0
	Dw	3	0	2	3	0	4	1	1	1	2	3	0	3
Nace-3	D	2	0	2	0	1	1	1	1	0	1	4	2	1
	Dw	2	1	1	1	0	1	1	2	0	1	4	0	1
Negative spill.														
Nace-2	D	4	0	2	3	0	2	2	0	1	0	4	0	1
	Dw	3	0	2	2	2	1	1	1	1	3	2	4	1
Nace-3	D	2	0	0	1	0	1	2	2	1	0	1	0	2
	Dw	1	0	2	0	3	1	1	1	0	1	4	2	2

Note: Each cell gives a number of countries with a significant coefficient (at 10 per cent at the least).
* Foreign affiliates are excluded from the summary, except for direct effects.

Appendix

Table A1: Results of the Heckman selection model [Probit estimations]

	BG	CZ	EE	HR	LT	LV	PL	RO	SI	UA
emp	**-6,4E-04**	**1,8E-03**	**7,3E-04**	-8,0E-05	**-6,2E-04**	**-7,2E-04**	-8,3E-05	-8,4E-05	-4,4E-04	**-4,3E-04**
	*-2,16***	*10,83****	*2,02***	*-0,35*	*-4,35****	*-3,19****	*-0,95*	*-2,07***	*-1,58*	*-1,71**
k /l	**1,4E-07**	**-1,7E-05**	**7,9E-05**	**7,2E-06**	**3,3E-06**	**5,8E-05**	**2,0E-05**	**2,1E-06**	**6,1E-08**	**4,1E-06**
	*4,74****	*-12,23****	*2,00***	*1,65**	*1,95***	*5,05****	*3,66****	*3,75****	*1,98***	*1,86**
va/l	-3,8E-07	1,2E-04	**7,4E-03**	-2,9E-04	**-2,5E-05**	**5,8E-04**	1,7E-04	**6,5E-04**	1,1E-05	-3,1E-04
	-0,01	*0,83*	*2,85****	*-0,75*	*-6,83****	*2,55***	*0,99*	*8,11****	*1,47*	*-1,51*
secsize	**-1,3E-06**	1,9E-08	**-3,4E-06**	**-9,7E-07**	**-1,4E-06**	**-2,5E-06**	**-1,1E-07**	**-6,1E-08**	**-9,5E-09**	**-4,2E-07**
	*-7,73****	*0,36*	*-11,82****	*-9,55****	*-14,45****	*-21,39****	*-12,25****	*-37,04****	*-13,66****	*-8,10****
hs	**-3,902**	**-8,058**	-0,539	**2,436**	0,737	**1,496**	**0,928**	**-2,612**	**1,001**	**-4,076**
	*-3,07****	*-14,41****	*-1,06*	*2,28***	*1,23*	*3,79****	*2,90****	*-31,51****	*2,34***	*-4,19****
N. obs	9509	33657	4350	3341	5902	4049	3690	49251	5355	4728
Prob chi^2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Note: Results from the probit model (9).
t-statistics in italics. ***,** and * indicate significance at 1, 5 and 10 per cent, respectively.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table A2: Summary statistics for regression results [Estimations based on model (11)]

