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

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Abstract

I examine whether foreign direct investment increases the productivity of manufacturing firms in the Czech Republic. I test the proposition that local firms benefit from supplying to multinationals (spillovers through backward linkages) and by purchasing inputs from multinationals (spillovers through forward linkages). To test spillovers at the firm level, I conducted field work based on in-depth interviews with CEOs of both Czech-owned and multinational firms. Apart from empirical evidence, I collected panel data that allowed me to construct and employ firm-level proxies for linkages. I find evidence for the existence of spillovers through backward linkages for 1995-2004. I do not find any econometric evidence in favor of spillovers through forward linkages. My results are robust with respect to a series of checks: I address self-selection into supplying multinational firms and control for possible productivity spillovers through both exporting and importing.

JEL classification: F2, O1, O3.

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1. Introduction

Nowadays many countries offer generous incentive packages to attract foreign direct investment (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 technology 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 is supported by 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, the question whether productivity spillovers from FDI exist remains open, despite its policy relevance. Researchers have lacked data about interactions between multinationals and local firms that would enable them to provide econometric evidence about spillovers directly at the firm level. To provide such evidence is the aim of my study.

I test whether foreign direct investment increases the productivity of domestic firms using a sample of firms from the Czech Republic. In particular, I examine whether Czech manufacturing firms benefit from supplying to multinationals (spillover through backward linkages) and by purchasing inputs from multinationals (spillover through forward linkages).

I contribute to the literature in three ways. First, I take a new methodological

approach. Unlike existing literature which studies spillovers at the industry level (inter-industry spillovers), I examine spillovers directly between individual firms. 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[2] were specifically tailored to determine whether foreign direct investment increases the productivity of Czech firms. I focused on firms in the following four industries: paper industry, machinery and equipment, electrical equipment and apparatus, and motor vehicles. I collected high quality data with a unique qualitative structure that enabled me to construct and employ firm-level proxies for backward and forward linkages in my econometric analysis. It is crucial to work with firm-level measures for linkages to identify spillovers between individual firms. Second, I provide empirical evidence about customer-supplier relationships between domestic and multinational firms in the Czech Republic for the years 1995-2004. Third, I control for both export and import channels of productivity spillovers.

My main results can be summarized as follows: I find strong support for the existence of productivity spillovers through backward linkages in the four industries of the Czech manufacturing sector for 1995-2004. A one-percent increase in the backward linkages of a Czech-owned firm would lead to an output expansion of 0.658 percent relative to any expansion of inputs, i.e., output per unit of input rises.[3] I do not find any econometric evidence supporting the hypothesis of productivity spillovers through forward linkages.

Empirical literature examining productivity spillovers through backward and

[2] The questionnaire can be found on my web page at: http://www.arts.cornell.edu/econ/pvacek/
[3] Based on system GMM results presented in Table 13, column 2.

forward linkages is scant.[4] My paper relates methodologically to the studies of Blalock and Gertler (2004a), Javorcik (2004), and Javorcik and Spatareanu (2004). However, all of these studies examine inter-industry spillovers, whereas I examine spillovers at the firm level.

Blalock and Gertler (2004a) study technology transfer from FDI to local suppliers in Indonesia. They ask whether domestic firms increase their productivity by supplying to multinational firms. They estimate a production function and examine whether "domestic establishments which sell more to foreign-owned firms produce more, *ceteris paribus*."[5] They construct an industry-level proxy for backward linkages, defined as the share of a sector's output sold to multinational firms. The authors employ input-output tables to measure the shares of output of a particular sector that are sold to other sectors. They find evidence of productivity gains among local firms upstream from foreign entrants.

Javorcik (2004) estimates whether productivity spillovers from FDI take place in the Lithuanian manufacturing industry. She uses industry-level measures for backward linkages, constructed as in Blalock and Gertler (2004a). 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 backward variable.

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[4] For models of spillovers through backward and forward linkages, see Rodriguez-Clare (1996), Markusen and Venables (1999), Pack and Saggi (2001), and Lin and Saggi (2004).
[5] Blalock and Gertler (2004a, p. 19).

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

In my paper, I test spillovers at the firm level using firm-level measures for backward and forward linkages. This is important for the following reasons: 1) Researchers using industry-level proxies for linkages assume that all firms within an industry have the same linkage. 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. Since I use firm-level data on sales to multinational firms, I can determine how the productivity of a domestic firm changes with changes in the share of its output sold to multinational firms. Thus, I am able to examine productivity spillovers *directly*. 2) Industry-level proxies for linkages rely on input-output matrices that 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 a significant 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.

Moreover, aforementioned studies do not control for all potential channels of productivity spillovers recognized in the literature.[6] Firms may learn by exporting as it brings them into contact with international best practice. They may also benefit from

[6] See e.g. Keller, W. (2004) for an overview of potential channels of productivity spillovers.

technology embodied in inputs purchased abroad. In my paper, apart from controlling for spillovers through backward and forward linkages, I control for exports of goods and imports of intermediate inputs to avoid omitted variable bias.

Personal discussions with managers and employees who were responsible for completing surveys enabled me to collect high-quality data crucial for the validity of my results. Such data are not available in any official or commercial database. Consider the following case: a respondent at Firm A acknowledges that the firm does not officially have a multinational buyer. However, Firm A sells products to another Czech-owned Firm B, which supplies these goods (without any changes) under its name to a multinational firm. Firm A uses Firm B as an intermediate to avoid having to obtain all the necessary certifications to qualify as an official supplier to the multinational firm. Because Firm A acknowledges that it obtains, indirectly via Firm B, technical knowledge and requirements from the multinational firm, I count the sales of A to B as sales to the multinational buyer. If I did not know about this business model (a trade secret), I would underestimate the impact of multinational firms on Czech-owned firms through backward linkages.[7]

I chose to analyze productivity spillovers in the Czech Republic for several reasons: 1) The Czech Republic has a highly open economy that received the highest inflow of foreign direct investment (henceforth FDI) per capita out of all transitional Eastern European countries during the 1990s. Figure 1 and Figure 2 below, present, respectively, FDI inflows in manufacturing between 1993 and 2004 and the territorial structure of the stock of FDI on December 31, 2004.

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[7] Firm B is not in my sample, so I do not count the sales to the multinational firm twice when constructing a measure for backward linkages. If the firm B would be in my sample, I would not include goods produced by A and sold by B to the multinational into the backward linkage of firm B, since firm B just resells goods produced by firm A to the multinational without any changes.

