Institute of Economic Studies, Faculty of Social Sciences
Charles University in Prague

Panel Data Evidence on Productivity Spillovers from Foreign Direct Investment: Firm-Level Measures of Backward and Forward Linkages

Pavel Vacek

IES Working Paper: 19/2010

Institute of Economic Studies,
Faculty of Social Sciences,
Charles University in Prague

[UK FSV – IES]

Opletalova 26
CZ-110 00, Prague
E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

Institut ekonomických studií
Fakulta sociálních věd
Univerzita Karlova v Praze

Opletalova 26
110 00 Praha 1

E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

Bibliographic information:
Vacek, P. (2010). "Panel Data Evidence on Productivity Spillovers from Foreign Direct Investment: Firm-Level Measures of Backward and Forward Linkages" IES Working Paper 19/2010. IES FSV. Charles University.

This paper can be downloaded at: http://ies.fsv.cuni.cz

Panel Data Evidence on Productivity Spillovers from Foreign Direct Investment: Firm-Level Measures of Backward and Forward Linkages

Pavel Vacek*

*IES, Charles University Prague
E-mail: vacek@fsv.cuni.cz

August 2010

Abstract:

I examine whether foreign direct investment increases the productivity of manufacturing firms. I test the proposition that local firms benefit from supplying multinational firms (spillovers through backward linkages) and by purchasing inputs from multinationals (spillovers through forward linkages). The existing literature on productivity spillovers has relied on industry-level proxies for spillovers. I identify spillovers directly at the firm level. I have conducted field work in the Czech manufacturing sector and built a unique data set that enabled me to construct firm-level measures of backward and forward linkages. My results provide strong support for the existence of productivity spillovers through backward linkages.

Keywords: FDI, spillovers, forward–backward linkages

JEL: F23

1. Introduction

Many countries offer generous incentive packages to attract foreign direct investment (henceforth FDI). These packages include, but are not limited to, tax holidays, duty exemptions, job creation grants, and subsidized industrial infrastructure. They are costly and viewed as unfair by some observers. What is the economic rationale for attracting FDI? Policymakers in both developed and developing countries often cite productivity transfer from multinational firms to local firms as one of the most important benefits of FDI. "*Foreign investment brings in new research, technology, and skills: … These advances are often adopted by locally-owned companies.*" (The U.S. Department of State, a press release from March 13, 2006). This belief propagates in part because of claims of productivity spillovers from FDI, such as those of the World Bank (2005, p. 60), which writes that "*one of the attractions of increasing FDI is that technology and expertise may spill over to local suppliers, customers, and competitors*."

However, despite having important policy implications, it is an open question whether productivity spillovers from FDI exist. Researchers have so far lacked firm-level data about interactions between multinational and local firms that would enable them to provide econometric evidence about spillovers between individual firms. Instead, they examine linkages between industries (inter-industry linkages) using aggregate, i.e. industry-level proxies for linkages. My aim is to fill this gap in the literature. The fundamental proposition of this study is that it is necessary to overcome existing data limitations and examine linkages *directly* at the firm level to identify productivity spillovers. I conducted my own field work to collect unique data that enable to test directly at the firm level whether foreign direct investment increases the productivity of domestic firms. In particular, I examine whether manufacturing firms in the Czech Republic benefit from supplying multinationals (spillover through backward linkages) and by purchasing inputs from multinationals (spillover through forward linkages).

Main findings can be summarized as follows: My results provide strong support for the existence of productivity spillovers through backward linkages in the Czech manufacturing sector for 1995-2004. Results are robust across many econometric specifications. I do not find any econometric evidence supporting the hypothesis of productivity spillovers through forward linkages.

This paper relates methodologically to the studies of Javorcik (2004), Javorcik and Spatareanu (2005), and Blalock and Gertler (2008). These researchers concentrate on vertical spillovers through backward and forward linkages.[1] However, all of these studies examine inter-industry spillovers whereas I examine spillovers at the firm level.

Javorcik (2004) examines whether productivity spillovers from FDI take place in the Lithuanian manufacturing industry. She asks whether domestic firms increase their productivity by supplying to multinational firms. She estimates a production function and examines whether domestic establishments selling more to foreign-owned firms produce more, *ceteris paribus*. She constructs an industry-level proxy for backward linkages, defined as the share of a sector's output sold to multinational

[1] For literature studying horizontal spillovers, see Haddad and Harrison (1993), Aitken and Harrison (1999), Djankov and Hoekman (2000), and Keller and Yeaple (2003).

firms. She employs input-output tables to measure the shares of output of a particular sector that are sold to other sectors. She introduces industry-level controls for forward linkages. They are defined analogously to measures for backward linkages as the weighted share of output in supplying sectors produced by firms with foreign capital participation. She employs input-output matrices to measure the shares of inputs purchased by a particular sector from other sectors. The key finding is the existence of a positive and significant coefficient on the proxy for backward linkage.

Javorcik and Spatareanu (2005) study spillovers through backward linkages in the Czech Republic and Romania, using the same methodology as in Javorcik (2004). They do not find any evidence for productivity spillovers through backward linkages.

Blalock and Gertler (2008) study technology transfer from FDI to local suppliers in Indonesia. They also employ industry-level measures for backward linkages. They find evidence of productivity gains among local firms upstream from foreign entrants.

I contribute to the literature in following ways:

First, unlike the existing literature which studies linkages between industries, I examine linkages directly between individual firms. My paper is based on unique data from my field work that enabled me to construct and employ firm-level measures for backward and forward linkages in my econometric analysis. This is important for the following reason: Firm-level measures of backward and forward linkages are conceptually correct measures of linkages. Researchers use industry-level proxies for linkages due to unavailability of firm-level data. They assume that all firms within an industry have the same linkage. In this regard, each industry is taken as one firm. As an example, consider backward linkages. Studies that employ industry-level measures for backward linkages analyze the impact of a percentage increase in the share of a *sector's* output sold to multinational firms on a percentage change in the output of *each* *domestic firm* in the supplying industry. Industry-level proxies would be suitable measures of linkages only if multinationals transfer their skills and expertise to all local firms.[2] However, my qualitative evidence does not suggest that multinationals distribute their expertise widely. On the contrary, it shows that direct contacts between multinationals and their Czech suppliers, and their interactions on a day to day basis are crucial for productivity spillovers. Suppliers to multinationals especially benefit from their assistance with financing, quality control, and training of employees. They also face stringent quality and on-time delivery requirements. Firms that are not suppliers to multinationals have very limited opportunity to benefit from their presence. Therefore, it is crucial to work with data that enables us to identify specific firms that interact with multinationals. However, I also include standard industry-level measures for spillovers in my estimations for comparison.

Second, identification of individual suppliers to multinationals in my data enables me to test a "self-selection hypothesis." The self-selection hypothesis has been well established in the literature on "learning by exporting." Clerides, Lach, and Tybout (1998) show that superior productivity performance of exporters stems from self-selection of ex ante more productive firms into exporting, and they do not find any evidence for productivity spillovers through exporting, or learning by exporting. Analogously to learning by exporting literature, I hypothesize that a decision to supply to multinationals may be endogenous, i.e. a part of the equilibrium. Ex ante more productive firms might self-select into supplying to multinationals. However, I do not

[2] Also note that even in this very unlikely case, existing measures of linkages are imprecise. The reason is that researchers use input-output matrices to construct industry-level proxies for linkages. Input-output matrices are usually not available for every year. Thus, researchers use the same input-output matrices for many years or their linear interpolations. If the structure of the economy changes, their industry-level proxies for spillovers become problematic. This is an issue, as productivity spillovers are often studied in emerging and transitional countries that are trying to catch up with more developed countries. But these are precisely the countries where the economy undergoes sweeping structural changes.

consider hypotheses of learning by supplying to multinationals and self-selection into supplying to multinationals to be mutually exclusive. It is possible that firms need to achieve some productivity threshold before they can qualify to supply multinationals but once they achieve it and start supplying them they benefit from their interactions with multinationals. My qualitative and econometric evidence suggests that in reality both effects take place.

Third, several channels of productivity spillovers have been recognized in the literature.[3] For example, firms may learn by exporting as it brings them into contact with international best practice. They may also benefit from technology embodied in inputs purchased abroad. Existing studies on backward and forward linkages do not control for all these potential channels of productivity spillovers. Therefore, they results might be biased. In my paper, apart from controlling for backward and forward linkages, I simultaneously control for both exports of goods and imports of intermediate inputs.

To test spillovers at the firm level, I conducted labor-intensive field work over the course of one year based on in-depth interviews with managers of both Czech-owned and multinational firms located in the Czech Republic. My survey design and questionnaire[4] were specifically tailored to determine whether foreign direct investment increases the productivity of Czech firms. Personal discussions with managers and employees who were responsible for completing surveys enabled me to collect high quality data and provide qualitative evidence about relationships between domestic and multinational firms in the Czech Republic for the years 1995-2004.

The remainder of the paper is organized as follows. In section 2, I contrast my firm-level findings with results from studies employing industry-level proxies for

[3] For the review, see: Keller, W. (2004)

[4] The questionnaire is available upon request.

linkages. In section 3, I briefly review a definition of spillovers and linkages. In section 4, I describe the design of my field research. I provide population summary statistics and summary statistics of my sample. I test whether there is any response bias. In section 5, I present qualitative evidence from surveys about relationships between local firms and multinational firms in the Czech Republic. I explain my estimation strategy and present my results in section 6. I test a self-selection hypothesis in section 7. I conduct a series of robustness checks in section 8. Section 9 contains my conclusions. All tables and figures are available in the Appendix.

2. Industry-level versus Firm-level Findings

To further illustrate how methodologically important it is to examine spillovers directly at the firm level, I contrast my firm-level findings with results from studies employing only industry-level proxies for spillovers in the Czech Republic. Table below summarizes studies using data for Czech manufacturing firms.

Industry-level versus Firm-level Findings

	Measures of linkages	Panel data for:	Backward linkage proxy	Forward linkage proxy
Javorcik and Spatareanu (2005)	**Industry-level**	1998-2000	**No effect**	Not included
This paper	**Industry-level**	2000-2002	**No effect**	No effect
This paper	**Firm-level**	1995-2004	**Positive effect**	No effect

Javorcik and Spatareanu (2005) employing industry-level measures for linkages did not find any evidence for productivity spillovers from multinationals to their Czech suppliers for 1998-2000. This conclusion is not consistent with my qualitative evidence that multinational firms provide assistance to Czech-owned firms. Moreover, macroeconomic characteristics of the Czech Republic make it a particularly likely candidate for productivity spillovers. It has a long industrial tradition and high endowment of skilled labor. From 1990, the Czech Republic has been trying to catch-up to more developed countries. It has a highly open economy that received the highest inflow of FDI per capita out of all transitional Eastern European countries during the 1990s. Figure 1 and Figure 2 in the Appendix present, respectively, FDI inflows in manufacturing between 1993 and 2004 and the territorial structure of the stock of FDI as of December 31, 2004. One of possible reasons why Javorcik and Spatareanu (2005) might not find any evidence for spillovers is that they work with data for 1998-2000. Figure 1 in the Appendix reveals that there was a surge in FDI inflow to the Czech Republic in 1998 and 1999. If it takes more time before spillovers through linkage manifest themselves, one should focus on the period after 1999. To check whether a focus on the later time period leads to a different conclusion, I used the existing methodology and tested for spillovers at the industry level with data for 2000-2002. Javorcik and Spatareanu (2005) used balance sheet data from the commercial database Amadeus. I made use of a panel data set designed by the Czech Statistical Office specifically for the purpose of this exercise. It contains balance sheet information on all manufacturing firms (NACE 15 – 36) above 100 employees and on a sample of firms with less than 100 employees from 2000 to 2002. However, despite using different dataset and focusing on later time period, I did not find any evidence in favor of spillovers through backward linkages at the aggregate level either.[5] These results sharply contrast with findings of this study. Here, using conceptually correct, i.e. firm-level measures of linkages, I find econometric evidence consistent with productivity spillovers from multinationals to their local suppliers. It shows that observation of a neutral or even a negative spillover effect at the aggregate level does not preclude the possibility of a positive impact at a more detailed level.