					Firms by size classes				Firms by quintiles of productivity					Gap of domestic vs. foreign firms in productivity		
		No dummies	Year dum.	Year & Region dum.	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	Gap1	Gap2	Gap3
BG	No. obs.	24.809	24.809	24.809	6.135	8.646	7.185	2.686	3.697	5.327	5.465	5.182	5.138	7.180	3.742	10.647
	R-sq.	0,23	0,24	0,24	0,17	0,19	0,32	0,44	0,19	0,18	0,22	0,19	0,39	0,24	0,28	0,23
CZ	No. obs.	19.940	19.940	19.940	4.348	9.605	4.987		3.602	4.370	4.153	3.997	3.818	8.509	3.814	5.683
	R-sq.	0,03	0,05	0,05	0,03	0,06	0,10		0,06	0,05	0,07	0,05	0,05	0,04	0,06	0,07
HR	No. obs.	19.472	19.472	19.472	9.265	5.587	3.259	1.276	3.900	3.977	3.908	3.939	3.748	4.399	5.344	4.441
	R-sq.	0,04	0,04	0,05	0,04	0,06	0,06	0,09	0,05	0,06	0,06	0,05	0,06	0,05	0,05	0,05
EE	No. obs.	13.935	13.935	13.935	5.359	6.495	1.780	239	1.694	2.727	3.163	3.197	3.154	10.624	1.048	851
	R-sq.	0,06	0,06	0,06	0,06	0,07	0,08	0,39	0,04	0,06	0,07	0,07	0,12	0,08	0,05	0,07
LT	No. obs.	4.080	4.080	4.080	187	1.307	1.802	768	735	810	831	886	818	2.048	118	668
	R-sq.	0,09	0,10	0,10	0,28	0,10	0,09	0,06	0,11	0,13	0,08	0,07	0,21	0,11	0,31	0,11
LV	No. obs.	3.176	3.176	3.176	99	850	1.701	512	629	647	645	641	614	1.193	174	979
	R-sq.	0,06	0,08	0,08	0,33	0,13	0,07	0,15	0,13	0,13	0,10	0,08	0,24	0,11	0,24	0,11
PL	No. obs.	12.059	12.059	12.059	392	2.501	5.772	3.361	1.968	2.335	2.517	2.582	2.657	7.268	2.229	2.335
	R-sq.	0,53	0,56	0,56	0,23	0,34	0,59	0,72	0,26	0,33	0,49	0,53	0,74	0,55	0,53	0,64
RO	No. obs.	171.270	171.270	171.270	78.252	61.997	21.269	8.940	14.641	30.453	38.382	42.952	44.842	125.797	35.267	10.044
	R-sq.	0,34	0,43	0,43	0,38	0,48	0,49	0,54	0,19	0,34	0,42	0,48	0,50	0,43	0,45	0,44
SI	No. obs.	27.916	27.916	27.916	14.456	7.227	4.567	1.634	5.027	5.683	5.797	5.772	5.637	10.706	14.604	1.919
	R-sq.	0,04	0,04	0,04	0,04	0,04	0,09	0,07	0,03	0,04	0,04	0,06	0,10	0,05	0,04	0,07
UA	No. obs.	18.750	18.750	18.750	155	1.302	9.526	7.757	2.594	3.981	4.143	4.255	3.777	5.973	2.265	4.192
	R-sq.	0,10	0,12	0,12	0,34	0,19	0,12	0,11	0,06	0,07	0,07	0,09	0,29	0,11	0,16	0,12

Note: Results from the full specification of the model (11).

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table A3: Horizontal spillover effects from FDI with NACE-3 digit sectors [OLS on first differences after Olley-Pakes]