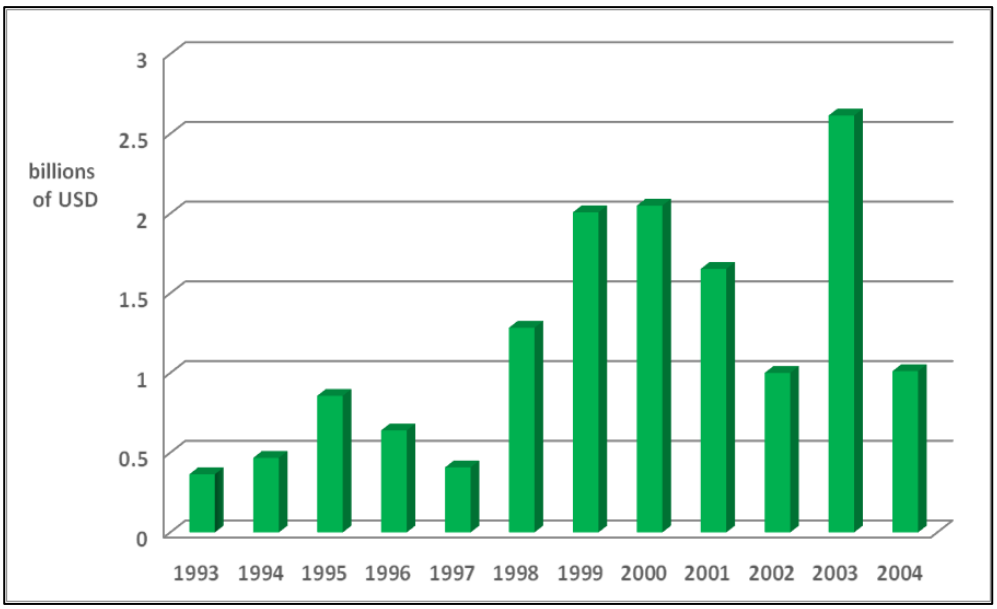

Figure 1 - The Czech Republic: Inward FDI in Manufacturing, 1993 – 2004
Source: Czech National Bank

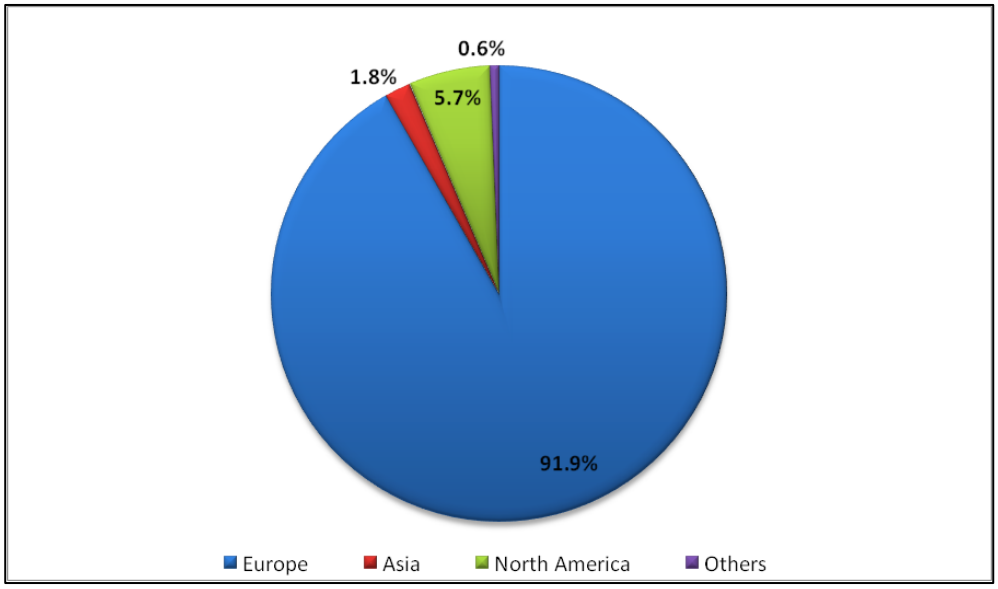

Figure 2 - Territorial Structure of Inward FDI, Stock on December 31, 2004
Source: Czech National Bank

2) A high endowment of skilled labor makes the Czech Republic a particularly likely candidate for productivity spillovers. 3) Relatively small country size reduces the cost of field work. 4) As a Czech citizen, I am familiar with many aspects of the Czech

Republic, including its accounting principles and cultural traditions. This provides me with the information necessary to organize effective and high-quality field work. 5) The Czech Republic offers a particularly comprehensive package of incentives to investors.[8] Although these incentives are offered both to Czech and foreign investors, only 11 percent of recipients are Czech-based companies.[9] There has been a lot of controversy about their provision as many local firms and some politicians find them unfair. Evidence that productivity spillovers from multinationals to local firms take place would provide an argument in their favor.

The remainder of the paper is organized as follows. In section 2, I briefly review a definition of spillovers through backward and forward linkages. In section 3, I describe the design of my field research. I provide population summary statistics and summary statistics of my sample. I discuss the representativeness of my sample and also test whether there is any response bias. In section 4, I present empirical 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 5. I conduct a series of robustness checks in section 6. Section 7 contains my conclusions.

[8] For a comprehensive overview of incentives offered in manufacturing in the Czech Republic, see a Czech Governmental Agency (Czech-Invest) web page at: http://www.czechinvest.org/web/pwci.nsf/pages/A0A24B29B3884F8AC1256EC30077CBA8?OpenDocument

[9] See Czech-Invest at: http://www.czechinvest.org/web/pwci.nsf/pages/9CD3FA28CC2A5E4AC1256EBC0057CCCD?OpenDocument

2. 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."

In the literature, the terms "backward linkage" and "forward linkage" date back at least to Hirschman (1958). Hirschman (1958, p. 101) defines the backward linkage effect as follows: "if the establishment of industry W may lead, through linkage effects, to the establishment of n additional industries with net outputs equal to x_i (i=1,2…n) and if the probability that each one of these industries will actually be set up as a result of the establishment of industry W is p_i (i=1,2…n), then the total linkage effect of industry W is equal to $\sum_i^n x_i p_i$." The probabilities are interpreted as measuring the strength of the stimulus that is set up. Thus, Hirschman interprets linkages through economies of scale. An industry creates a backward linkage when its demand enables upstream industries to be established, i.e. to reach at least minimum economic size.

Hirschman (1958, p. 100) defines the forward linkage effect as follows: "The output-utilization or forward linkage effects, i.e., every activity that does not by its nature cater exclusively to final demands, will induce attempts to utilize its outputs as inputs in some new activities." The forward linkage is understood as the ability of an industry to reduce the costs of potential downstream users of its products and thus push them over the threshold of profitability.[10]

[10] Notice, according to Hirschman's interpretation, if the downstream firm is profitable and the linkage makes it ten times more profitable, this is not taken as a forward linkage because the firm does not cross the profitability threshold.

In this paper, 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 transfers 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 empirical evidence (see section 4.1) 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 empirical evidence, local suppliers who consider their multinational customers to be more demanding than Czech buyers mention in particular multinationals' higher quality requirements. (See section 6.1).

I define forward linkages 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 empirical evidence (see section 4.3) 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.