[5] Results are available upon request. I included also measures of forward linkages but they did not have any effect either.

3. Definition of Spillovers and Linkages

I use the term “spillover” as defined by Javorcik (2004, p. 607): “Spillovers from FDI take place when the entry or presence of multinational corporations increases the productivity of domestic firms in a host country and the multinationals do not fully internalize the value of these benefits.”

Backward linkages are understood as contacts between multinational firms and their local suppliers. They are a potential channel for productivity spillovers. Productivity spillovers through backward linkages may take place through, for example, direct knowledge transfer from multinational firms to their local suppliers. Multinational firms have an incentive to provide assistance to their suppliers to ensure high quality and on-time delivery of their production inputs. I collected qualitative evidence (see section 5.1) showing that multinational firms indeed provide assistance to their suppliers. It is also possible that multinational buyers have higher requirements for product quality and on-time delivery compared to local firms, which might stimulate their local suppliers to improve their production process. According to my qualitative evidence, local suppliers who consider their multinational customers to be more demanding than Czech buyers mention in particular multinationals’ higher quality requirements (see section 7).

Forward linkages are defined as contacts between multinationals and their local downstream consumers. Productivity spillovers through forward linkages may take place through gaining access to new, higher quality or less costly intermediate inputs produced by multinationals in upstream sectors. I collected qualitative evidence (see section 5.2) showing that this might be the case. Inputs purchased from multinationals may also be accompanied by the provision of complementary services that were not previously available and that may increase the productivity of local firms.

4. Data and Field Work

My own field work research was necessary to get any information about relationships between multinational and Czech-owned firms in the Czech Republic. In this section, I first define which firms are subjects of my research. Second, I describe how I conducted my field work research. Third, I discuss the characteristics of the sample I obtained from my field work.

4.1 Population of Firms

There were too many manufacturing firms in the Czech Republic for me to study the whole manufacturing sector[6], so I focused on firms in four selected NACE[7] sectors: 21 - Pulp, paper, and paper products; 29 - Machinery and equipment; 31 - Electrical equipment and apparatus; and 34 - Motor vehicles. I chose these industries because they represent Czech manufacturing well in the sense that they have a long tradition and a wide presence in the area.

Within these four sectors I concentrated on firms that had at least one hundred employees on December 31, 2004. There are several reasons for focusing on relatively large firms. Bigger firms have reporting requirements to the Czech Statistical Office by operation of law and therefore are used to reporting financial data. Smaller firms are often family businesses that consider their financial data confidential. Small firms also do not have a large enough administrative labor force to be able to cooperate on comprehensive surveys. Small firms are also less relevant to my research since they are less likely to interact with multinational firms.

For the manufacturing firms in NACE sectors 21, 29, 31 and 34 that had at least 100 employees on December 31, 2004, I obtained the following information from the

[6] There were 9163 manufacturing firms (NACE sectors 15-36) with at least 20 employees on December 31, 2003, according to the Business Registrar of the Czech Statistical Office.
[7] NACE denotes General Industrial Classification of Economic Activities in the European Communities, (Nomenclature générale des activités économiques dans les Communautés européennes).

Business Register of the Czech Statistical Office: a) name of the company, b) to which NACE sector it belongs and c) the form of ownership of the company. The Czech Statistical Office (CZSO) distinguishes between three forms of ownership: Czech-owned, international, and foreign firms. The ownership is classified as "Czech-owned" if the share of foreign capital in the firm's equity is zero, as "International" if a firm is owned by both domestic and foreign capital, and as "Foreign" if a firm is owned only by foreign capital. According to the CZSO, there were a total of 691 firms in the four industries of interest that had at least one hundred employees on December 31, 2004. However some of these firms were not relevant for my study. I excluded 20 firms either because they were cooperatives which employed primarily handicapped workers or because they were state military companies. These firms are not governed by standard market conditions. I ended up with 671 firms. These firms form the population of firms for my research. Table 1 in the Appendix presents detailed information about the number of firms in the population, divided according to industry and form of ownership.

4.2 Design of Field Work

For my analysis I needed to collect firm-level panel data. For this purpose I constructed a questionnaire and in December 2004 I visited a couple of firms to test its design. I started full-fledge field work research in January 2005 and finished it in December 2005. I determined which firms to contact as follows. I assigned a random number from a uniform distribution to each of the 671 firms in the population. I assigned random numbers to firms in each of the four industries studied separately. I sorted the firms in each industry according to increasing assigned number. I contacted the firms in each industry using these randomized lists. My budget constraint allowed me to contact 44 percent of the firms in the population.

Due to the complexity of data that I asked for, I did not mail any surveys to the sampled firms. Instead I set up appointments with CEOs over the phone first and then each firm was visited personally. The survey had two parts. The first part of the questionnaire was filled in mostly during interviews with CEOs in the firms. Its aim was to provide qualitative evidence about relationships between local and multinational firms in the Czech Republic. Qualitative evidence based on this part of the survey is presented in Section 5.

The second part of the questionnaire contained questions regarding financial data. I asked firms to provide information for the period 1995-2004.[8] I collected balance sheet data, data on exports and material imports. In order to be able to construct a control for backward linkages in my econometric analysis, I collected information on the structure of the firms' consumers. I know whether in each given year a firm had any multinational consumers. If the firm had a multinational consumer I know its percentage share in the firm's sales of its own products. I also have information about the share of foreign ownership in the firm of the multinational consumer. In order to be able to model forward linkages, I collected analogical information about each firm's suppliers of material inputs. I know whether in a given year a firm had any multinational material suppliers. If the firm had a multinational supplier I know about its percentage share in the firm's material consumption. I also have information about the share of foreign ownership in the firm of multinational supplier.

[8] I did not collect data prior to 1995 because the first five years after the Velvet Revolution, which took place in November 1989, were full of turbulent changes: state firms were being privatized, firms were realigning into new entities or going bankrupt, and there were not many multinational firms in the Czech Republic until 1995. 2004 was the last year for which data was available when I started my data collection.

4.3 Testing for Response Bias

In any analysis based on surveys there is a possibility of response bias. During my field work I encountered firms that did not wish to participate in my research when I contacted them and firms that allowed me to visit their firms and interview them but did not return completed surveys. Table 2 in the Appendix provides a detailed summary of the firms contacted. I contacted 295 firms, which amounts to 44 percent of the firm population. 37 firms, which amounts to 12.6 percent of the firms contacted, refused to be visited and interviewed. 258 firms (38.5 percent of the population) were personally visited and interviewed. Out of 258 visited firms, 155 firms either never sent back the second part of the surveys or filled it out incompletely. These firms amount to 52.5% of all firms contacted. The major reason firms mentioned for not completing the survey was its complexity. Although firms know who their multinational consumers and suppliers are, they often do not have readily available information about shares of multinationals in their sales or in material consumption. It is demanding to extract this data from their information systems, especially data for several years back. 103 firms returned the second part of the survey filled out in such a way that I could use it in my econometric analysis. These firms amount to 34.9 percent of the firms contacted and 15.35 percent of the population.

Are firms that provided data systematically different from those that did not provide data? I was able to compile data about sales, tangible assets, and profits for 129 of the firms that declined to be interviewed or did not return filled surveys. This data is available for various years between 1995 and 2003, and it comes from Data Monitor database from the year 2003. Firms that did not provide data have higher mean sales and stocks of tangible assets and smaller mean profits. However, a t-test shows that there is no statistically significant difference in mean sales, mean stocks of tangible assets, and mean profits between firms in my sample and firms that did not provide data. Testing statistics are presented in Table 3 in the Appendix. Although I cannot conclude that there is no bias on the basis of three characteristics, these test statistics give me at least some evidence that the presence of a bias is less likely.

4.4 Sample Summary Statistics

I obtained data for 103 firms and they form an unbalanced panel data set. I have minimally 3 years of data for each firm, maximally 10 years and on average 6.9 years. Table 4 in the Appendix provides precise information about the number of firms in my sample in each sector and their shares in the relevant population.

Table 5 in the Appendix contains information about the numbers of firms in my sample divided both according to industry and owner nationality. I distinguish Czech-owned firms from multinationals. I define Czech-owned firms as firms that do not have any foreign capital in their equities. Figure 3 in the Appendix shows the precise distribution of foreign share in the firms in my sample. A histogram reveals that the majority of firms have either zero foreign share in their equity or more than 50 percent. Therefore my classification of firms as Czech-owned and multinational is not very sensitive to the arbitrary choice of the size of share of foreign capital in the firm's equity. If I classify type of ownership as of December 31, 2004, my sample contains 58 Czech-owned firms and 45 multinational firms. I collected data for 18.2 percent of the population of Czech-owned firms and 12.8 percent of the population of multinationals.

Table 6 in the Appendix contains detailed summary statistics for Czech-owned and multinational firms.

5. Qualitative Evidence from the Questionnaire

A sample of 44 multinationals and 90 Czech-owned firms provided answers. These questions were answered by general managers during interviews in the firms.

5.1 Do Multinationals Provide Assistance to Their Suppliers?

I asked firms whether they had provided any assistance to their supplier(s) so that I could provide qualitative evidence about productivity spillovers through backward linkages. 75 percent of multinational firms claimed that they had helped their suppliers. When asked what kind of assistance they had provided, multinationals mentioned in particular (see Figure 4 in the Appendix):[9] help with financing (e.g. advanced payments) in 50 percent of cases, quality control (30%), and improvement of production technology (20%). The other most frequent forms of assistance included: help with storage of material (14%), machinery maintenance (11%), and finding new customers (9%). 7 percent of multinationals also provided employee training to their suppliers. Other forms of assistance named were suggestions about the production of new products, help with the development of new material and its production technology, and the possibility of testing new technologies.

I asked Czech-owned firms about their experience with their multinational consumers located within the Czech Republic. 48 percent of Czech-owned firms that have at least one multinational consumer indicate that they have received help. When asked what kind of help they have received, Czech firms report in particular (see Figure 5 in the Appendix): help with financing (49%), quality control (43%), employee training (34%), and technology improvement (26%).

Figure 6 in the Appendix summarizes perceived influence of the entry of multinational firms into the Czech Republic on respondents' firms.

[9] These percentages do not add up to 100% as firms received multiple forms of assistance.

5.2 Inputs of Production – Sourcing Patterns

I asked firms whether and, if so, why they buy material inputs from multinational firms located in the Czech Republic to provide qualitative evidence about productivity spillovers through forward linkages. 78 percent of firms reported that they bought inputs from multinationals located in the Czech Republic. What are their reasons? In most cases (see Figure 7 in the Appendix)[10] Czech-owned firms do not produce the needed inputs (56%). In 34 percent of cases they buy inputs from multinationals because the multinationals' products are of higher quality, are cheaper (23%), or multinationals offer the best quality-price ratio (10%). In 9 percent of cases customers require firms to purchase their inputs from specific multinational suppliers.

I asked firms whether and, if so, why they import material inputs. 92 percent of firms import inputs of production. When asked why they import material, (see Figure 8 in the Appendix) firms claim: it is not available in the Czech Republic (83%), imported material is cheaper (30%), it is of higher quality (28%), specific material from abroad is required by their customers (8%), and imports offer the best quality-price ratio (4%).

To conclude, qualitative evidence shows that multinationals provide assistance to their suppliers. There is also some evidence that inputs from multinationals and imported material might be of higher quality and can be a source of productivity increase.

6. Research Strategy and Estimation Results

My identification strategy follows an approach similar to Javorcik (2004) and Blalock and Gertler (forthcoming). I test whether firms that sell more products to multinationals produce more, *ceteris paribus* (spillover through backward linkage)

[10] These percentages do not add up to 100% as firms gave multiple reasons for purchasing inputs from multinationals.

and whether firms that purchase more inputs from multinationals produce more, *ceteris paribus* (spillover through forward linkage). To this purpose, I estimate several variants of production functions. I augment the production functions by including firm-level controls for backward and forward linkages.