		All	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	Gap1	Gap2	Gap3
BG	hs	0,018	-0,038	0,037	0,022	-0,024	0,128	0,005	0,035	-0,086	0,016	-0,181	-0,566	-0,016
BG	hsw	0,025	0,163	-0,005	0,020	0,173	-0,617	0,174	0,072	0,226	0,029	0,072	0,068	0,024
BG	hsf	0,003	0,137	-0,076	-0,097	0,194	-0,831	-0,087	-0,067	0,015	0,104	-0,113	0,082	-0,143
BG	hsfw	-0,005	-0,093	0,051	0,034	-0,034	0,088	0,037	0,038	-0,016	-0,010	-0,035	-0,031	0,038
CZ	hs	-0,010	-0,044	-0,014	-0,004	0,000	-0,020	-0,028	0,024	-0,021	-0,016	-0,012	-0,020	0,005
CZ	hsw	0,009	0,043	0,013	0,012		0,034	0,033	-0,023	0,021	0,006	0,003	0,022	0,052
CZ	hsf	0,024	0,100	0,030	0,032	0,000	-0,133	0,031	-0,036	0,060	0,006	0,019	0,045	-0,032
CZ	hsfw	-0,020	-0,091	-0,009	-0,027		0,220	-0,055	0,064	-0,060	-0,013	-0,020	-0,029	0,036
EE	hs	-0,012	-0,027	-0,040	0,005	0,065	0,028	-0,036	-0,033	-0,055	-0,003	-0,041	-0,007	0,006
EE	hsw	0,023	0,011	0,073	0,024	0,067	-0,122	0,076	0,086	0,058	0,017	0,067	0,196	-0,064
EE	hsf	0,003	0,083	0,036	-0,033	-0,030	0,016	-0,239	0,388	0,106	-0,042	0,012	-0,106	0,059
EE	hsfw	0,013	-0,039	-0,046	0,045	-0,050	0,648	0,517	-0,684	-0,051	0,038	-0,019	0,036	-0,013
HR	hs	-0,019	-0,013	-0,042	-0,031	0,016	-0,028	-0,060	-0,038	-0,015	-0,025	-0,009	-0,048	-0,013
HR	hsw	0,032	0,017	0,067	0,045	0,032	0,100	0,116	0,082	0,029	0,027	0,013	0,086	0,030
HR	hsf	0,044	-0,105	0,214	0,049	0,047	-0,009	0,085	0,016	0,029	0,076	0,019	0,016	0,023
HR	hsfw	-0,044	0,328	-0,209	-0,062	-0,035	0,017	-0,150	-0,010	-0,021	-0,047	-0,017	-0,036	-0,015
LT	hs	0,051	0,127	0,086	0,024	0,007	0,101	0,159	-0,038	0,104	-0,020	0,080	0,000	0,031
LT	hsw													
LT	hsf	-0,051	-4,070	-0,086	-0,009	-0,028	-0,649	3,214	-0,756	-0,137	-0,014	-0,024	0,508	0,267
LT	hsfw													
LV	hs	0,024	1,498	-0,017	-0,056	0,383	-0,051	0,024	0,122	0,055	0,071	0,193	0,000	0,270
LV	hsw													
LV	hsf	-0,013	0,000	0,000	0,005	-0,064	-0,024	-0,263	-0,212	-0,033	-0,011	-0,032	0,000	-0,033
LV	hsfw													
PL	hs	0,000	-0,107	-0,028	0,026	-0,006	-0,024	0,051	-0,007	0,002	-0,012	0,010	-0,043	0,000
PL	hsw	0,004	0,037	0,024	-0,022	0,012	0,050	-0,072	0,001	0,010	0,004	-0,004	0,009	0,001
PL	hsf	0,026	0,190	0,071	-0,005	0,035	0,065	-0,185	-0,065	-0,025	0,036	0,025	-0,034	0,070
PL	hsfw	-0,015	-0,066	-0,034	0,033	-0,040	-0,164	0,336	0,113	0,081	-0,014	-0,004	0,061	-0,071
RO	hs	-0,068	-0,005	-0,133	-0,282	-0,212	-0,299	-0,435	-0,420	-0,352	-0,014	-0,048	-0,028	-0,150
RO	hsw	0,018	0,008	0,016	0,049	0,037	0,148	0,166	0,113	0,087	0,011	0,014	0,069	0,037
RO	hsf	0,117	0,051	0,068	0,138	0,354	-0,446	0,225	-0,078	0,128	0,130	0,096	0,472	0,359
RO	hsfw	0,005	0,052	0,005	-0,029	-0,021	0,061	-0,060	0,112	0,020	0,007	0,006	-0,050	-0,008
SI	hs	-0,021	-0,018	-0,056	-0,012	-0,003	-0,040	-0,045	0,002	-0,065	-0,040	-0,023	-0,031	0,008
SI	hsw	0,092	0,084	0,195	0,070	0,067	0,386	0,357	-0,032	0,326	0,093	0,158	0,127	-0,009
SI	hsf	0,059	0,064	0,149	0,008	0,021	0,073	0,197	-0,022	0,136	0,056	0,051	0,083	0,101
SI	hsfw	-0,022	-0,022	-0,046	-0,004	-0,015	0,049	-0,105	0,031	-0,056	-0,019	-0,025	-0,028	-0,018
UA	hs	-0,052	-0,139	-0,007	-0,017	-0,283	-0,303	-0,290	-0,230	-0,007	-0,031	-0,384	0,209	-0,245
UA	hsw	0,020	0,350	0,048	0,018	0,184	0,520	0,189	0,240	0,017	0,012	0,105	0,011	0,158
UA	hsf	-0,062	0,000	0,125	0,699	0,505	0,201	0,479	0,367	0,336	-0,123	0,108	-0,664	0,830
UA	hsfw	-0,003	0,000	-0,239	-0,191	-0,191	0,337	-0,342	-0,528	-0,183	0,007	-0,271	0,221	-0,264
pos.	D	1	0	0	0	0	1	2	0	1	0	0	0	1
	Dw	7	6	5	2	5	3	4	4	4	6	6	4	1
neg.	D	5	3	5	2	1	0	4	3	4	1	5	2	1
	Dw	0	0	0	1	0	0	1	0	0	0	0	0	1