3. Data and Field Work

My field work research was necessary to get information about actual firm-level relationships between multinationals and Czech-owned firms in the Czech Republic. In this section, I first define the firms that are the subject 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.

3.1 Population of Firms

There were too many manufacturing firms in the Czech Republic for me to study the whole manufacturing sector[11], so I focused on firms in four selected NACE[12] 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 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-

[11] There were 9163 manufacturing firms with at least 20 employees on December 31, 2003, according to the Business Registrar of the Czech Statistical Office.

[12] NACE denotes General Industrial Classification of Economic Activities in the European Communities, (Nomenclature générale des activités économiques dans les Communautés européennes).

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. Moreover, the military companies cannot disclose any data. I ended up with 671 firms. These firms form the population of firms for my research.

Table 1 presents information about the number of firms in the population, divided according to industry and form of ownership.

Table 1 - Population Summary Statistics – Ownership Structure

	N21 Paper, pulp		N29 Machinery		N31 Electrical Equipment	
	Number of Firms	% Share	Number of firms	% Share	Number of firms	% Share
Czech-Owned	21	51.2	196	60.7	71	38.2
International	5	12.2	39	12.1	31	16.7
Foreign	15	36.6	88	27.2	84	45.1
Total	41	100	323	100	186	100

Table 1 (continued)

	N34 Motor Vehicles		Total number of firms across sectors
	Number of firms	% Share	
Czech-Owned	31	25.6	319
International	22	18.2	97
Foreign	68	56.2	255
Total	121	100	671

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

There are 41 firms in NACE 21, 323 firms in NACE 29, 186 firms in NACE 31, and 121 firms in NACE 34. The share of Czech-owned firms is the largest in machinery (60.7%) and the smallest in the motor vehicle industry (25.6%). The motor vehicle industry is especially high in foreign firms (56.2%).

3.2 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 few firms to test its design. This allowed me to make changes to improve it. I started full-fledge field work research in January 2005 and finished it in December 2005. This was an economically and politically stable period in the Czech Republic and thus I am not aware of any event that could have adversely influenced my field work.

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. Given my financial constraints, I planned to contact around half of the population. I actually contacted 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 my research assistant or I visited each firm personally.

The survey had two parts. The first part contained questions about consumer-supplier relationships, sourcing patterns, and perceptions about the influence of multinational firms on Czech-owned firms. This part was filled in mostly during personal visits at interviews with CEOs.[13] In the second part of the survey I asked about accounting information. I always tried to thoroughly explain this part of the survey directly to the employees who were responsible for filling them out later. Since the surveys were very comprehensive, I allowed the firms a few weeks to fill them out. If I did not get a completed survey back within the agreed-upon time period, I contacted the firms again to ensure the highest possible rate of return. I also did follow-ups to complete missing information, to verify data in some cases, and to correct any logical inconsistencies I noticed. This allowed me to get high-quality data.

I asked firms to provide me with data for the period from 1995 to 2004 at one time, retrospectively, instead of conducting surveys each year. The design of my data collection makes estimators that remove fixed firm-specific heterogeneity particularly suitable, as they also remove fixed firm-specific data errors.

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[13] In some cases, CEOs preferred to provide written answers later with the second part of the questionnaire.

3.3 Structure of the Questionnaire

The first part of the questionnaire was filled in mostly during interviews with CEOs in the firms. Its aim was to provide empirical evidence about relationships between local and multinational firms in the Czech Republic. I asked directors whether their firms received any assistance from their multinational consumers located in the Czech Republic, whether they provided any assistance to their suppliers, and what influence the entry of multinational firms into the Czech Republic had on their business. I was also interested in whether it was more difficult to supply to multinationals than to domestic firms. I also examined sourcing patterns. I asked whether firms purchased inputs from multinationals and from abroad and what reasons they had for doing that. I asked whether the director of the firm could speak English or German fluently on the phone, whether he or she had previously worked in a multinational firm, and, if so, if the multinational firm was in the same field. Lastly, I examined how many patents each firm purchased and registered during 1995-2004. Empirical evidence based on this part of the survey is presented in Section 4.

The second part of the questionnaire contained questions regarding financial and other data. I asked firms to provide information for the period 1995-2004. 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.

In order to be able to control for backward linkages, 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 multinational consumers I know their percentage shares in the firm's sales of its products and the road distances in

kilometers between each consumer and the firm. I also have information about the share of foreign ownership in the firm of each multinational consumer. In order to be able to model forward linkages, I collected analogous 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 multinational suppliers I know for each one its percentage share in the firm's material consumption, the road distance between the firm and the supplier, and the supplier firm's share of foreign ownership.

I collected information about the sales of the firms' products, changes in inventories of the firms' products, profits before taxation, material consumption, consumption of energy and fuels, net tangible assets, net intangible assets, R&D expenditures, gross investment in tangible assets, gross investment in intangible assets, numbers of skilled and unskilled employees,[14] wages without counting social and health insurance, the share of the firm's total equity owned by foreign investors, ownership share of the biggest foreign investor, country of origin of the biggest foreign investor, and mode of entry of foreign investor (ex. greenfield investment, joint-venture). I collected information about exports and their geographical distribution and about total imports of material.

3.4 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 refused to even agree to an appointment with me when I contacted them and firms that allowed me to visit their firms and interview them but did not return completed surveys. Table 2 provides a detailed summary of the firms contacted.

[14] Measured as a number of employees out of production and in production, respectively.

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	100.0	n/a
Total number of firms contacted [B]	295	44.0	100.0
Contacted firms that refused to be visited and interviewed	37	n/a	12.6
Visited firms that did not return surveys or returned them incomplete	155	n/a	52.5
Total number of complete surveys	**103**	**15.4**	**34.9**

n/a = not applicable

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. 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 15.4 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. Although I cannot conclude that there is no bias on the basis of these three characteristics, these test statistics give me at least some evidence that the presence of a bias is less likely.

Table 3 - Testing Sample Bias: Ho: difference = 0

Variable	Firms that Provided Data		Firms that did not Provide Data	
	No. of Obs.	Mean	No. of Obs.	Mean
Sales	814	532.00	230	581.37
Profit	789	32.52	664	25.10
Tangible Assets	802	244.00	666	254.63

Table 3 (continued)

Variable	Difference in Mean	Ha: diff < 0	Ha: diff ≠ 0	Ha: diff > 0
Sales	-49.37	Pr(T < t) = 0.25	Pr(|T| > |t|) = 0.50	Pr(T > t) = 0.75
Profit	7.43	Pr(T < t) = 0.88	Pr(|T| > |t|) = 0.23	Pr(T > t) = 0.12
Tangible Assets	-10.67	Pr(T < t) = 0.37	Pr(|T| > |t|) = 0.73	Pr(T > t) = 0.63

3.5 Representativeness of the Data Collected

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 below provides precise information about the number of firms in my sample in each sector and their shares in the relevant population.