6.1 Baseline Pooled OLS Estimation

First, I estimate a production function in the form:

$$(1)\quad \ln Y_{it} = \alpha_1 + \alpha_2 \cdot \ln M_{it} + \alpha_3 \cdot \ln E_{it} + \alpha_4 \cdot \ln U_{it} + \alpha_5 \cdot \ln S_{it} + \alpha_6 \cdot \ln K_{it} + \alpha_7 \cdot FS_{it} + \alpha_8 \cdot Backward_{it} + \alpha_9 \cdot Forward_{it} + \alpha_t + \alpha_j + \alpha_r + \varepsilon_{it},$$

where Y_{it} stands for a real output of firm i at time t. Output is calculated as a sum of sales and a change in inventories of the firm's own products. It is deflated by a producer price index for the proper 2-digit NACE sector obtained from the Czech Statistical Office. M_{it} denotes a real consumption of material. A deflator for material was constructed for each sector using a 1999 input-output matrix and producer price indices for the relevant 2-digit NACE sectors. E_{it} is real energy consumption. Energy consumption was deflated by a producer price index for energy. I distinguish skilled and unskilled workers: U denotes the number of unskilled workers and is measured as the number of people in production; S denotes the number of skilled workers and is measured as the number of people out of production. K_{it} stands for real net tangible capital at the beginning of the year. Net tangible capital was deflated by a simple average of producer price indices for the following 2-digit NACE sectors: machinery and equipment, motor vehicles and electrical equipment and apparatus. I use the net capital instead of gross capital because it takes into account a vintage of capital.

FS_{it} stands for a share of foreign capital in the firm's equity (Foreign Share). The variable attains values from zero to one. Firms that have zero share of foreign capital in their equity are classified as "Czech-owned firms." I call firms with a positive foreign share "multinationals."

$Backward_{it}$ as a measure of backward linkages is a variable of particular interest. It measures the percentage of output sold to multinational firms. The unique structure of my data allows me to work with a firm-level measure of backward linkages. It is defined as follows:

$$Backward_{it} = \sum_{c=1}^{C} \frac{FS_c \cdot S_c}{S_T},$$

where c=1,….C indexes consumers of firm i, FS_c is the share of foreign capital in the firm of consumer c, S_c is an own output that firm i sold to consumer c and S_T are total sales of own goods and services of firm i. As an example, suppose that firm i had three consumers in 2004. If it sold 1/5 of its production to Consumer 1, of which 100% was owned by foreign capital, 1/20 of its production to Consumer 2, of which 50% was owned by foreign capital, and 3/4 of its production to Consumer 3, which was a Czech-Owned firm, then $Backward_{it}$ equals $\frac{1}{5}\cdot 1+\frac{1}{20}\cdot 0.5+\frac{3}{4}\cdot 0 = 0.225$.

$Forward_{it}$ measures that percentage of consumption of material that firm i bought from multinationals. It is defined analogically to Backward variable as:

$$Forward_{it} = \sum_{s=1}^{S} \frac{FS_s \cdot M_s}{M_T},$$

where s=1, …S indexes suppliers of material of the firm i, FS_s is a share of foreign capital in the firm of supplier s, M_s is a value of consumed material supplied by supplier s to the firm i and M_T is the firm's i total consumption of material.

α_t, α_j and α_r are fixed effects for years (10), NACE industries (4), and regions (14), respectively.

Table 7 in the Appendix contains the pooled OLS results in columns 1 and 3 for the full sample and the subsample of Czech-owned firms, respectively. Coefficients on material, energy, and unskilled and skilled labor have expected positive signs in both specifications, and they are also statistically significant at the 1% level. The coefficient on capital is negative and highly statistically insignificant in both specifications. The poor estimate of the capital coefficient is likely caused by the nature of the measure of capital used; stock of capital is an accounting entry that does not capture well the services of capital used at production. The coefficient on foreign share is positive and statistically significant. This indicates that firms with foreign capital are more productive than Czech-owned firms.

The most important result is that the coefficient on the Backward variable is positive and statistically significant at the 1% level in both specifications. This provides the first indication of the existence of productivity spillovers through backward linkages in this study. Its magnitude seems economically meaningful and important. A one-percentage-point increase in the backward linkage of a Czech-owned firm is associated with a 0.772 percent rise in its output.[11] Coefficients on the Forward variable are not statistically significant. The coefficient on Forward variable even takes a negative sign in the full sample of firms. There is thus no evidence of spillovers through forward linkages.

It is important to note that there is qualitative evidence showing that multinational firms are more aggressive in negotiating prices with their suppliers (see section 6 for qualitative evidence). CEOs often complained that “multinationals want everything for free.” As big players, they have better negotiating positions to enforce

[11] See Table 7, column 3 in the Appendix.

lower prices for their inputs than smaller Czech-owned firms.[12] I interpret productivity gains through backward linkages as an extra value of output a Czech-owned firm produces by increasing the share of output supplied to multinationals in total sales of its own products and services by 1 percentage point, *ceteris paribus*. The "price squeeze effect" goes against the "spillover". Although Czech-owned suppliers to multinationals are being price-squeezed, I can see that the higher the share of output sold to multinationals, the more Czech firms produce, *ceteris paribus*. This suggests that I am capturing productivity gain and not simply the price effect. This reasoning applies for spillovers through backward linkages in all specifications presented in the paper.

On the other hand, in the case of forward linkages, the price effect goes in the same direction as the hypothesized spillover. Multinational suppliers may produce more sophisticated products and sell them at higher prices. The Czech-owned firms may not be able to make use of the better technology embodied in these inputs but they bear the higher costs. This might be a reason why I find positive but insignificant and, in several cases, even negative coefficients on the Forward variable.

If it takes more time before productivity spillovers manifest themselves, lagged rather than contemporaneous measures for backward and forward linkages should be included in the model. Therefore I re-estimate the model (1) with one-period lagged linkage variables. Results from the full sample of firms and the subsample of Czech-owned firms are reported in Table 7 in the Appendix, columns 2 and 4, respectively. Again, all coefficients of production inputs but capital are positive and statistically significant at the 1% level. Coefficients on the Backward variable are positive and statistically significant at the 1% level in both columns. They are similar in magnitude

[12] See Table 6 in the Appendix to compare the size of multinational firms and Czech-owned firms based on my sample.

to estimates with contemporaneous linkages. Coefficients on the Forward variable are not statistically significant.

So far, I have worked with the Cobb-Douglas production function. This motivates an alternative estimation with a more flexible functional form to test the sensitivity of my results to the choice of the form of the production function.

6.2 Translog Production Function

I estimate model in the form:

$$
\begin{aligned}
(2)\quad \ln Y_{it} = {} & \alpha_1 + \alpha_2 \cdot Backward_{it} + \alpha_3 \cdot Forward_{it} + \alpha_4 \cdot FS_{it} + \alpha_5 \cdot \ln M_{it} + \alpha_6 \cdot \ln K_{it} + \alpha_7 \cdot \ln E_{it} \\
& + \alpha_8 \cdot \ln U_{it} + \alpha_9 \cdot \ln S_{it} + \alpha_{10} \cdot \ln^2 M_{it} + \alpha_{11} \cdot \ln^2 K_{it} + \alpha_{12} \cdot \ln^2 E_{it} + \alpha_{13} \cdot \ln^2 U_{it} + \\
& + \alpha_{14} \cdot \ln^2 S_{it} + \alpha_{15} \cdot \ln K_{it} \cdot \ln M_{it} + \alpha_{16} \cdot \ln K_{it} \cdot \ln E_{it} + \alpha_{17} \cdot \ln K_{it} \cdot \ln U_{it} + \\
& + \alpha_{18} \cdot \ln K_{it} \cdot \ln S_{it} + \alpha_{19} \cdot \ln S_{it} \cdot \ln M_{it} + \alpha_{20} \cdot \ln S_{it} \cdot \ln E_{it} + \alpha_{21} \cdot \ln U_{it} \cdot \ln S_{it} + \\
& + \alpha_{22} \cdot \ln U_{it} \cdot \ln M_{it} + \alpha_{23} \cdot \ln U_{it} \cdot \ln E_{it} + \alpha_{24} \cdot \ln M_{it} \cdot \ln E_{it} + \alpha_t + \alpha_j + \varepsilon_{it}
\end{aligned}
$$

All variables are defined and denoted as before. The translog production function controls for input levels and scale effects. Table 7 in the Appendix shows OLS results estimated for the full sample and the subsample of Czech-owned firms in columns 5 and 8, respectively. Owing to space constraints, only the coefficients on linkages and the foreign share are reported. Again I get evidence for the existence of productivity spillovers through backward linkages and no evidence for forward linkages. A one-percentage-point increase in the backward linkage of a Czech-owned firm is associated with a 0.358 percent rise in output.[13] Although this coefficient is smaller compared to the baseline case (0.772), it is still economically significant. This indicates that previous results were not driven by the use of the Cobb-Douglas production function.

So far I have ignored the fact that there might be unobserved firm characteristics that influence firm productivity. Such characteristics may include, but

[13] See Table 7, column 8 in the Appendix.

are not limited to, talented or, on the other hand, poor managers, advantageous geographical location, and access to better infrastructure. If this is the case, the OLS results are inconsistent. In the next section I make use of a panel structure of my data to account for fixed firm-specific unobserved factors.

6.3 Fixed Effects Estimator and Model in the First Differences

To account for a fixed firm-specific heterogeneity, I apply a within estimator first. I estimate model (3) using the fixed effects estimator (FE):

$$(3)\quad \ln Y_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_4 \cdot \ln M_{it} + \alpha_5 \cdot \ln E_{it} + \alpha_6 \cdot \ln U_{it} + \alpha_7 \cdot \ln S_{it} + \alpha_8 \cdot \ln K_{it} + \alpha_t + \lambda_i + \varepsilon_{it}.$$

where λ_i denotes the firm-specific effect. In Table 7 in the Appendix, results of the fixed effects estimator for the full sample and the subsample of Czech-owned firms are presented in columns 6 and 9, respectively. I find a positive and statistically significant coefficient on the Backward variable in both cases. The magnitude of the effect is economically meaningful. A one-percentage-point increase in the backward linkage of a Czech-owned firm is associated with a 0.356 percent rise in its output.[14] The coefficients on the Forward variable are positive but not statistically significant at standard levels.

Alternatively to fixed effects, I remove fixed firm-specific unobservable variation by estimating model (1) in the first differences. In addition to removing any fixed firm-specific unobservable variation, differencing will remove fixed regional and industrial effects.[15] Since spillovers through linkages are likely to influence productivity with a time lag, I include one-period lagged differences of linkage variables.

[14] See Table 7, column 9 in the Appendix.

[15] When there are more than two periods, the choice between first differencing and fixed effects hinges on the assumption about the idiosyncratic errors. In particular, the FE estimator is more efficient if the idiosyncratic errors are serially uncorrelated, while the first difference estimator is more efficient when the idiosyncratic errors follow a random walk. See Wooldridge, M.J. (2002, p. 284) for more details.

The model in the first differences is specified as:

$$(4)\quad \Delta \ln Y_{it} = \beta_1 \cdot \Delta\, Backward_{i,t-1} + \beta_2 \cdot \Delta Forward_{i,t-1} + \beta_3 \cdot \Delta FS_{it} + \beta_4 \cdot \Delta \ln M_{it} + \beta_5 \cdot \Delta \ln E_{it} + \beta_6 \cdot \Delta \ln U_{it} + \beta_7 \cdot \Delta \ln S_{it} + \beta_8 \cdot \Delta \ln K_{it} + \Delta \alpha_t + \mu_{it}.$$

Table 7 in the Appendix contains results from the model in the first differences with the one-period lagged differences in linkage variables for the full sample of firms and for the subsample of Czech-owned firms in columns 7 and 10, respectively. Again, I find evidence of spillovers through backward linkages and no evidence of spillovers through forward linkages.