Notes: Results from the full specification of the model (11). See Table A2 for regression statistics. t-statistics are omitted from the results due to space limitations. Shadowed results indicate that the coefficient is significant at 10 per cent at the least.
Full results are available from the authors at request.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Table A4: Vertical spillover effects from FDI with NACE-3 digit sectors [OLS on first differences after Olley-Pakes]

		All	Micro	Small	Medium	Large	Q1	Q2	Q3	Q4	Q5	Gap1	Gap2	Gap3
BG	vs	-0,059	0,106	-0,083	0,003	0,010	-0,172	-0,046	-0,085	0,119	0,036	0,150	0,102	-0,047
BG	vsw	0,046	-0,527	0,197	0,137	-0,263	0,142	0,014	0,121	-0,466	-0,044	-0,123	-0,418	0,492
BG	vsf	-0,147	-0,677	0,095	0,379	-0,479	0,448	0,563	0,047	-0,046	-0,756	-0,488	-0,349	0,622
BG	vsfw	0,459	0,359	-0,161	-0,160	0,101	0,261	-0,284	-0,037	0,010	0,143	0,174	0,128	-0,223
CZ	vs	-0,018	0,030	-0,008	-0,018		-0,135	0,008	-0,068	0,007	-0,015	-0,013	-0,029	-0,078
CZ	vsw	0,038	-0,003	0,034	0,023		0,434	0,019	0,087	0,004	0,008	0,031	0,045	-0,019
CZ	vsf	-0,029	-0,160	-0,125	-0,034		0,329	-0,010	0,057	-0,157	0,028	-0,019	-0,129	0,094
CZ	vsfw	0,001	0,155	-0,021	0,027		-0,129	-0,040	-0,106	0,134	0,005	0,007	0,088	-0,150
EE	vs	0,017	0,035	0,065	-0,106	-0,211	-0,037	0,095	0,069	-0,004	-0,039	0,071	0,157	-0,236
EE	vsw	-0,003	0,000	-0,015	0,016	0,022	0,035	-0,015	-0,014	0,009	-0,001	-0,013	-0,039	0,042
EE	vsf	-0,036	-0,214	-0,144	0,278	0,132	0,252	0,464	-0,241	-0,159	0,141	-0,042	-0,066	-0,015
EE	vsfw	-0,001	0,010	0,017	-0,032	-0,022	-0,160	-0,148	0,349	0,000	-0,009	0,006	0,024	-0,015
HR	vs	0,041	0,012	0,075	0,066	-0,028	-0,005	0,028	0,001	0,024	0,113	-0,071	0,098	-0,035
HR	vsw	-0,005	0,007	-0,010	-0,007	-0,015	0,010	-0,001	0,004	0,001	-0,005	0,009	-0,012	0,012
HR	vsf	-0,088	0,405	-0,461	-0,157	-0,079	0,055	-0,175	-0,157	-0,191	-0,150	0,265	-0,157	-0,032
HR	vsfw	0,016	-0,090	0,047	0,026	0,043	-0,032	0,048	0,032	0,030	0,010	-0,010	0,030	0,026
LT	vs	-0,132	-0,517	-0,151	-0,090	-0,120	-0,142	-0,418	0,230	-0,304	-0,086	-0,157	0,000	-0,304
LT	vsw													
LT	vsf	0,205	10,828	0,452	-0,147	0,256	0,388	0,196	0,126	0,464	0,377	-0,190	0,840	-0,290