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 app.	31	26	14
Motor vehicles	34	16	13.2
Overall		**103**	**15.4**

***** See Table 1 for numbers of firms in the population for each industry.

I collected data for 29.3 percent of the firms in the pulp and paper industry, 15.2 percent of the firms in machinery, 14 percent of the firms in electrical equipment industry and 13.2 percent of the firms in the motor vehicles industry. Overall I have panel data for 15.4 percent of the firms in the population.

Table 5 contains information about the numbers of firms in my sample divided both according to industry and owner nationality.

Table 5 - Sample Summary Statistics – Classification According to Sector and Ownership[15]

NACE	Number of Firms in Sample		% Share of Population*	
	Czech-Owned	Foreign Capital	Czech-Owned	Foreign Capital
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**

***** See Table 1 for numbers of firms in the population for each industry.

[15] Type of ownership classified according to the status on December 31, 2004.

I distinguish Czech-owned firms from firms with foreign capital (multinationals). I define Czech-owned firms as firms that do not have any foreign capital in their equities. Figure 3 shows the precise distribution of foreign share in the firms in my sample.

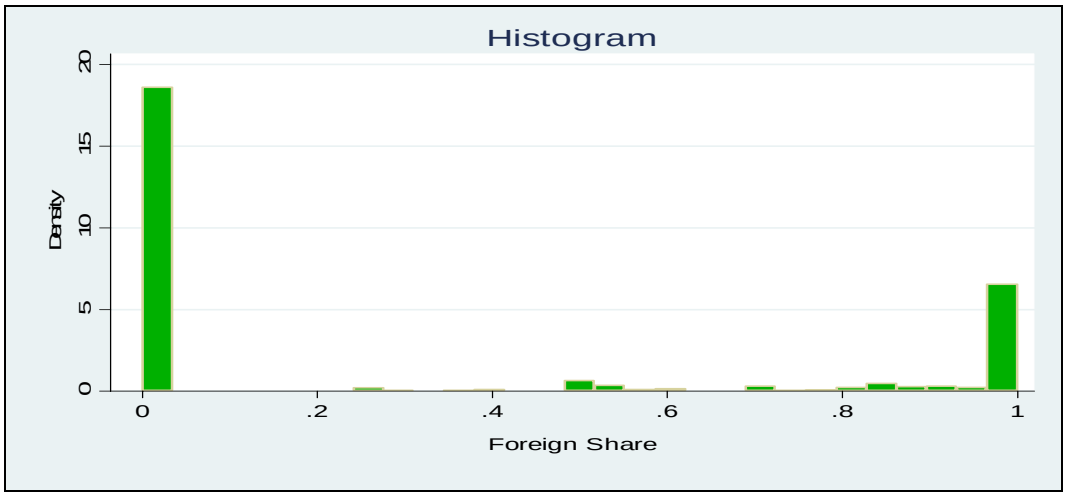

Figure 3 - Histogram of Foreign Share on Equity of Firms in the Sample
Source: Own computations based on sample data.

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 firms with foreign capital.[16] I collected data for 28.6 percent of the Czech-owned firms in the paper industry, 16.8 percent in machinery and equipment, 16.9 percent in electrical equipment, and 22.6 percent in motor vehicles.

[16] In the firms with foreign capital, the share of foreign capital in the firm's equity exceeds 50 percent in 42 firms.

Overall, I collected data for 18.2 percent of the population of Czech-owned firms and 12.8 percent of the population of multinationals. When I classify multinationals according to the industry, I collected the highest share of the population of multinationals in the paper industry (30 percent) and the lowest share in the motor vehicle industry (10 percent).

3.6 Sample Summary Statistics

Table 6 and Table 7 contain summary statistics for Czech-owned and multinational firms, respectively. Czech-owned firms are on average smaller than multinational firms. They have lower total sales and profits, less tangible and intangible capital, fewer skilled and unskilled workers and less investment in tangible and intangible capital. Czech-owned firms are less profitable. An average share of profit before taxation in output in Czech firms is 4.02 percent compared to 4.74 percent in multinational firms. Czech-owned firms on average have a higher share of workers out of production (32.9 percent of employees) than multinationals (26.3 percent of employees).

Taking investment in intangible capital per worker as a proxy for investment in human capital,[17] multinationals invest annually in human capital on average twice more (CZK 3457) than Czech-owned firms (CZK 5137). The average stock of intangible capital per worker in multinational firms (CZK 17895) is also twice that of a worker in Czech-owned firms (CZK 7965). The average stock of tangible capital per worker in multinational firms is CZK 0.7 million compared to CZK 0.3 million in Czech-owned firms.

[17] Investment in intangible capital is a reasonable proxy for investment in human capital as it includes expenditures on software, copyrights, licenses, and research and development. Purchases of new software and new technologies enable workers to learn new skills and improve their human capital.

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

In millions of Czech crowns (CZK) unless otherwise indicated.

Variable	Mean	Std. Dev.	Min	Max
Sales	260.01	342.30	5.49	3124.96
Change in Inventories	0.73	8.89	-39.03	58.51
Output	260.75	342.53	5.55	3124.96
Profit	11.59	30.21	-187.63	203.85
Profitability=Profit/Output in %	4.02	12.12	-157.39	36.56
Total Exports	114.57	213.19	0	1625.51
Number of Skilled Workers	96.32	96.04	3	572
Number of Unskilled Workers	208.19	233.58	3	2162
Wages	45.38	49.38	0.69	420.67
Average Hourly Wage in US $[18]	4.00	1.22	1.40	8.62
Material	132.34	228.55	0.00	2435.78
Imported Material	41.52	100.28	0	907.46
Energy	11.06	19.86	0.11	192.24
Tangible Capital	111.51	176.13	0.02	1450.16
Intangible Capital	3.04	9.28	0	94.02
Investment in Tangible Capital	16.38	33.07	0	278.17
Investment in Intangible Capital	1.06	3.56	0	35.35
Investment in Intangibles per Worker[19]	3.45	12.3	0	119.0
Stock of Intangible Capital per Worker[20]	7.96	21.5	0	312.6
R&D Expenses	3.40	8.94	0	78.21
Backward Linkage in %	14.57	20.50	0	100
Forward Linkage in %	13.36	20.89	0	100

[18] 22.358 CZK/USD exchange rate as of December 31, 2004. See: www.oanda.com .
[19] In thousands of CZK
[20] In thousands of CZK

Table 7 - Summary Statistics of Sample Data – Multinational Firms

In millions of Czech crowns (CZK) unless otherwise indicated.