At least as early as Marschak and Andrews (1944), researchers have been concerned about possible correlation between input levels and the unobserved firm-specific productivity shocks when estimating production function parameters. Ignoring the potential endogeneity may lead to biased parameter estimates. In the next section I take the possible endogeneity of input choices into account by applying the system GMM estimator.

6.4 System GMM

The OLS method is not appropriate for estimating coefficients of production function if inputs cannot be treated as exogenous. If a firm chooses its inputs of production based on its productivity, which is observed by the firm but not by the econometrician, the inputs are endogenous and OLS estimates will be biased.[16]

In this section I consider a model in the form:

$$(5)\quad \ln Y_{it} = \alpha_1 + \alpha_2 \cdot \ln M_{it} + \alpha_3 \cdot \ln E_{it} + \alpha_4 \cdot \ln U_{it} + \alpha_5 \cdot \ln S_{it} + \alpha_6 \cdot \ln K_{it} + \alpha_7 \cdot FS_{it} + \alpha_8 \cdot Backward_{it} + \alpha_9 \cdot Forward_{it} + \lambda_i + \varepsilon_{it}$$

I regard all right-hand side variables to be endogenous. I use the system GMM estimator of Blundell and Bond (1998, 1999) to estimate the model (5). The system GMM estimator is based on two sets of moment conditions. The first set of the

[16] See Griliches and Mairesse (1995).

moment conditions comes from the first differenced equations (to remove the firm-specific effect) with lagged levels of the variables as instruments (c.f. Arellano and Bond, 1991). A problem with the original Arellano-Bond estimator is that lagged levels are often poor instruments for first differences. Arellano and Bover (1995) described how, if the original equations in levels were added to the system, additional moment conditions could be used to increase efficiency. These additional moment conditions are based on the level equations with lagged differences of the variable as instruments.[17]

I assume that there is no serial dependence in ε_{it}, i.e. for all i, $E[\varepsilon_{it} * \varepsilon_{is}]=0$ for $s \neq t$. I assume that all right-hand side variables are endogenous, i.e. $E[x_{it} * \varepsilon_{is}] \neq 0$ for $s \leq t$ but $E[x_{it} * \varepsilon_{is}]=0$ for all $s>t$. I use following instruments: for the first-difference equations, lagged levels dated t-2 and earlier of the endogenous variables are used as instruments, and, for the levels equations, first-differences of endogenous variables dated t-1 are used as instruments.

Results estimated for the subsample of Czech-owned firms are presented in Table 7 in the Appendix in column 11.[18] The Hansen test of overidentifying restrictions confirms that instruments are jointly exogenous. I also present the Arellano-Bond test for AR(2) in the first differences. Estimated differenced residuals, $\Delta\varepsilon_{it}$, do not exhibit second-order serial dependence, which is important for the validity of my identification assumption of no serial dependence of ε_{it}. The coefficients on Backward and Forward linkages are positive. However, only the coefficient on Backward linkage is statistically significant (p-value=0.08). A one-percentage-point

[17] Blundell and Bond (1998, 1999) precisely characterized the necessary assumptions for this augmented estimator and tested it with Monte Carlo simulations. The main assumption is that $E[\lambda_i * \Delta \varepsilon_{it}]=0$, which means that the unobserved firm-specific effects are not correlated with changes in the error term.

[18] I employed the xtabond2 command in Stata with a collapse option, see: Roodman, D. (2005).

increase in the backward linkage of a Czech-owned firm leads to a 0.658 percent rise in its output.[19] This provides further evidence that Czech-owned firms benefit from their interactions with their multinational customers.

Olley and Pakes (1996) and Levinsohn and Petrin (2003) proposed alternative methods how to deal with the endogeneity of input choices. I use both of them to check the robustness of my system GMM results.

6.5 Levinsohn-Petrin Estimator of Production Function

Levinsohn-Petrin (2003) show how intermediate inputs, such as material and energy, can be used to control for correlation between input levels and the unobserved productivity shock. Their procedure can be applied both for production functions in value-added form and revenue (output) form. Given my relatively limited sample size, I estimate the production function in value-added form, as there are fewer coefficients to be estimated compared to revenue case. Value-added (VA) is defined as the difference between real output and real material and energy consumption. I consider a model in the form:

$$(6)\quad va_{it} = \alpha_0 + \alpha_s \cdot s_{it} + \alpha_u \cdot u_{it} + \alpha_k \cdot k_{it} + \alpha_b \cdot Backward_{it} + \alpha_f \cdot Forward_{it} + \omega_{it} + \varepsilon_{it},$$

where $va_{it} = \ln VA_{it}$, $s_{it} = \ln S_{it}$, $u_{it} = \ln U_{it}$ and $k_{it} = \ln K_{it}$. The error term is assumed to have two components: ω_{it}, the transmitted productivity component, and ε_{it}, an error term that is uncorrelated with input choices. The transmitted productivity component ω_{it} is a state variable that impacts the firm's decision rules. It is not observed by the econometrician, but it may impact the choice of inputs, which leads to the simultaneity problem in production function estimation. I estimate (6) using the nonlinear semi-parametric LP procedure on the full sample of firms as follows.

[19] See Table 7, column 11 in the Appendix.

I assume that demand for the energy $e_{it} = \ln E_{it}$ depends on the firm's state variables, capital k_{it} and ω_{it}, i.e. $e_{it} = e_{it}(k_{it}, \omega_{it})$. LP (2003, Appendix A) showed that under mild assumptions about the firm's production technology, the demand function is monotonically increasing in ω_{it} and can be thus inverted: $\omega_{it} = \omega_{it}(k_{it}, e_{it})$. A final identification restriction concerns the development of productivity. LP (2003) follow Olley-Pakes (1996) in assuming that productivity is governed by a first-order Markov process: $\omega_{it} = E(\omega_{it} \mid \omega_{i,t-1}) + \xi_{it}$, where ξ_{it} is an innovation to productivity that is uncorrelated with k_{it}. The model (6) can be written as:

$$va_{it} = \alpha_s \cdot s_{it} + \alpha_u \cdot u_{it} + \alpha_b \cdot Backward_{it} + \alpha_f \cdot Forward_{it} + \phi_{it}(k_{it}, e_{it}) + \varepsilon_{it},$$

where $\phi_{it}(k_{it}, e_{it}) = \alpha_0 + \alpha_k \cdot k_t + \omega_{it}(k_{it}, e_{it})$. I follow Petrin, Levinsohn and Poi (2004) in substituting a third-order polynomial approximation in k_{it} and e_{it} in place of $\phi_{it}(k_{it}, e_{it})$ and estimate coefficients on Skilled and Unskilled labor and Backward and Forward linkages by OLS. In the second stage, the coefficient on capital is identified. The estimated value for ϕ_{it} can be calculated as: $\hat{\phi}_{it} = \hat{va}_{it} - \hat{\alpha}_s \cdot s_{it} - \hat{\alpha}_u \cdot u_{it} - \hat{\alpha}_b \cdot Backward_{it} - \hat{\alpha}_f \cdot Forward_{it}$. For any candidate value α_k^*, one can compute (up to a scalar constant) a prediction for ω_{it} for all periods using $\hat{\omega}_{it} = \hat{\phi}_{it} - \alpha_k^* \cdot k_{it}$. These values are used to estimate a consistent non-parametric approximation to $E(\omega_{it} \mid \omega_{i,t-1})$. It is given by the predicted values from the regression $\hat{\omega}_{it} = \gamma_0 + \gamma_1 \cdot \omega_{i,t-1} + \gamma_2 \cdot \omega_{i,t-1}^2 + \gamma_3 \cdot \omega_{i,t-1}^3 + \varepsilon_{it}$ and denoted as $\hat{E}(\omega_{it} \mid \omega_{i,t-1})$. Given $\hat{\alpha}_s$, $\hat{\alpha}_u$, $\hat{\alpha}_b$, $\hat{\alpha}_f$, α_k^* and $\hat{E}(\omega_{it} \mid \omega_{i,t-1})$, the sample residual of the production function is given as: $\varepsilon_{it} + \hat{\xi}_{it} = va_{it} - \hat{\alpha}_s \cdot s_{it} - \hat{\alpha}_u \cdot u_{it} - \hat{\alpha}_b \cdot Backward_{it} - \hat{\alpha}_f \cdot Forward_{it} - \alpha_k^* \cdot k_{it} - \hat{E}(\omega_{it} \mid \omega_{i,t-1})$.

The estimate of α_k is defined as an argument minimizing the sum of squared residuals: $\min_{(\alpha_k^*)} = \sum_i \sum_t \left(va_{it} - \hat{\alpha}_s \cdot s_{it} - \hat{\alpha}_u \cdot u_{it} - \hat{\alpha}_b \cdot Backward_{it} - \hat{\alpha}_f \cdot Forward_{it} - \alpha_k^* \cdot k_{it} - \hat{E}(\omega_{it} \mid \omega_{i,t-1}) \right)^2$.

Standard errors are obtained by bootstrap. Results are presented in Table 8, column 1. The coefficient on the Backward variable is positive, and its size (0.475) is economically meaningful.

In the next section, I use LP technique to take the possible endogeneity of input choices into account again. However, instead of augmenting production function with proxies for linkages, I construct a measure of total factor productivity first and use it as a dependent variable in the basic model.

6.6 LP Residuals as a Measure of Total Factor Productivity

Javorcik (2004) studied inter-industry spillovers in Lithuanian manufacturing. She estimated the coefficients of production function first, recovered residuals, and used them as a measure of total factor productivity (TFP) in the estimation of the basic model as a dependent variable. I would like to see whether my results are robust with respect to this methodological approach. I estimate a production function on the full sample of firms in the form: (7) $va_{it} = \alpha_0 + \alpha_s \cdot s_{it} + \alpha_u \cdot u_{it} + \alpha_k \cdot k_{it} + \omega_{it} + \varepsilon_{it}$,

using the nonlinear semi-parametric LP procedure. I assume that capital is the only state variable over which the firm has control.[20] I also estimate production function (7) using the OLS and the fixed effects estimator to check whether LP procedure works according to the theoretical prediction of Levinsohn and Petrin (2003).

Estimated coefficients of production function are presented in Table 8, columns 2-4 in the Appendix. The LP technique seems to work quite well. OLS estimates of skilled and unskilled labor exceed the LP estimates, confirming the theoretical results

[20] In section 6.7 I drop this assumption and consider decisions to supply to multinationals and to purchase inputs from multinationals as additional state variables in the input decision of firms.

discussed in Levinsohn-Petrin (2003). The fixed effects estimates do not differ substantially from the OLS and the LP estimates regarding capital and unskilled labor. In the case of skilled labor, the FE estimate is of lower quality. Likely, there is not enough within variation in the number of skilled workers to identify the coefficient well.

The residuals from the LP estimation of the model (7) become a measure of total factor productivity: $TFP_{it} = e^{va_{it} - \hat{va}_{it}}$. To test the hypotheses of productivity spillovers through backward and forward linkages, I estimate a model where the logarithm of TFP is a dependent variable in the form:

(8) $\ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_t + \varepsilon_{it}$.

To account for a fixed firm-specific heterogeneity, I estimate (8) using the fixed effects estimator. I also apply the random effects estimator and use the Hausman test to decide which estimator is more appropriate in my case. Results for the full sample and the subsample of Czech-owned firms are presented in Table 8, columns 5-6 and 7-8, respectively. For both samples the Hausman test suggests that the random effects model is more suitable than the fixed effect model.[21] In all four regressions, I find a positive and significant coefficient on the Backward variable. A one-percentage-point increase in the backward linkage of a Czech-owned firm is associated with a 0.860 percent rise in its output.[22] I do not find any evidence in favor of spillovers through forward linkages.