LT	vsfw													
LV	vs	-0,015	-0,209	-0,017	0,005	-0,264	-0,176	-0,039	-0,026	-0,028	0,033	-0,043	0,000	-0,012
LV	vsw													
LV	vsf	-0,010	0,000	0,303	-0,047	0,438	0,325	0,142	0,132	0,487	-0,046	0,019	0,000	-0,012
LV	vsfw													
PL	vs	-0,006	0,199	0,033	-0,071	0,016	-0,020	-0,148	-0,092	-0,061	0,027	-0,031	0,007	-0,024
PL	vsw	0,000	-0,065	-0,025	0,067	-0,014	0,039	0,223	0,119	0,032	-0,002	0,037	-0,013	0,002
PL	vsf	-0,048	-0,686	-0,110	0,040	-0,083	-0,188	0,400	0,201	0,078	-0,098	-0,015	0,038	-0,120
PL	vsfw	0,037	0,211	0,060	-0,074	0,094	0,340	-0,708	-0,271	-0,118	0,038	-0,008	-0,082	0,112
RO	vs	-0,159	-0,115	-0,256	-0,060	0,243	0,031	0,458	0,141	-0,096	-0,160	-0,309	-0,220	0,215
RO	vsw	0,239	0,190	0,557	-0,272	-0,214	0,315	-0,165	-0,546	-0,168	0,226	0,651	-0,111	-0,384
RO	vsf	-0,099	-0,545	-0,475	-0,491	-0,317	-0,143	-0,135	-0,042	-0,358	-0,127	0,076	-0,154	-0,420
RO	vsfw	-0,029	-0,024	0,090	0,147	-0,005	0,745	0,511	0,015	-0,040	-0,035	-0,064	0,402	-0,003
SI	vs	0,008	-0,005	0,032	0,012	-0,030	-0,135	-0,003	-0,011	0,040	0,032	0,005	0,002	-0,003
SI	vsw	-0,001	-0,004	-0,007	0,005	0,022	0,099	0,024	0,076	-0,019	-0,010	-0,032	0,000	0,051
SI	vsf	-0,011	-0,020	-0,017	-0,009	-0,003	0,042	-0,061	0,009	-0,035	-0,013	-0,012	-0,015	0,007
SI	vsfw	0,049	0,095	0,056	0,035	0,013	-0,450	0,332	-0,082	0,172	0,053	0,068	0,063	-0,038
UA	vs	0,014	-0,007	0,018	0,005	0,041	0,101	0,031	0,095	-0,016	0,009	0,151	0,100	0,036
UA	vsw	-0,003	-0,020	0,000	-0,003	-0,020	-0,111	-0,037	-0,081	0,015	-0,002	-0,041	0,004	-0,018
UA	vsf	0,004	0,000	-0,142	-0,252	-0,043	0,000	-0,857	-0,350	-0,212	0,014	-0,613	-0,441	-0,058
UA	vsfw	-0,002	0,000	0,117	0,005	0,015	-0,502	0,696	0,639	0,004	-0,004	0,130	-0,003	0,018
pos.	D	2	0	2	0	1	1	1	1	0	1	4	2	1
	Dw	2	1	1	1	0	1	1	2	0	1	4	0	1
neg.	D	2	0	0	1	0	1	2	2	1	0	1	0	2
	Dw	1	0	2	0	3	1	1	1	0	1	4	2	2

Notes: Results from the full specification of the model (11). See Table A2 for regression statistics. t-statistics are omitted from the results due to space limitations. Shadowed results indicate that the coefficient is significant at 10 per cent at the least.
Full results are available from the authors at request.