Variable	Mean	Std. Dev.	Min	Max
Sales	983.51	1854.60	4.56	17161.87
Change in Inventories	3.76	53.88	-472.48	307.25
Output	987.27	1868.71	4.56	17215.51
Profit	67.94	207.40	-328.39	2006.07
Profitability=Profit/Output in %	4.47	10.50	-30.51	35.19
Total Exports	583.58	1704.57	0	17159.10
Number of Skilled Workers	138.16	157.67	2	858
Number of Unskilled Workers	415.44	596.71	16	4422
Wages	111.52	166.94	2.81	1502.74
Average Hourly Wage in US $[21]	5.16	1.67	1.81	10.75
Material	554.32	1166.83	0.01	10278.96
Imported Material	227.56	351.63	0	1900.00
Energy	19.69	23.38	0.01	150.26
Tangible Capital	460.91	1227.98	0.07	12536.79
Intangible Capital	8.46	17.68	0	177.31
Investment in Tangible Capital	124.61	497.30	0	5489.22
Investment in Intangible Capital	4.27	15.57	0	158.21
Investment in Intangibles per Worker[22]	5.13	13.54	0	100.51
Stock of Intangible Capital per Worker[23]	17.89	42.67	0	351.44
R&D Expenses	8.74	21.20	0	153.69
Backward Linkages in %	15.47	21.98	0	90.60
Forward Linkages in %	10.37	19.82	0	97.20

[21] 22.358 CZK/USD exchange rate as of December 31, 2004. See: www.oanda.com .
[22] In thousands of CZK
[23] In thousands of CZK

On average, Czech-owned firms annually invest in research and development CZK 3.40 million, which is about 40 percent of what multinational companies invest (CZK 8.74 million).

Average hourly wages in multinational firms (USD 5.17) are 30 percent higher than in the Czech-owned firms (USD 4.0). Czech-owned firms sell, on average, 14.58 percent of their goods to multinational firms located in the Czech Republic. They purchase, on average, 13.36 percent of their material from multinationals located in the Czech Republic.

Multinational firms are highly export-oriented. They export, on average, 60 percent of their production, compared to 40 percent in the case of the Czech-owned firms. The volume of exports of multinationals is, on average, more than 5 times greater than the export volume of Czech-owned firms.

4. Empirical Evidence from the Questionnaire

As noted in previous sections, the questionnaire included a variety of questions regarding supplier-consumer relationships, the choice of suppliers, and the perceived influence of multinational firms on domestic firms. A sample of 44 multinational firms and 90 Czech-owned firms provided answers. These questions were answered by general managers and financial directors during interviews in the firms.

4.1 Do Multinationals Help Their Suppliers?

I asked firms whether they had provided any assistance to their supplier(s) so that I could provide empirical 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: 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. This information is summarized in Figure 4 below:

Figure 4 – Assistance Provided by Multinationals to Their Suppliers

Other forms of assistance named were suggestions about the production of new products, help with the development of new materials, and production 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 indicated that they have received help. When asked what kind of help they have received, Czech firms report in particular: help with financing (49%), quality control (43%), employee training (34%), technology

improvement (26%), finding new customers (23%), leasing of machinery (14%), and storage of material (3%). These reasons are summarized in the Figure 5 below:

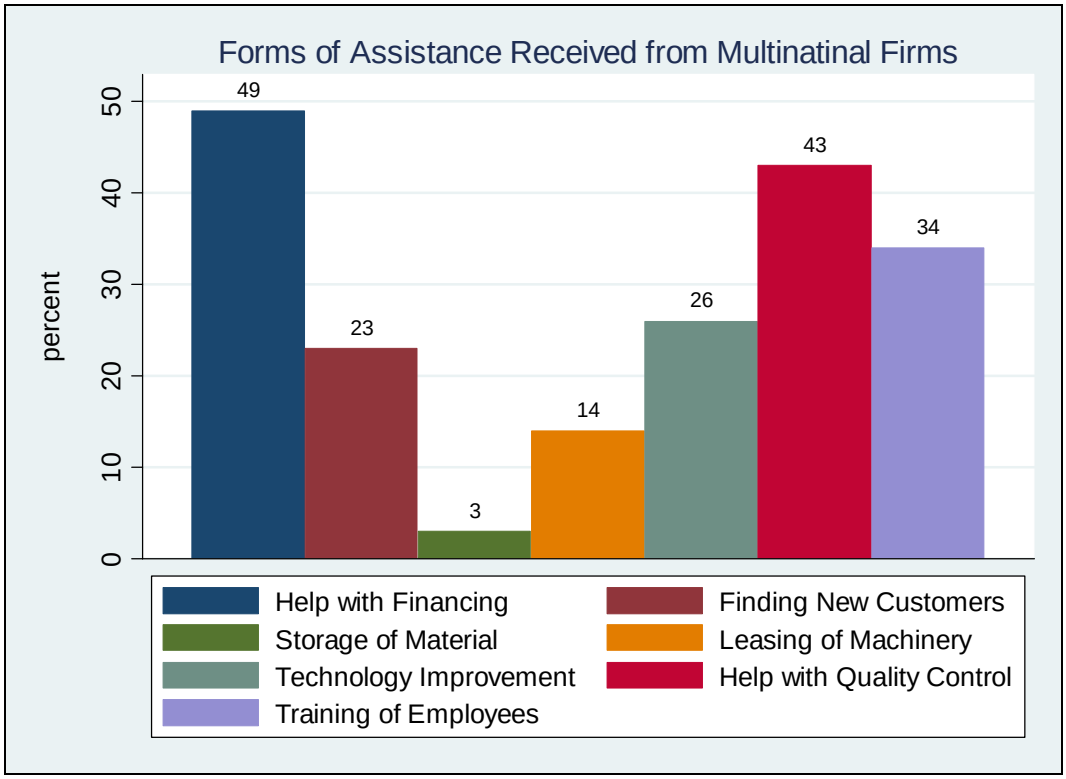

Figure 5 - Forms of Assistance Czech-Owned Firms Received from Their Multinational Customers

4.2 Perceptions about Multinational Firms

What is the perceived influence of the entry of multinational firms into the Czech Republic on respondents' firms? 98 percent of firms indicated that multinationals impact them, negatively and/or positively. One third of firms experienced an increase in competition. Almost one fifth (19%) of firms complained that multinationals were headhunting their workers. 17 percent of firms experienced a decrease in market share. On the other hand, 14 percent of firms learned new technologies, and 11 percent of firms learned new marketing techniques. 3 percent of domestic firms acknowledged that they were headhunting employees of multinational

firms. This evidence is summarized in Figure 6.