To verify robustness of my FE results, I alternatively remove a fixed firm-specific heterogeneity by using the first differences. To take into account that the fact

[21] Chi-square statistics is positive for both full sample and subsample of Czech-owned firms, however in the latter case it is very small (0.47) and Prob>chi-square is 1, which means that the test is weak.
[22] Based on random effects estimate for the subsample of Czech-owned firms, see Table 8, column 8.

that spillovers through linkages are likely to influence productivity with a time lag, I include one-period lagged differences of linkage variables. I estimate:

$$(9)\quad \Delta \ln TFP_{it} = \alpha_1 \cdot \Delta Backward_{i,t-1} + \alpha_2 \cdot \Delta Forward_{i,t-1} + \alpha_3 \cdot \Delta FS_{it} + \Delta\alpha_t + \varepsilon_{it}.$$

Results for the full sample and the subsample of Czech-owned firms are presented in Table 8 in the Appendix, in columns 9 and 10, respectively. Results confirm previous findings.

When I estimated the production function in the value-added form (7), I used the whole sample of firms due to data limitations. However, it would have been optimal to estimate the production function separately for each industry. To test the sensitivity of my results to this procedure, I selected the industry for which I had the most data, which is machinery and equipment industry, and re-estimated models (7)-(9). Results lead to the same conclusions and therefore I do not present them.

When estimating the production function (7) from which I recovered residuals as a measure of TFP, I assumed that capital was the only state variable over which firms had control. But firms that receive a positive productivity shock may decide to become suppliers to multinationals and/or purchase inputs from multinationals. Therefore, in the next section, I extend Olley-Pakes (OP) procedure to take these factors into account to correct for potential biases in the estimation of the total factor productivity.

6.7 OP Residuals as a Measure of Total Factor Productivity

To test the hypotheses of productivity spillovers through backward and forward linkages, I re-estimate the model (8): $\ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_t + \varepsilon_{it}$, where I use residuals as a measure of TFP recovered from production function estimated using Olley-Pakes (1996) method. More importantly, I include decisions to supply to multinationals and to purchase inputs from multinationals as additional state variables in my OP estimation of a production function to control for unobserved productivity shocks that are correlated with the supplier and the purchaser status of a firm.

I extend OP estimator as follows. I consider the production function given in (7): $va_{it} = \alpha_0 + \alpha_s \cdot s_{it} + \alpha_s \cdot u_{it} + \alpha_k \cdot k_{it} + \omega_{it} + \varepsilon_{it}$. In each period the firm has to decide about its inputs (skilled and unskilled labor) and investment. Investment (denoted as i) determines the capital stock at the beginning of each period: $k_{i,t+1} = (1-\delta) \cdot k_{it} + i_{it}$, where δ stands for the rate of depreciation. In standard OP model, the investment decision depends on the capital stock (k) and on a transmitted productivity component (ω). To take into account that suppliers to multinationals and purchasers of inputs from multinationals may face to different market and operating conditions when they make decisions about investment, I include two dummy variables into investment function – b_{it} and f_{it}. The variable b takes the value 1 if the firm is a supplier to multinationals and 0 otherwise; the variable f takes the value 1 if the firm is purchasing inputs from multinationals and 0 otherwise. Investment I_{it} is defined as a gross investment into tangible assets. It is expressed as a function of the state variables and the productivity shock: $\ln(I_{it}) = i_{it} = i_{it}(\omega_{it}, k_{it}, b_{it}, f_{it})$. Assuming that investment is monotonically increasing in productivity shock conditioned on supplier and purchaser status, investment function can be inverted. Unobservable productivity shock can be expressed as a function of observable investment, capital and supplier and purchaser dummies: $\omega_{it} = h_{it}(i_{it}, k_{it}, b_{it}, f_{it})$. By substituting for ω_{it} in the production function (7), I obtain:

$$va_{it} = \alpha_s \cdot s_{it} + \alpha_u \cdot u_{it} + \phi_{it}(k_{it}, i_{it}, b_{it}, f_{it}) + \varepsilon_{it} \text{ where } \phi_{it}(k_{it}, i_{it}, b_{it}, f_{it}) = \alpha_0 + \alpha_k \cdot k_{it} + h_{it}(k_{it}, i_{it}, b_{it}, f_{it}).$$

Since the error term ε_{it} is uncorrelated with the inputs, in the first stage, estimation of this production function provides unbiased estimates of α_s and α_u. I use a third-order polynomial expansion in i_{it}, k_{it}, b_{it} and f_{it} to approximate unknown function ϕ_{it}.

As in OP (1996), I assume that productivity follows a first order Markov process: $\omega_{it} = E(\omega_{it} \mid \omega_{i,t-1}) + \xi_{it}$, where ξ is the innovation term in productivity. In the second stage, I identify the coefficient on capital by a nonlinear least squares estimation on: $va_{i,t+1} - \alpha_s \cdot s_{i,t+1} - \alpha_u \cdot u_{i,t+1} = \alpha_0 + \alpha_k \cdot k_{i,t+1} + g((\hat{\phi}_{it}(k_{it}, i_{it}, b_{it}, f_{it}) - \alpha_k \cdot k_{it}) + \mu_{t+1}$,

where g is a third-order polynomial in $(\hat{\phi}_{it}(k_{it}, i_{it}, b_{it}, f_{it}) - \alpha_k \cdot k_{it})$ and the error term μ has two parts: the i.i.d. shock ε and the innovation term ξ in the Markov process.

The residuals recovered from model (7) become a measure of total factor productivity: $TFP\_OP_{it} = e^{va_{it} - \hat{va}_{it}}$. I denote this total factor productivity as TFP_OP to distinguish it from TFP obtained using the LP technique in the section 6.6.

Having acquired a measure of total factor productivity, TFP_OP, I can re-estimate the model (8) where I use $\ln TFP\_OP_{it}$ as a dependent variable. I apply the fixed effects estimator to control for a fix firm-specific unobservable heterogeneity. In the Appendix, results for the full sample and the subsample of Czech-owned firms are presented in Table 9, columns 1-2, respectively. In both cases, I find positive and highly statistically significant coefficients on backward linkages. Coefficients on forward linkages are not statistically significant. These findings correspond to results from the section 6.6 where the dependent variable, the total factor productivity, was obtained using LP method without controlling for the supplier and the purchaser status (see Table 8, columns 5-8, in the Appendix).

I have fewer observations for the total factor productivity obtained using the modified OP technique compared to the total factor productivity acquired using LP estimator. The reason is that unlike data about intermediate inputs, I do not have data about investment for each firm in my sample. Moreover, the investment proxy cannot be used for firms reporting zero investment and thus zero-investment observations are truncated from estimation when using the OP technique.[23] Therefore, in the rest of my paper I work with the total factor productivity (TFP) obtained using the LP technique in the section 6.6.

So far all the evidence suggests that firms in the Czech Republic benefit from supplying to multinationals. However, before I can conclude that this is indeed the case, I need to rule out a few alternative explanations. I test the self-selection hypothesis in chapter 7.

7. Self-Selection Hypothesis (Reverse Causality)

If it is more demanding to start to supply multinational firms it is possible that *ex ante* more-productive firms self-select into supplying multinationals and *ex ante* less-productive firms choose to supply Czech-owned firms. Do my previous results capture productivity spillovers or are they driven merely by self-selection? Or, do these two effects take place simultaneously?

Clerides, Lach, and Tybout (1998) tested the self-selection hypothesis when studying whether firms in Colombia, Mexico, and Morocco were learning by exporting. They concluded that (p. 903) “the positive association between exporting and efficiency is explained by the self-selection of the more efficient firms into the export markets.” In other words, they found that causality flew in the opposite direction: instead of exporting causing efficiency gains, the relatively more efficient firms self-selected into exporting.

[23] This is due to an invertibility of the investment function, the monotonicity condition does not hold for zero-investment observations.

Melitz (2003) showed in a general equilibrium model that if there are sunk costs associated with an entry into export markets, firms with *ex ante* higher productivity self-select into exporting. In my case, it is interesting to look at whether there are higher sunk costs associated with becoming a supplier to a multinational firm compared to a Czech-owned firm. During my field work I collected qualitative evidence that indicates that self-selection into supplying to multinationals might take place. When asked whether it is more demanding to start to supply multinationals compared to Czech-owned firms, almost a half of the firms (47 percent) claimed that it is more difficult. When the firms that claimed it was more difficult were asked why, they mentioned pressure for high quality (57%) and low prices (25%). Several managers claimed that "multinationals want everything for free." Managers also noted that multinationals set strict delivery terms (14%) and require demanding initial audits (13%). Among other reasons firms included the existence of various artificial barriers (certifications), a need for frequent visits to foreign headquarters, a higher labor cost induced by a need to have more skilled employees, requirements for reducing costs, and, lastly, some firms claimed that "multinationals behave as if they were superior and could dictate conditions to Czech-owned firms." Figure 9 in the Appendix summarizes these reasons. Also 70 percent of suppliers to multinationals say they needed an ISO certification to be eligible to supply them. I propose two ways to address the issue of self-selection: restriction of the sample to suppliers to multinationals and the use of a dynamic panel model.

7.1 Restriction of Sample - Suppliers to Multinationals

First I would like to see whether my results are robust to restricting my estimation sample to only Czech-owned firms that were suppliers to multinational firms located in the Czech Republic for the whole period for which I have them in my database. The restriction of the sample only to the firms that were able to overcome a productivity threshold and became suppliers to multinationals should mitigate the effect of self-selection. The idea is that even *ex ante* more productive firms that self-select into supplying to multinationals may benefit from their interactions with multinationals once they start supplying them. If I can still find that the more these firms supply to multinationals, the higher TFP they achieve, *ceteris paribus*, I bring evidence in favor of productivity spillovers.

I re-estimate the model (8)[24] using the fixed and the random effects on the subsample of Czech-owned suppliers to multinational firms. As a measure of total factor productivity I use TFP, i.e. the measure obtained in the section 6.6 using LP estimator to maximize the number of observations.[25] Results are presented in Table 9, columns 3-4, in the Appendix. Estimates confirm previous findings. They are economically meaningful and similar in magnitude to results estimated using the unrestricted sample of all Czech-owned firms (see Table 8, columns 7 and 8).

7.2 Dynamic Panel Model

In this section I try to disentangle the potential effect of self-selection of *ex ante* more-productive firms into supplying to multinationals from the effect of productivity spillovers from multinationals to local firms by considering a model in the form:

$$(10)\quad \ln TFP_{it} = \alpha_0 + \alpha_1 \cdot \ln TFP_{i,t-1} + \alpha_2 \cdot Backward_{i,t-1} + \alpha_3 \cdot Forward_{i,t-1} + \alpha_t + \lambda_i + \varepsilon_{it}\ .$$

I include one-period lagged TFP as a regressor to capture the persistence in total factor productivity. I include proxies for backward and forward linkages to test whether firms improve their productivity by supplying to multinationals and by

[24] See page 28.

[25] An estimation with TFP_OP measure obtained in the section 6.7 using the modified Olley-Pakes technique leads to the same conclusions.

purchasing inputs from multinationals. Linkage variables are included with a one-period lag to reduce the simultaneity problems. Time dummies are included and denoted as α_t. If there are no productivity spillovers and firms merely self-select into supplying to multinationals based on their ex ante productivity, the coefficient α_1 should be positive and significant and coefficients α_2 and α_3 insignificant. Based on my qualitative evidence, I expect that in reality both effects simultaneously take place.

I use the system GMM estimator proposed by Blundell and Bond (1998, 1999) to estimate model (10). I assume that there is no serial dependence in ε_{it}, i.e. for all i, $E[\varepsilon_{it} \cdot \varepsilon_{is}] = 0$ for s≠t. I assume that regressors are endogenous, specifically $E[Backward_{it} \cdot \varepsilon_{is}] \neq 0$ for s≤t but $E[Backward_{it} \cdot \varepsilon_{is}] = 0$ for all s>t, $E[Forward_{it} \cdot \varepsilon_{is}] \neq 0$ for s≤t but $E[Forward_{it} \cdot \varepsilon_{is}] = 0$ for all s>t and analogously for lnTFP. In the first-difference equations, I instrument for $\Delta \ln TFP_{i,t-1}$, $\Delta Backward_{i,t-1}$ and $\Delta Forward_{i,t-1}$ with the second and higher lags of variables in levels, i.e. with $\ln TFP_{i,t-2}$, $Backward_{i,t-2}$, $Forward_{i,t-2}$ and their higher lags. In the levels equations, I instrument for $\ln TFP_{i,t-1}$, $Backward_{i,t-1}$ and $Forward_{i,t-1}$ with the first differences dated t-1, i.e. with $\Delta \ln TFP_{i,t-1}$, $\Delta Backward_{i,t-1}$ and $\Delta Forward_{i,t-1}$. Year dummies α_t are included in the model. They are considered exogenous and are also used as additional instruments.