BG = Bulgaria, CZ = Czech Republic, EE = Estonia, HR = Croatia, LT = Lithuania, LV = Latvia, PL = Poland, RO = Romania, SI = Slovenia, UA = Ukraine.

Appendix 2

Discussion of empirical methods to correct for endogeneity between inputs and output in production functions

Present applications to estimating production functions have revealed significant problems of potential correlation between input levels and the unobserved firm-specific shocks. The idea is that firms that experience a large positive productivity shock may respond by using more inputs, which violates the OLS assumption of strict exogeneity of inputs and the error term. Let us show this by rewriting our basic model (2) in order to capture possible endogeneity between inputs and performance. Consider a modified TFP growth-accounting model:[i]

(A1) $y_{it} = \gamma t_{it} + \alpha k_{it} + \beta l_{it} + \delta_{ti} + (\eta_i + u_{it} + m_{it})$, where $\alpha + \beta \neq 1$

(A2) $u_{it} = \rho u_{i,t-1} + o_{it}$ $|\rho| < 1$

$o_{it}, m_{it} \sim \text{MA}(0)$,

where of the error components, η_i is an unobserved firm-specific effect, u_{it} is an autoregressive (productivity) shock and m_{it} represents serially uncorrelated measurement errors. Note that both labor (l_{it}) and capital (k_{it}) are potentially correlated with firm-specific effects (η_i) as well as with both productivity shocks (t_{it}) and measurement errors (m_{it}).

Given the AR(1) process in u_{it} according to model (A2), a firm's response to a positive productivity shock in the past ($u_{i,t-1} > 0$) by using more inputs in the period t clearly violates the OLS assumption on strict exogeneity between inputs and the error term ($\text{E}(\mathbf{z}_{it}'u_{it}) \neq 0$).[ii] This endogeneity usually shows up in OLS estimations in the form of persistent serial correlation and yields biased parameter estimates. Levinsohn and Petrin (2000) demonstrate that in the case where capital and labor are positively correlated, and both are also correlated with the productivity shock, the parameter for labor input will tend to be overestimated and the parameter for capital will tend to be underestimated. Given the usual quality of firm level datasets, this is the most likely case. Unfortunately, biased parameter estimates for capital and labor inevitably lead to biased estimates of productivity.

There is a need, hence, to find suitable methods to account for this correlation between inputs and the error term. Any such method, however, will inevitably prove to be inefficient as long as we have to deal with serious measurement problems in the stock of capital (see Griliches and Mairesse, 1995). The most simple methods are the application of fixed effects or first difference transformation in order to wipe out the firm-specific unobserved effects η_i. However, the drawback of both methods is to require that a component of the productivity shock is fixed over time, which gives little hope that we have dealt with the problem efficiently.

Another alternative is to apply the instrumental variables approach, but valid instruments are required that are correlated with firm-level input choices and orthogonal to the productivity shock. The problem is that, usually, there are simply no valid instruments.

Recently, three more sophisticated methods applied to estimating a production function in a dynamic panel data context were developed that claim to solve the problem of endogeneity between input levels and the unobserved firm-specific shocks in a satisfactory way. Olley and Pakes (OP, 1996) propose to use investment expenditure as a proxy for unobservable technological shocks. The advantage of this method is that we do not assume that unobserved productivity is fixed over time, and since there is no need for differencing, it leaves more variance in capital and labor. Another advantage of the OP method is that it also controls for the selection issue. There is, namely, a clear relationship between firm productivity, on one hand, and firm survival and input demand, on the other. Olley and Pakes find that as the least productive firms exit the market, the existing capital is redistributed to their more productive counterparts generating a strong negative bias on the capital coefficients in the production function. A common way of dealing with the selection issue is to consider only a balanced sample (by excluding the observations that are not present throughout the period of observation) but, as Olley and Pakes also show, firm decisions are made, at least to some extent on their perceptions of future productivity and those, in turn, are partially determined by the realizations of their current productivity. If one were to consider only those firms that survived over the entire period this would imply that a sample is being selected, in part, on the basis of the unobserved productivity realizations. This generates a selection bias in both the estimates of the production function parameters and in the subsequent analysis of productivity. Therefore they present an alternative solution that serves to deal with both the simultaneity and self-selection issues at the same time.