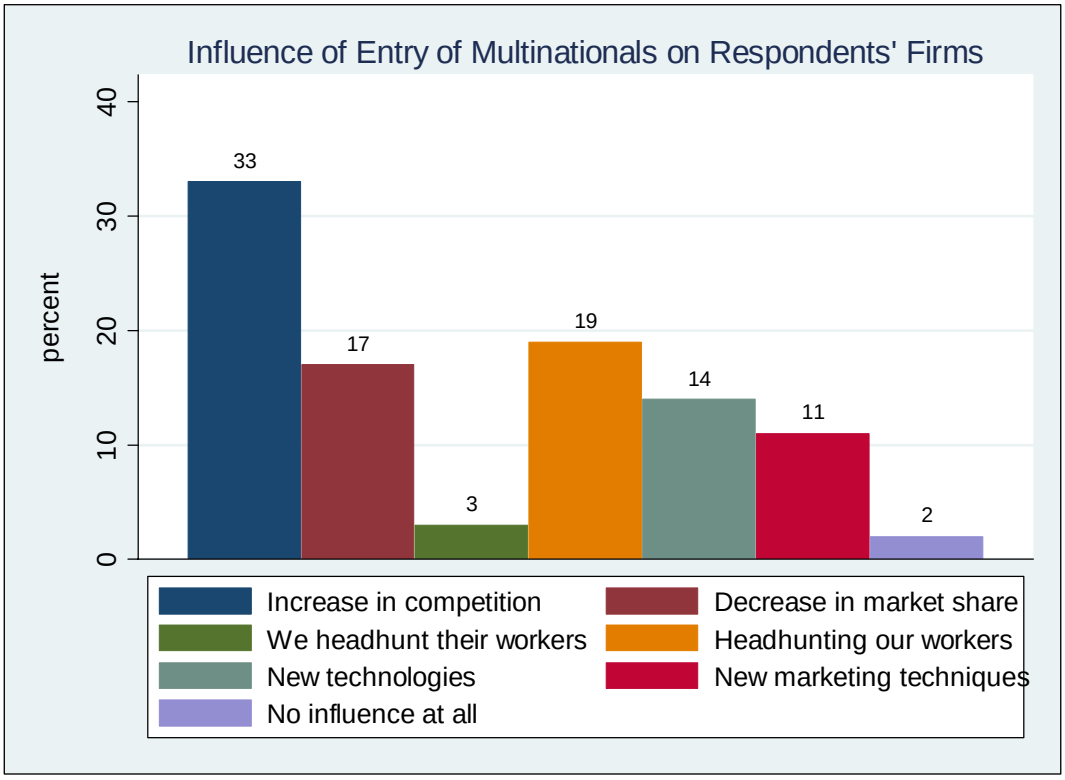

Figure 6 - Perceived Influence of an Entry of Multinationals on Respondents' Firms

4.3 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 so that I could generate empirical 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 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 explicitly require firms to purchase their inputs from specific multinational suppliers.[24] Figure 7 summarizes these findings.

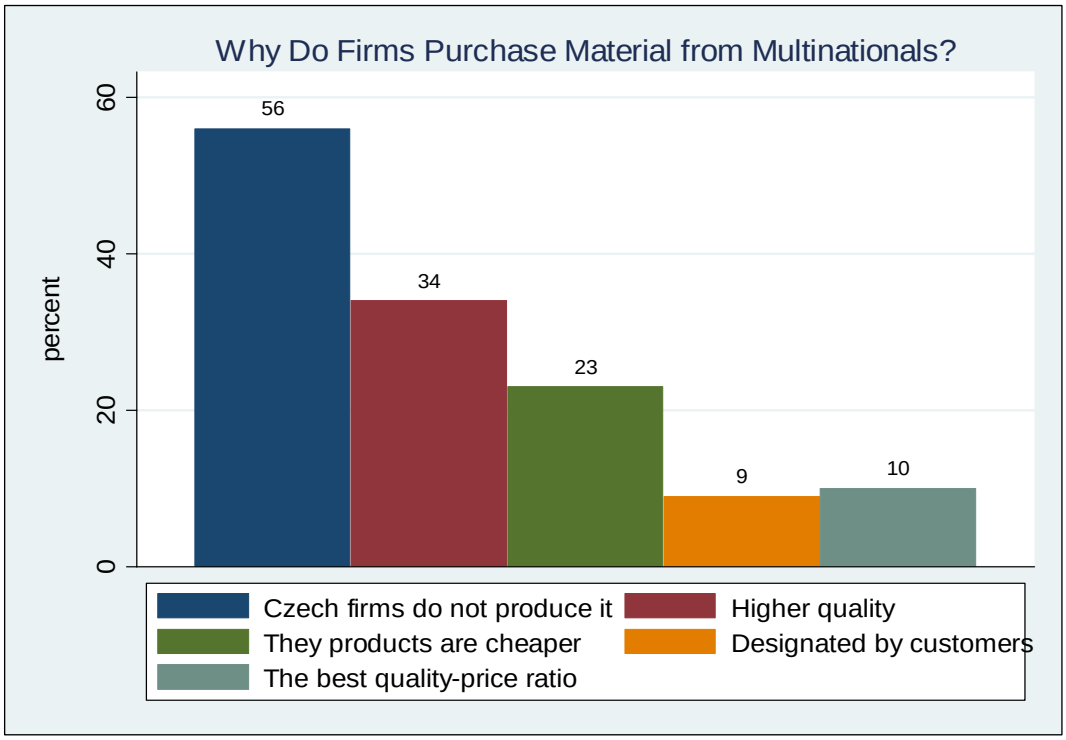

Figure 7 - Reasons for Purchasing Inputs from Multinationals

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, 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%). Figure 8 summarizes this

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

evidence.

To conclude, empirical 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.