Robust, one-step GMM results for the full sample and the subsample of Czech-owned firms are presented in Table 9 in the Appendix, in columns 7 and 8, respectively.[26] In both cases, the Hansen test of overidentifying restrictions confirms that instruments are jointly exogenous. I also present the Arellano-Bond test for AR(2) in the first differences. Estimated differenced residuals, $\Delta\varepsilon_{it}$ do not exhibit

[26] I employed the xtabond2 command in Stata with a collapse option, see: Roodman, D. (2005).

second-order serial dependence, which is important for the validity of my identification assumption of no serial dependence of ε_{it}. The system GMM results demonstrate that a) productivity is persistent over time, b) firms benefit from their backward linkages,[27] and c) there is no evidence for productivity spillovers through forward linkages. These findings are consistent with productivity spillovers from multinationals to their local Czech suppliers.

Next I consider two other potential channels of productivity spillovers – exporting goods and importing intermediate inputs. Ignoring these potential sources of spillovers recognized in the literature could cause an omitted variable bias in my previous specifications.

8. Robustness Checks

8.1 Export Channel of Productivity Spillovers

It has been argued in the literature that access to foreign markets might be a source of productivity spillovers. For example, Grossman and Helpman (1991, p. 166) wrote: "When local goods are exported, the foreign purchasing agents may suggest ways to improve the manufacturing process." There are many studies testing whether firms learn by exporting.[28] In my sample, 98 percent of the firms are exporters. This is not surprising given that I concentrate on firms with at least 100 employees and given the small internal market of the Czech Republic and its advantageous geographical location within the European Union. With information on the value of exports, I construct a measure for exporting experience, Real Export Ratio.

I define Real Export Ratio as the ratio of real exports to total real output. The Czech Statistical Office provides export deflators for nine groups of products. They

[27] However note, that the coefficient on the Backward variable is only marginally significant for the subsample of Czech-owned firms (p-value=0.105).
[28] See e.g. Bernard and Jensen (1995), Clerides, Lach and Tybout (1998) and Blalock and Gertler (2004).

do not correspond to the NACE sectors. Therefore, I deflate the exports of firms in NACE 21: Pulp, paper and paper products and NACE 31: Electrical Equipment and apparatus by a deflator for "Various Industrial Products." I deflate exports of firms in NACE 29: Machinery and equipment and NACE 34: Motor vehicles by a deflator for "Machines and Means of Transport." I include Real Export Ratio (RER) as an additional control and estimate a model in the form:

(11) $\ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_4 \cdot RER_{it} + \alpha_t + \lambda_i + \varepsilon_{it}$.

I use the fixed effects estimator to control for any fixed firm-specific unobservable heterogeneity. Results are presented in Table 9 in the Appendix for the full sample and the subsample of the Czech-owned firms, columns 10 and 12, respectively. The Backward variable is still positive and significant at 1% in both specifications. The coefficients on the Forward variable and the Real Export Ratio are not statistically significant.

To take into account possible simultaneity between the productivity shock and regressors, I employ the system GMM estimator by Blundell and Bond (1998, 2000) again and estimate a model on the subsample of Czech-owned firms in the form:

(12) $\ln TFP_{it} = \alpha_1 \cdot \ln TFP_{i,t-1} + \alpha_2 \cdot Backward_{i,t-1} + \alpha_3 \cdot Forward_{i,t-1} + \alpha_4 \cdot RER_{i,t-1} + \alpha_t + \lambda_i + \varepsilon_{it}$.

I assume that there is no serial dependence in ε_{it}, i.e for all i, $E[\varepsilon_{it} * \varepsilon_{is}]=0$ for $s \neq t$. I assume that regressors are endogenous, specifically $E[Backward_{it} * \varepsilon_{is}] \neq 0$ for $s \leq t$ but $E[Backward_{it} * \varepsilon_{is}]=0$ for all $s>t$, similarly that $E[Forward_{it} * \varepsilon_{is}] \neq 0$ for $s \leq t$ but $E[Forward_{it} * \varepsilon_{is}]=0$ for all $s>t$, $E[RER_{it} * \varepsilon_{is}] \neq 0$ for $s \leq t$ but $E[RER_{it} * \varepsilon_{is}]=0$ for all $s>t$ and analogously for lnTFP. These two assumptions imply that for the first-difference equations, lagged levels dated t-2 and earlier of firm performance, linkages and real export ratio can be used as instruments and for the levels equations, first-differences of firm performance, linkages and real export ratio dated t-1 can be used. Year dummies are included in the model. They are considered exogenous and also used as additional instruments. Results are presented in Table 9, column 9, in the Appendix. They confirm previous findings.

8.2 Import Channel of Productivity Spillovers

Another potential channel for productivity spillovers acknowledged in the literature is import of intermediate inputs.[29] Embodied technology in intermediate goods might be a source for spillovers. Especially for Czech-owned firms, imported inputs might be important. With firm-level information about the value of imported material, I define a Material Import Ratio as the ratio of real imported material to real material consumption, defined as:

$$\text{Material Import Ratio} = \frac{\text{Imported Material}}{\text{Import Deflator}} \Bigg/ \left(\frac{\text{Imported Material}}{\text{Import Deflator}} + \frac{\text{Material Consumption-Imported Material}}{\text{Material Deflator}} \right)$$

In the denominator of the Material Import Ratio, I separate material purchased in the Czech Republic from material imported in order to deflate each of them by an appropriate price index. The Czech Statistical Office provides import deflators for nine groups of products. Since I do not have information about exactly which material inputs each firm imports, I deflate imported material by an overall import deflator. I estimate a model in the form:

$$(13)\quad \ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_4 \cdot RER_{it} + \alpha_5 \cdot MIR_{it} + \alpha_t + \lambda_i + \varepsilon_{it},$$

where MIR stands for Material Import Ratio. Results from the fixed effects estimation are presented in Table 9 in the Appendix in columns 11 and 13 for the full sample and for the Czech-owned firms, respectively. The coefficients on the Backward variable are still positive and statistically significant at 1% level. Results also suggest that imports of material are important for productivity of Czech-owned firms.

[29] See Keller, W. (2004, p. 765).

8.3 Other Robustness Checks

I conducted additional robustness checks. To mitigate the potential influence of the self-selection, I re-estimated models (11) and (13) on the subsample of Czech-owned firms that were suppliers to multinationals for the whole period for which I have them in my database. Lastly, I re-estimated the key specifications (models 3, 8 and 13) allowing for AR(1) shocks in disturbances. These additional robustness checks confirmed my previous findings. Owing to space constraints, I do not report their results.

9. Conclusions

I carried out field work in the Czech Republic to collect information about relationships between multinationals and Czech-owned firms in paper, machinery, electrical, and motor vehicle industries in the period 1995-2004. In contrast to earlier literature, which relies on industry-level proxies for backward and forward linkages, I construct firm-level measures for them.

My results provide strong support for the existence of productivity spillovers through backward linkages in the Czech manufacturing sector. I do not find any evidence for spillovers through forward linkages. Results are robust with respect to many different econometric specifications. They do not seem to be driven by the self-selection of *ex ante* more-productive firms into supplying to multinational firms. Results are robust to controlling for export and import channels of technology spillovers.

I strongly believe that researchers studying productivity spillovers between firms should work with firm-level panel data sets that contain detailed information about relationships between firms instead of relying on aggregate industry-level measures. By constructing firm-level measures, my paper improves upon the current methodology.

To what extent, if at all, countries should provide incentives to foreign investors is an important and highly debated policy issue. Incentive packages for investors are costly. My findings suggest that multinational investors are a source of productivity spillovers through backward linkages to local firms. This provides an argument in favor of a policy of attracting foreign direct investment. However, I do not claim that the Czech Republic or other countries should provide incentive packages to attract foreign direct investors. Productivity spillovers are just one, though very important, part of a complex cost-benefit analysis of the provision of incentive packages.

REFERENCES

Aitken, Brian J., and Ann E. Harrison. 1999. “Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela.” American Economic Review 89(3): 605-618.

Arellano, Manuel, and Stephen Bond. 1991. “Some Tests of Specification for Panel Data: Monte Carlo Evidence and Application to Employment Equations,” Review of Economic Studies 58: 277-279.

Arellano, Manuel, and Olympia Bover. 1995. “Another Look at the Instrumental Variable Estimation of Error-Components,” Journal of Econometrics 68: 29-51.

Bernand, Andrew B., and Bradford J. Jensen. 1999. “Exceptional Exporter Performance: Cause, Effect, or Both?” Journal of International Economics 47(1): 1-25.

Blalock, Garrick, and Paul J. Gertler. 2004. "Learning from Exporting Revisited in a Less Developed Setting," Journal of Development Economics 75 (2): 397-416.

Blalock, Garrick, and Paul J. Gertler. 2008. “Welfare Gains from Foreign Direct Investment through Technology Transfer to Local Suppliers.” Journal of International Economics 74(2): 402-421.

Blundell, Richard, and Stephen Bond. 1998. “Initial Conditions and Moment Restrictions in Dynamic Panel Data Models,” Journal of Econometrics 87: 115-143.

Blundell, Richard, and Stephen Bond. 1999. “GMM Estimation with Persistent Panel Data: An Application to Production Functions,” Working Paper W99/04, Institute for Fiscal Studies, London.

Clerides, Lach and James R. Tybout. 1998. “Is Learning by Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico, and Marocco,” The Quarterly Journal of Economics 113 (3): 903-948.

Djankov, Simeon and Bernard Hoekman. (2000). “Foreign Investment and Productivity Growth in Czech Enterprises.” World Bank Economic Review 14(1): 49-64.

Griliches, Zvi, and Jacques Mairesse. 1995. “Production Functions: the Search for Identification,” NBER WP No. 5067.

Grossman, Gene M., and Elhanan Helpman. 1991. “Innovation and Growth in the World Economy,” Cambridge, MA: MIT Press.

Haddad, Mona and Ann E. Harrison. 1993. “Are There Positive Spillovers from Direct Foreign Investment? Evidence from Panel Data for Morocco.” Journal of Development Economics 42(1): 51-74.

Javorcik, Beata Smarzynska. 2004. "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages," The American Economic Review 94(3): 605-627.

Javorcik, Beata Smarzynska, and Mariana Spatareanu. 2005. "Disentangling FDI Spillover Effects: What Do Firm Perceptions Tell Us?" in Does Foreign Direct Investment Promote Development?, ed. by T. H. Moran, E. M. Graham, and M. Blomstrom, 45-72. Institute for International Economics, Washington, DC.

Keller, Wolfgang and Stephen R. Yeaple. 2003. "Multinational Enterprises, International Trade and Productivity Growth: Firm Level Evidence from the United States." National Bureau of Economic Research, Cambridge, MA, Working Paper No. 9504.

Keller, Wolfgang. 2004. "International Technology Diffusion," Journal of Economic Literature, 42: 752-782.

Levinsohn, James, and Amil Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables," Review of Economic Studies 70: 317-341.

Marschak, Jacob, and William H. Andrews. 1944. "Random Simultaneous Equations and The Theory of Production," Econometrica 12 (3-4): 143-205.

Melitz, Marc J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," Econometrica 71 (6): 1695-1725.

Olley, Steven, and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry," Econometrica 64 (6): 1263-1297.

Petrin, Amil, James Levinsohn, and Brian P. Poi. 2004. "Production Function Estimation in Stata Using Inputs to Control for Unobservables," The Stata Journal, 4(2): 113-123.

Roodman, Daniel. 2005. xtabond2: Stata module to extend xtabond dynamic panel data estimator. Center for Global Development, Washington. http://econpapers.repec.org/software/bocbocode/s435901.htm (accessed March 20, 2006).