The estimation procedure that was first introduced by Olley and Pakes (1996) and since used extensively relies on a three step procedure to estimate the unbiased coefficients on labor and capital in the production function. The crucial first step of the estimation serves to estimate the unobserved productivity shocks u_{it} for each firm by employing the (firm-specific) investment equation and the dependence of investment on productivity shocks. These estimates can subsequently be used to control for the unobservable productivity shocks u_{it} in our estimations of (A1). In our empirical estimations presented in the next section we will use a forth order polynomial in capital and investment only (with a full set of interaction terms) to approximate u_{it}, since data on firm age was not available. Using the estimates of productivity shocks, the primary production function is estimated to obtain unbiased estimates of the coefficient on labor as well as predicted values of the remaining(residual) part of the production function (A1). The second step of the estimation process involves the determination of the survival probability (the probability that a firm will survive in the local market), which depends on the firm's productivity remaining above the perceived cut-off level. In estimating the survival probability we use a fourth order polynomial in (k_i, i_t) with industry and time dummies (which serve as a proxy for differences in market conditions and time-specific factors that impact the survival probability). The third and final step of the estimation procedure utilizes the preceding two steps (whereby the first step estimation results are used to control for simultaneity, while the results of the second step serve to mitigate the self-selection bias) to estimate an expanded production function and obtain unbiased estimates of the coefficient on capital. We estimate the third step of the estimation algorithm using nonlinear least squares with bootstrapped regression coefficients (in line with Pavcnik, 2002, 1000 repetitions were used in the bootstrap). Again, in contrast to the Olley - Pakes estimation, we have to forego the use of the firm age variable since it is not a part of the data set. Consistent and unbiased estimates of coefficients on capital ($\overline{\alpha}$) and labor ($\overline{\beta}$) can ultimately be used to obtain unbiased estimates of total factor productivity (TFP):

$$\text{(A3)} \qquad \overline{tfp}_{it} = y_{it} - \overline{\alpha} k_{it} - \overline{\beta} l_{it}$$

The estimates of TFP will be used in place of the value added measures in estimations of production function (1) subject to (2). The specification of the model will differ slightly from (1) since capital and labor will no longer need be included in the estimation.

The drawback of the OP approach, however, is in their assumption that there is only one single component of unobservable heterogeneity in the system, which is fully transmitted to the investment equation. In other words, OP assume that if capital input has already adjusted to the anticipated part of the productivity process ($\rho u_{i,t-1}$ in (A2)), the investment proxy will only account for the "news," i.e. the unanticipated part of the technology shock (o_{it}). As a consequence, some correlation between the unobserved technological shock and capital, and therefore some bias, would remain in the estimated production function coefficients.

Instead, Levinsohn and Petrin (LP, 2000) propose to use materials (energy consumption or material costs) as a proxy for unobserved technological shocks. Material costs respond to the entire productivity shock u_{it} and not just to the unanticipated part of it. In addition, Basu and Fernald (1995) also suggest using material cost in the production function with value added as a dependent variable in order to control for unobserved demand shocks. Including material costs directly into the model as suggested by Basu and Fernald or applying the LP instrumentalization does not necessarily reduce the bias. While Levinsohn - Petrin method provide a viable alternative to the Olley - Pakes estimation algorithm by introducing material costs (in place of investments) in the first step of the estimation procedure, it is mostly difficult to employ it due to the lack of available data on the use of specific materials, such as energy consumption (instead, only data on aggregate expenditure on materials is available).