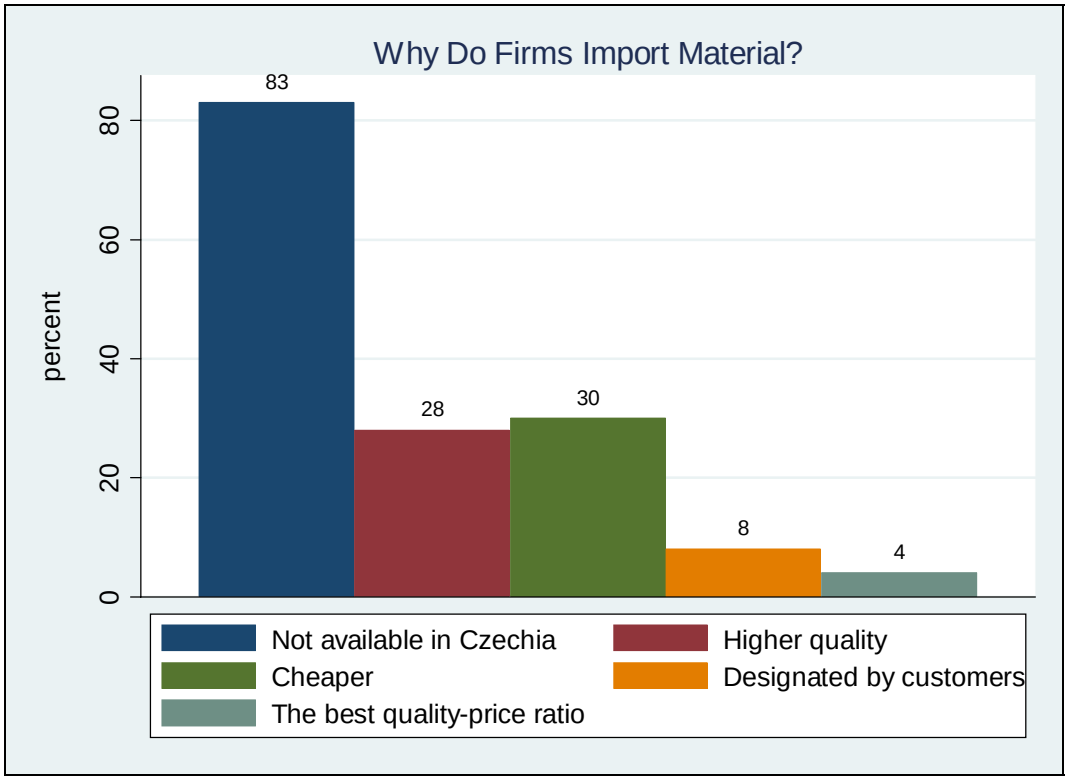

Figure 8 - Reasons for Material Imports

5. Research Strategy and Estimation Results

I would like to test whether firms that sell more products to multinationals produce more, ceteris paribus (spillover through backward linkage) 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 controls for backward and

forward linkages.

5.1 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). This 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 the output that firm i sold to consumer c and S_T is the total sales 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 the 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 8 presents pooled OLS results for a full sample and a subsample of Czech-owned firms. 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.

Table 8 - Baseline Pooled OLS

Dependent variable in both specifications is ln (Output).

VARIABLE	Full Sample	Czech-Owned
ln (Material)	0.282***	0.274***
	(0.018)	(0.018)
ln (Energy)	0.174***	0.130***
	(0.018)	(0.023)
ln (Unskilled)	0.400***	0.356***
	(0.028)	(0.037)
ln (Skilled)	0.135***	0.165***
	(0.019)	(0.025)
ln (Capital)	-0.036	-0.038
	(0.022)	(0.028)
Foreign Share	0.375***	
	(0.037)	
Backward	0.479***	0.772***
	(0.090)	(0.130)
Forward	-0.058	0.046
	(0.072)	(0.093)
Year Dummies	YES	YES
Industry Dummies	YES	YES
Regional Dummies	YES	YES
No. of Obs.	712	447
R-Squared	0.93	0.90

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

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. Its magnitude seems economically meaningful and important. A one-percent increase in the backward linkage of a Czech-owned firm is associated with a 0.772 percent rise in its output.

Coefficients on the Forward variable are not statistically significant. The coefficient on the 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 empirical evidence showing that multinational firms are more aggressive in negotiating prices with their suppliers (see section 6.1 for empirical evidence). CEOs often complained that "multinationals want everything for free." As big players, they have better negotiating positions to enforce lower prices for their inputs than smaller Czech-owned firms.[25] 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 percent, ceteris paribus. The "price squeeze effect" goes against the "spillover" effect. 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

[25] See section 1.3.6 to compare the size of multinational firms and Czech-owned firms based on my sample.

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 would explain 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 estimate a model in the form:

$$(2) \qquad \ln Y_{it} = \alpha_1 + \alpha_2 \cdot \ln M_{it} + \alpha_3 \cdot \ln E_{it} + \alpha_4 \cdot \ln U_{it} + \alpha_5 \cdot \ln S_{it} + \alpha_6 \cdot \ln K_{it} + \alpha_7 \cdot FS_{it} + \alpha_8 \cdot Backward_{i,t-1} + \alpha_9 \cdot Forward_{i,t-1} + \alpha_t + \alpha_j + \alpha_r + \varepsilon_{it}$$

Results from the full sample of firms and the subsample of Czech-owned firms are reported in Table 9. Again, all coefficients of production inputs but capital are positive and statistically significant at the 1% level.

Coefficients on the Backward variable are again positive and statistically significant at the 1% level in both columns. They are similar in magnitude to estimates from model (1). Coefficients on the Forward variable are still not statistically significant.

Both models (1) and (2) assume a Cobb-Douglas production function. This motivates an alternative estimation with a more flexible form of production function. In the next section I use a translog function to test the sensitivity of my results to the functional form of the production function.

Table 9 - Baseline Pooled OLS, Lagged Linkage Variables

Dependent variable in both specifications is ln (Output).

VARIABLE	Full Sample	Czech-Owned
ln (Material)	0.266***	0.266***
	(0.018)	(0.018)
ln (Energy)	0.155***	0.112***
	(0.019)	(0.022)
ln (Unskilled)	0.414***	0.360***
	(0.030)	(0.040)
ln (Skilled)	0.141***	0.167***
	(0.020)	(0.026)
ln (Capital)	-0.017	-0.022
	(0.023)	(0.031)
Foreign Share	0.370***	
	(0.038)	
Backward (t-1)	0.473***	0.793***
	(0.092)	(0.143)
Forward (t-1)	-0.062	0.010
	(0.076)	(0.105)
Year Dummies	YES	YES
Industry Dummies	YES	YES
Regional Dummies	YES	YES
No. of Obs.	618	384
R-Squared	0.93	0.90

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

5.2 Translog Production Function

I estimate model (3) in the form:

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

All variables are defined and denoted as before. Table 10 shows OLS results estimated for the full sample and the subsample of Czech-owned firms.

Table 10 - Translog Production Function, Pooled OLS

Dependent variable is ln (Output)

	Full Sample	**Czech-Owned**
Backward	0.326***	0.358***
	(0.068)	(0.092)
Forward	-0.047	0.052
	(0.048)	(0.047)
FS	0.158***	
	(0.031)	
ln(Material)	0.541***	0.549***
	(0.063)	(0.082)
ln(Energy)	-0.071	-0.192**
	(0.070)	(0.088)
ln(Unskilled)	0.222	-0.079
	(0.144)	(0.170)
ln(Skilled)	0.261***	0.439***
	(0.087)	(0.095)
ln(Capital)	-0.045	-0.125
	(0.070)	(0.080)
ln(Material)*ln(Material)	0.036***	0.034***
	(0.006)	(0.008)
ln(Energy)*ln(Energy)	0.004	0.0003
	(0.006)	(0.014)
ln(Unskilled)*ln(Unskilled)	0.062***	0.065***
	(0.022)	(0.025)

Table 10 (continued)

ln(Skilled)*ln(Skilled)	-0.013	-0.014
	(0.014)	(0.020)
ln(Capital)*ln(Capital)	0.013	-0.011
	(0.010)	(0.011)
ln(Capital)*ln(Material)	-0.011	0.001
	(0.013)	(0.013)
ln(Capital)*ln(Energy)	0.013	-0.024
	(0.013)	(0.015)
ln(Capital)*ln(Unskilled)	-0.014	0.046*
	(0.024)	(0.025)
ln(Capital)*ln(Skilled)	0.007	0.001
	(0.016)	(0.018)
ln(Skilled)*ln(Material)	0.049***	0.018
	(0.017)	(0.028)
ln(Skilled)*ln(Energy)	0.002	0.080***
	(0.020)	(0.022)
ln(Unskilled)*ln(Skilled)	-0.060***	-0.086***
	(0.021)	(0.021)
ln(Unskilled)*ln(Material)	-0.079***	-0.057**
	(0.015)	(0.023)
ln(Unskilled)*ln(Energy)	0.022	0.048***
	(0.019)	(0.018)
ln(Material)*ln(Energy)	-0.012	-0.049**
	(0.012)	(0.020)
No. of Obs.	712	447
R-Squared	0.97	096

Robust standard errors in parenthesis. ***, ** and * denote significance level at 1%, 5% and 10% respectively. Year and industry dummies included.