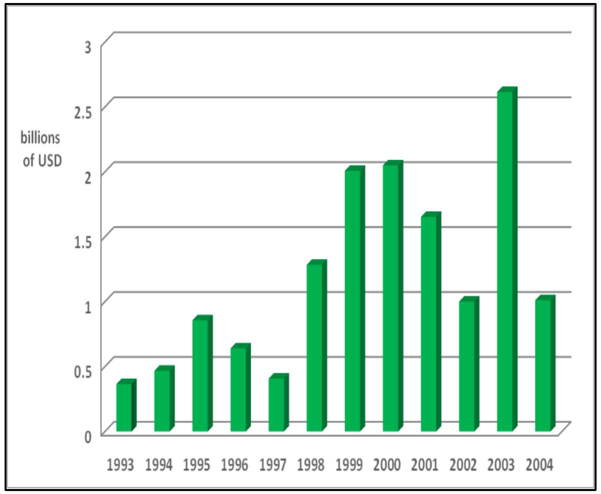
The U.S. Department of State. (March 13, 2006). "How Foreign Direct Investment Benefits the United States," The Press Release, Office of the Spokesman, Washington, DC.

Wooldridge, Jeffrey M. 2002. "Econometric Analysis of Cross Section and Panel Data," Cambridge: The MIT Press.

World Bank. 2004. "World Development Report 2005," A Copublication of the World Bank and Oxford University Press.

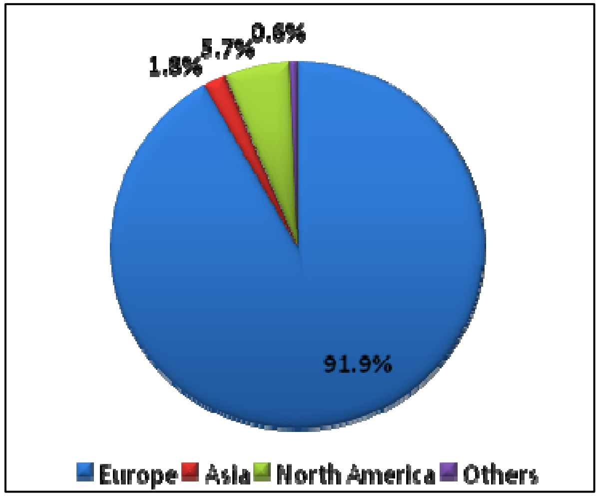
Appendix

Figure 1 - the Czech Republic: Inward FDI in Manufacturing, 1993 – 2004



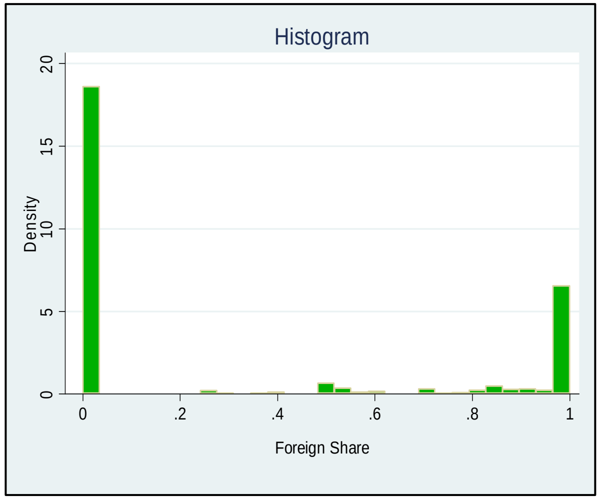
Source: Czech National Bank.

Figure 2 - Territorial Structure of Inward FDI, Stock on December 31, 2004



Source: Czech National Bank.

Figure 3 – Histogram of Foreign Share on Equity of Foreign Firms in My Sample



Source: Own computations based on sample data.

Table 1 - Population Summary Statistics – Ownership Structure

	N21 Paper, pulp		N29 Machinery		N31 Electrical Equipment		N34 Motor Vehicles		Total number of firms across sectors
	Number of Firms	% Share	Number of firms	% Share	Number of firms	% Share	Number of firms	% Share	
Czech-Owned	21	51.2	196	60.7	71	38.2	31	25.6	319
International	5	12.2	39	12.1	31	16.7	22	18.2	97
Foreign	15	36.6	88	27.2	84	45.1	68	56.2	255
Total	41	100	323	100	186	100	121	100	**671**

Source: Own computations based on data from the Business Register of the Czech Statistical Office, data as of December 31, 2004.

Table 2 – Summary of Firms Contacted

Firm Category	Number of Firms	% Share if [A] = 100%	% Share if [B] = 100%
Total number of firms in population [A]	671	100.00	---
Total number of firms contacted [B]	295	43.96	100.00
Contacted firms that refused to be visited and interviewed	37	---	12.54
Visited firms that did not return surveys or returned them incomplete	155	---	52.54
Total number of complete surveys	**103**	**15.35**	**34.92**

Table 3 – Testing Sample Bias: Ho: difference in mean = 0

Variable	Firms that Provided Data		Firms that did not Provided Data		Difference in Mean	Ha: diff < 0	Ha: diff $\neq 0$	Ha: diff > 0
	No. of Obs.	Mean	No. of Obs.	Mean				
Sales	814	532.00	230	581.37	-49.37	P(T < t)=0.25	P(|T| > |t|)=0.50	P(T > t)=0.75
Profit	789	32.52	664	25.10	7.43	P(T < t)=0.88	P(|T| > |t|)=0.23	P(T > t)=0.12
Tangible Assets	802	244.00	666	254.63	-10.67	P(T < t)=0.37	P(|T| > |t|)=0.73	P(T > t)=0.63

Table 4 - Sample Summary Statistics – Sectoral Classification of Firms

Sector	NACE	Number of Firms in Sample	% Share of Population
Pulp, paper, and paper products	21	12	29.3
Machinery and equipment	29	49	15.2
Electrical equipment and apparatus	31	26	14.0
Motor vehicles	34	16	13.2
Overall		**103**	**15.3**

Table 5 - Sample Summary Statistics – Classification According to Sector and Ownership[30]

NACE Code	Number of Firms in Sample		% Share of Population	
	Czech-Owned	Multinationals	Czech-Owned	Multinationals
21	6	6	28.6	30.0
29	33	16	16.8	12.6
31	12	14	16.9	12.2
34	7	9	22.6	10.0
Overall	**58**	**45**	**18.2**	**12.8**

[30] Type of ownership classified according to the state on December 31, 2004.

Table 6 - Summary Statistics of Sample Data – Czech-Owned and Multinational Firms

In millions of Czech crowns – CZK as long as not otherwise indicated.

	Czech-Owned Firms		**Multinational Firms**	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Sales	260.018	342.302	983.515	1854.608
Output	260.755	342.532	987.277	1868.711
Profit	11.599	30.213	67.944	207.409
Profitability=Profit/Output in %	4.022	12.125	4.471	10.500
Total Exports	114.570	213.194	583.583	1704.578
Number of Skilled Workers	96.321	96.048	138.165	157.677
Number of Unskilled Workers	208.197	233.583	415.447	596.714
Wages	45.381	49.381	111.528	166.945
Average Hourly Wage in US $[31]	4.002	1.220	5.169	1.670
Material	132.347	228.558	554.321	1166.839
Imported Material	41.523	100.281	227.567	351.636
Energy	11.061	19.860	19.690	23.387
Tangible Capital	111.517	176.134	460.912	1227.983
Intangible Capital	3.046	9.289	8.463	17.681
Investment in Tangible Capital	16.381	33.078	124.617	497.304
Investment in Intangible Capital	1.069	3.562	4.274	15.576
Investment in Intangibles per Worker (in thousands of CZK)	3.457	12.35	5.137	13.541
Stock of Intangible Capital per Worker (in thousands of CZK)	7.965	21.52	17.895	42.679
R&D Expenses	3.400	8.941	8.740	21.203
Backward Linkage in %	14.576	20.505	15.478	21.985
Forward Linkage in %	13.364	20.895	10.376	19.824

[31] 22.358 CZK/USD exchange rate as of December 31, 2004. See: www.oanda.com .

Figure 4 – Assistance Provided by Multinationals To Their Suppliers

Figure 5 – Forms of Assistance Czech-Owned Firms Received from Their Multinational Customers

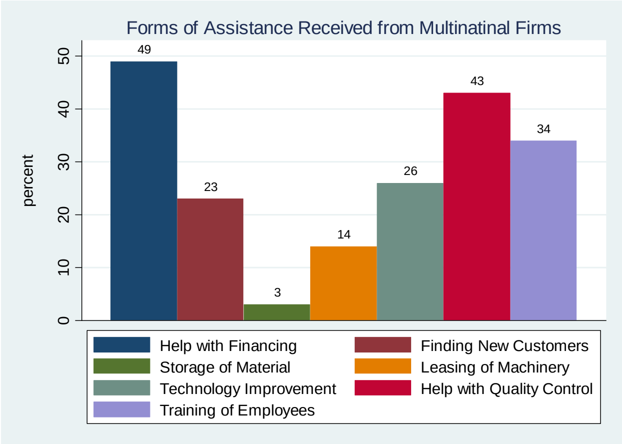


Figure 6 – Perceived Influence of an Entry of Multinationals on Respondents' Firms

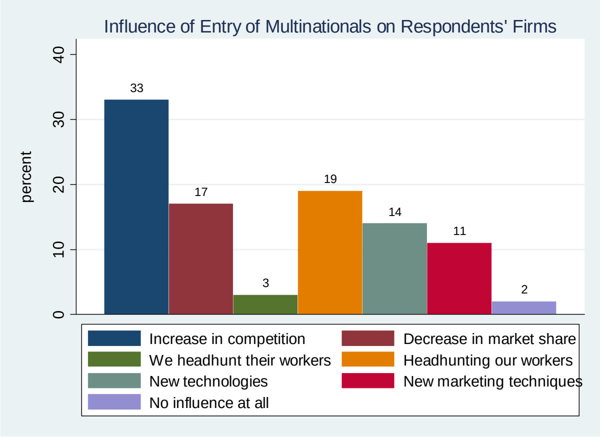


Figure 7 – Reasons for Purchasing Inputs from Multinationals

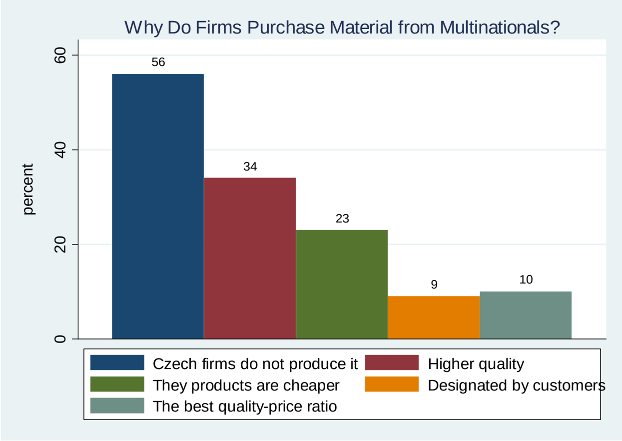


Figure 8 – Reasons for Material Imports

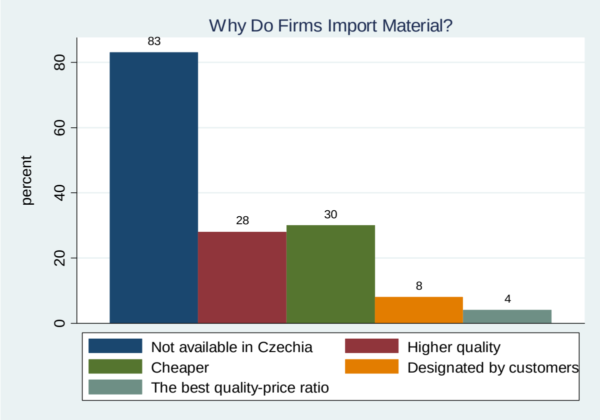


Figure 9 – In What Regard Are Multinational Firms More Demanding Buyers?