An alternative approach to control for the seemingly persistent simultaneity bias is to model the production function as a dynamic process since present firm growth is inevitably correlated with the past performance of the firm. Arellano and Bond (1991, 1998), Arellano and Bover (1995) and Blundell and Bond (1998, 1999) propose related econometric techniques to deal with the simultaneity bias in a dynamic panel data context. Consider a dynamic version of the growth model (A1):

$$\text{(A4)} \quad y_{it} = \rho y_{i,t-1} + \alpha k_{it} - \rho\alpha k_{i,t-1} + \beta l_{it} - \rho\beta l_{i,t-1} + (\delta_t - \rho\delta_{t-1}) + \\ + (\gamma t_{it} - \rho\gamma t_{i,t-1} + \eta_i(1-\rho) + o_{it} + m_{it} - \rho m_{i,t-1}).$$

In model (A4), one can show that the OLS estimator will be seriously biased due to correlation of the lagged dependent variable with the individual-specific effects as well as with the independent variables. This is due to the fact that y_{it} is a function of η_i in model (A1), and then $y_{i,t-1}$ is also a function of η_i. As a consequence, $y_{i,t-1}$ is correlated with the error term, which renders the OLS estimator biased and inconsistent, even if

u_{it} and m_{it} in model (A1) are not serially correlated. This holds also whether the individual effects are considered fixed or random (see Hsiao, 1986; Baltagi, 1995; Wooldridge, 2002). One way of controlling for this unobserved heterogeneity and simultaneity is to include exogenous variables into the first-order autoregressive process. This, in turn, reduces the bias in the OLS estimator, but its magnitude still remains positive. Another way of controlling for the simultaneity is to apply the Anderson-Hsiao instrumental variable approach. We may first differentiate our model (A1) in order to eliminate η_i, which is the source of the bias in the OLS estimator. Then we may take the second lag of the level ($y_{i,t-2}$) and the first difference of this second lag ($\Delta y_{i,t-2}$) as possible instruments for $\Delta y_{i,t-1}$, since both are correlated with it ($\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$) but uncorrelated with the error term Δu_{it} ($= u_{it} - u_{i,t-1}$). This approach, though consistent, is not efficient since it does not take into account all the available moment conditions (i.e. restrictions on the covariances between regressors and the error term).

An appropriate approach that allows for controlling for the unobserved simultaneity in model (A4) is the application of GMM (general method of moments) estimators. Most studies estimate production function in first differences in order to obtain estimates of differences in growth performance of privatized firms as well as to eliminate unobserved firm-specific effects. Since lagged-level instruments used in the difference-GMM approach are shown to be weak instruments for first-differenced equation (see Arellano and Bover, 1995; Blundell and Bond, 1998, 1999), one may apply the system-GMM approach, which in addition to lagged levels uses also lagged first differences as instruments for equations in levels. As the model is estimated in first differences, corresponding instruments for $\Delta x_{i,t-3}$ are $x_{i,t-1}$ and $\Delta x_{i,t-1}$ (where x stands generally for all included variables), and so on for higher time periods. This allows for a larger set of lagged levels and first-differences instruments and therefore to exploit fully all of the available moment conditions. Hence, the system-GMM approach, in principle, maximizes both the consistency as well as the efficiency of the applied estimator.

However, this is not necessarily true in every case. Levinsohn and Petrin (2000) point out that "…lagged values of inputs will not generally be valid instruments because chosen input levels may depend upon past values of the (potentially correlated) shock. Frequently, instrumental variables suffers from the same drawback as that of the within estimator; valid instruments are usually weak instruments - that's generally what makes the exclusion restriction believable - and weak instruments significantly weaken the signal, exacerbating other imperfections in the data."

Hence, we should notice again that the above methods can be efficient only when we are dealing with accurately measured datasets. When this precondition is violated, no existing econometric technique can help in controlling for the unobserved productivity shocks and simultaneity bias.

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[i] We use the Blundell and Bond (1999) notations.

[ii] Where, again, $\mathbf{z}_{it}$ is a matrix of inputs k_{it} and l_{it}.