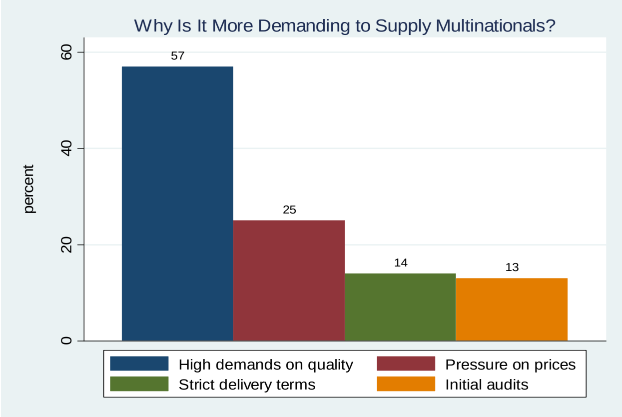


Table 7 – Specifications using OLS, the Fixed Effects, the First Differences and System GMM

	Full Sample		Czech-Owned		Full Sample			Czech-Owned			Czech-Owned
Estimator	OLS	OLS	OLS	OLS	OLS	FE	$1^{st}\ \Delta$	OLS	FE	$1^{st}\ \Delta$	System GMM
Column No.	1	2	3	4	5	6	7	8	9	10	11
Backward	**0.479***** **(0.090)**	**0.473***** **(0.092)**	**0.772***** **(0.130)**	**0.793***** **(0.143)**	**0.326***** **(0.068)**	**0.258***** **(0.084)**	**0.181*** **(0.104)**	**0.358***** **(0.092)**	**0.356***** **(0.134)**	**0.224**** **(0.108)**	**0.658*** **(0.376)**
Forward	**-0.058** **(0.072)**	**-0.062** **(0.076)**	**0.046** **(0.093)**	**0.010** **(0.105)**	**-0.047** **(0.048)**	**0.024** **(0.075)**	**-0.022** **(0.076)**	**0.052** **(0.047)**	**0.080** **(0.082)**	**-0.034** **(0.100)**	**0.151** **(0.339)**
Foreign Share	0.375*** (0.037)	0.370*** (0.038)			0.158*** (0.031)	-0.002 (0.051)	-0.043 (0.030)				
ln (Material)	0.282*** (0.018)	0.266*** (0.018)	0.274*** (0.018)	0.266*** (0.018)		0.608*** (0.037)	0.559*** (0.062)		0.566*** (0.051)	0.512*** (0.028)	0.418*** (0.116)
ln (Energy)	0.174*** (0.018)	0.155*** (0.019)	0.130*** (0.023)	0.112*** (0.022)		0.116*** (0.027)	0.192*** (0.055)		0.130** (0.064)	0.178*** (0.039)	0.237*** (0.086)
ln (Unskilled)	0.400*** (0.028)	0.414*** (0.030)	0.356*** (0.037)	0.360*** (0.040)		0.183*** (0.047)	0.136** (0.066)		0.141** (0.071)	0.178*** (0.062)	0.157 (0.152)
ln (Skilled)	0.135*** (0.019)	0.141*** (0.020)	0.165*** (0.025)	0.167*** (0.026)		0.050 (0.041)	-0.017 (0.064)		0.115 (0.073)	-0.011 (0.058)	-0.134 (0.188)
ln (Capital)	-0.036 (0.022)	-0.017 (0.023)	-0.038 (0.028)	-0.022 (0.031)		-0.007 (0.019)	-0.003 (0.019)		0.001 (0.024)	-0.001 (0.025)	0.079 (0.075)
Number of Obs.	712	618	447	384	712	712	512	447	447	317	447
R-Squared	0.93	0.93	0.90	0.90	0.97	0.89	0.72	0.96	0.86	0.70	
P-value of Hansen test of overidentifying restrictions											0.501
P-value of Arellano-Bond test for AR(2) in $1^{st}\ \Delta$											0.242

Robust standard errors in parenthesis. ***, ** and * denote significance level at 1%, 5% and 10% respectively.
In models 7 and 10, the dependent variable is Δ ln (Output); in all other models, the dependent variable is ln (Output).
Within R-Squared reported with fixed (FE) estimates. One-step system GMM results in model 11.
Only coefficients on linkage variables and the foreign share reported in trans-log models 5 and 8 due to a space constraint.
Year, industry and regional dummies included in models 1-4, models 5 and 8 include year and industry dummies, models 6, 7, 9 and 10 include year dummies.

Table 8 – Specifications using Levinsohn-Petrin (LP), Olley-Pakes (OP), Fixed Effects (FE) and Random Effects (RE) Estimators

	Full Sample	Full Sample			Full Sample		Czech-Owned		Full Sample	Czech-Owned
Estimator	LP	OLS	FE	LP	FE	RE	FE	RE	1^{st} Δ	1^{st} Δ
Column No.	1	2	3	4	5	6	7	8	9	10
Backward	**0.475***				**0.732*****	**0.718*****	**0.875*****	**0.860*****	**0.466*****	**0.493***
	(0.283)				**(0.165)**	**(0.144)**	**(0.229)**	**(0.181)**	**(0.178)**	**(0.258)**
Forward	**0.078**				**-0.044**	**-0.0002**	**0.068**	**0.043**	**-0.127**	**-0.052**
	(0.192)				**(0.138)**	**(0.116)**	**(0.150)**	**(0.131)**	**(0.196)**	**(0.197)**
Foreign Share					0.129	0.252***			-0.083	
					(0.129	(0.083)			(0.089)	
ln (Unskilled)	0.446***	0.570***	0.562***	0.463***						
	(0.078)	(0.024)	(0.114)	(0.098)						
ln (Skilled)	0.263***	0.253***	0.089	0.218***						
	(0.077)	(0.032)	(0.091)	(0.070)						
ln (Capital)	0.320**	0.171***	0.181***	0.294***						
	(0.128)	(0.021)	(0.038)	(0.106)						
Number of Obs.	709	772	772	772	709	709	444	444	509	314
R-Squared	---	0.98	0.41	---	0.079	0.071	0.074	0.073	0.05	0.07
Hausman test						8.70		0.47		
Prob>chi^2 for Hausman						0.65		(1.00)		

Robust standard errors in parenthesis in columns 2-12. Bootstrapped standard errors in parenthesis in column 1.
Within R-Squared reported with fixed (FE) and random effects (RE) estimates.
***, ** and * denote significance level at 1%, 5% and 10% respectively.
Year dummies are included in models in columns 5-10; models in columns 6 and 8 include also industry dummies.
In models 1-4, the dependent variable is ln (value added); in models 5-8, the dependent variable is ln (TFP); in models of columns 9-10, the dependent variable is Δln (TFP).

Table 9 – Robustness Checks

	Full Sample	Czech-Owned	Czech-Owned Suppliers to Multinationals				Full Sample	Czech-Owned		Full Sample		Czech-Owned	
Estimator	FE	FE	FE	RE	FE	FE	System GMM			FE	FE	FE	FE
Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Backward	**0.574***	**0.654***	**0.778***	**0.776***	**0.839***	**0.808***	**0.704***	**0.726†**	**0.753***	**0.700***	**0.715***	**0.888***	**0.600***
	(0.167)	**(0.226)**	**(0.239)**	**(0.207)**	**(0.282)**	**(0.313)**	**(0.365)**	**(0.447)**	**(0.453)**	**(0.206)**	**(0.249)**	**(0.259)**	**(0.259)**
Forward	**0.057**	**0.128**	**-0.071**	**-0.019**	**-0.043**	**-0.167**	**-0.378**	**-0.469**	**-0.372**	**0.025**	**-0.138**	**0.076**	**-0.097**
	(0.147)	**(0.155)**	**(0.207)**	**(0.139)**	**(0.203)**	**(0.242)**	**(0.400)**	**(0.429)**	**(0.346)**	**(0.140)**	**(0.154)**	**(0.150)**	**(0.186)**
ln (TFP)							**0.446***	**0.366***	**0.371***				
							(0.075)	**(0.096)**	**(0.103)**				
Foreign Share	0.073									0.155	0.185		
	(0.131)									(0.131)	(0.146)		
Real Export Ratio					0.453*	0.319			0.205	0.014	0.007	0.007	-0.243
					(0.270)	(0.313)			(0.219)	(0.103)	(0.120)	(0.215)	(0.241)
Material Import Ratio						0.635*					0.148		0.914***
						(0.352)					(0.218)		(0.182)
Number of Obs.	630	379	287	287	277	211	603	373	361	680	518	432	326
R-Squared	0.141	0.097	0.04	0.08	0.09	0.13	---	---	---	0.08	0.08	0.07	0.17
P-value of Hansen test of overid. Restrictions							0.601	0.557	0.690				
P-value of Arellano-Bond test for AR(2) in 1st Δ							0.552	0.681	0.494				

Robust standard errors in parenthesis.
Within R-Squared reported with fixed (FE) and random effects (RE) estimates.
***, ** and * denote significance level at 1%, 5% and 10% respectively.
In models 7-9, these are one-step system GMM results.
† denotes p-value=0.105.
Year dummies are included in all specifications.
In models 1-2, the dependent variable is ln (TFP-OP); in models 3-13, the dependent variable is ln (TFP).
In system GMM specifications - models 7-9, all right-hand side variables are included with a one-period lag.

IES Working Paper Series

2010

1. Petra Benešová, Petr Teplý : *Main Flaws of The Collateralized Debt Obligation's Valuation Before And During The 2008/2009 Global Turmoil*
2. Jiří Witzany, Michal Rychnovský, Pavel Charamza : *Survival Analysis in LGD Modeling*
3. Ladislav Kristoufek : *Long-range dependence in returns and volatility of Central European Stock Indices*
4. Jozef Barunik, Lukas Vacha, Miloslav Vosvrda : *Tail Behavior of the Central European Stock Markets during the Financial Crisis*
5. Onřej Lopušník : *Různá pojetí endogenity peněz v postkeynesovské ekonomii: Reinterpretace do obecnější teorie*
6. Jozef Barunik, Lukas Vacha : *Monte Carlo-Based Tail Exponent Estimator*
7. Karel Báťa : *Equity Home Bias in the Czech Republic*
8. Petra Kolouchová : *Cost of Equity Estimation Techniques Used by Valuation Experts*
9. Michael Princ : *Relationship between Czech and European developed stock markets: DCC MVGARCH analysis*
10. Juraj Kopecsni : *Improving Service Performance in Banking using Quality Adjusted Data Envelopment Analysis*
11. Jana Chvalkovská, Jiří Skuhrovec : *Measuring transparency in public spending: Case of Czech Public e-Procurement Information System*
12. Adam Geršl, Jakub Seidler : *Conservative Stress Testing: The Role of Regular Verification*
13. Zuzana Iršová : *Bank Efficiency in Transitional Countries: Sensitivity to Stochastic Frontier Design*
14. Adam Geršl, Petr Jakubík : *Adverse Feedback Loop in the Bank-Based Financial Systems*
15. Adam Geršl, Jan Zápal : *Economic Volatility and Institutional Reforms in Macroeconomic Policymaking: The Case of Fiscal Policy*

16. Tomáš Havránek, Zuzana Iršová : *Which Foreigners Are Worth Wooing? A Meta-Analysis of Vertical Spillovers from FDI*
17. Jakub Seidler, Boril Šopov : *Yield Curve Dynamics: Regional Common Factor Model*
18. Pavel Vacek : *Productivity Gains From Exporting: Do Export Destinations Matter?*
19. Pavel Vacek : Panel Data Evidence on Productivity Spillovers from Foreign Direct Investment: Firm-Level Measures of Backward and Forward Linkages

All papers can be downloaded at: http://ies.fsv.cuni.cz

Univerzita Karlova v Praze, Fakulta sociálních věd
Institut ekonomických studií [UK FSV – IES] Praha 1, Opletalova 26
E-mail : ies@fsv.cuni.cz http://ies.fsv.cuni.cz