Again I get strong evidence for the existence of technological diffusion through backward linkages and no evidence for forward linkages. A one-percent increase in the backward linkage of a Czech-owned firm is associated with a 0.358 percent rise in output. This coefficient is smaller compared to the baseline case (0.772) but 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 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.

5.3 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 (4) using the fixed effects estimator (FE):

$$(4)\ \ln Y_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_4 \cdot \ln M_{it} + \alpha_5 \cdot \ln E_{it} + \alpha_6 \cdot \ln U_{it} + \alpha_7 \cdot \ln S_{it} + \alpha_8 \cdot \ln K_t + \alpha_t + \beta_i + \varepsilon_{it},$$

where β_i denotes the firm-specific effect.

In Table 11, results of the fixed effects estimator for the full sample and the subsample of Czech-owned firms are presented in the first two columns, respectively.

I find evidence for productivity spillovers through backward linkages in both cases. The coefficient on the Backward variable estimated for a sample of Czech-owned firms is higher than the estimate for the full sample of firms. This suggests that backward linkages are important for Czech-owned firms in particular. The magnitude of the effect is economically meaningful. A one-percent increase in the backward linkage of a Czech-owned firm is associated with a 0.356 percent rise in its output. The coefficients on the Forward variable are positive but not statistically significant at standard levels.

Table 11 - Fixed Effects Estimates

Dependent variable in all columns is ln (Output).

	Full Sample	**Czech-Owned**	**Multinationals**
Backward	0.258***	0.356***	0.109
	(0.084)	(0.134)	(0.102)
Forward	0.024	0.080	-0.265
	(0.075)	(0.082)	(0.182)
Foreign Share	-0.002		
	(0.051)		
ln (Material)	0.608***	0.566***	0.650***
	(0.037)	(0.051)	(0.040)
ln (Energy)	0.116***	0.130**	0.084***
	(0.027)	(0.064)	(0.021)
ln (Unskilled)	0.183***	0.141**	0.206***
	(0.047)	(0.071)	(0.052)
ln (Skilled)	0.050	0.115	-0.011
	(0.041)	(0.073)	(0.045)
ln (Capital)	-0.007	0.001	0.002
	(0.019)	(0.024)	(0.026)
Year Dummies	YES	YES	YES
No. of Obs.	712	447	265
R-Squared	0.89	0.86	0.94

Robust standard errors in parenthesis.
Within R-Squared reported.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

The third column in Table 11 contains results estimated for the subsample of multinational firms. The coefficient on the Backward variable is positive but small, and it is not statistically significant at standard levels. This suggests again that backward linkages are important for Czech-owned firms in particular.

Alternatively, I remove fixed firm-specific unobservable variation by estimating model (1) in first differences. According to Wooldridge (2002, p. 284), "when T>2, 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 FD estimator is more efficient when the idiosyncratic errors follow a random walk."

In addition to removing any fixed firm-specific unobservable variation, differencing will remove fixed regional and industrial effects. The model in the first differences is specified as:

$$(5)\ \Delta \ln Y_{it} = \beta_1 \cdot \Delta\, Backward_{it} + \beta_2 \cdot \Delta Forward_{it} + \beta_3 \cdot \Delta FS_{it} + \beta_4 \cdot \Delta \ln M_{it} + \beta_5 \cdot \Delta \ln E_{it} + \beta_6 \cdot \Delta \ln U_{it} + \beta_7 \cdot \Delta \ln S_{it} + \beta_8 \cdot \Delta \ln K_{it} + \Delta\alpha_t + \mu_{it}$$

As linkages are likely to influence productivity with a time lag, I also consider model (2) estimated in first differences. I estimate the equation in the form:

$$(6)\ \Delta \ln Y_{it} = \beta_1 \cdot \Delta\, Backward_{i,t-1} + \beta_2 \cdot \Delta Forward_{i,t-1} + \beta_3 \cdot \Delta FS_{it} + \beta_4 \cdot \Delta \ln M_{it} + \beta_5 \cdot \Delta \ln E_{it} + \beta_6 \cdot \Delta \ln U_{it} + \beta_7 \cdot \Delta \ln S_{it} + \beta_8 \cdot \Delta \ln K_{it} + \Delta\alpha_t + \mu_{it}$$

Table 12 contains results from the first differences with the contemporaneous and one-period lagged changes in linkage variables for the full sample of firms and for the subsample of Czech-owned firms.

Table 12 - Model with Contemporaneous and Lagged Linkages in the 1st Differences

Dependent variable in all specifications is a Δ ln (Output).

	Full Sample	Full Sample	Czech-Owned	Czech-Owned
Δ Backward (t)	0.104		0.026	
	(0.080)		(0.106)	
Δ Forward (t)	-0.03		-0.034	
	(0.081)		(0.096)	
Δ Backward (t-1)		0.181**		0.224**
		(0.081)		(0.108)
Δ Forward (t-1)		-0.022		-0.034
		(0.085)		(0.100)
Δ FS (t)	-0.057	-0.043		
	(0.055)	(0.055)		
Δ ln (Material)	0.562***	0.559***	0.529***	0.512***
	(0.020)	(0.022)	(0.026)	(0.028)
Δ ln (Energy)	0.185***	0.192***	0.175***	0.178***
	(0.027)	(0.032)	(0.033)	(0.039)
Δ ln (Unskilled)	0.180***	0.136***	0.254***	0.178***
	(0.039)	(0.040)	(0.059)	(0.062)
Δ ln (Skilled)	-0.002	-0.017	0.021	-0.011
	(0.039)	(0.040)	(0.056)	(0.058)
Δ ln (Capital)	-0.010	-0.003	-0.020	-0.001
	(0.019)	(0.020)	(0.025)	(0.025)
Δ Year Dummies	YES	YES	YES	YES
No. of Obs.	606	512	377	317
R-Squared	0.74	0.72	0.73	0.70

Standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

An important fact is revealed: Backward linkages are statistically significant only in specifications with lagged differences. This suggests that it takes some time before spillovers through backward linkages increase productivity. Results confirm my previous findings regarding spillovers through forward linkages; there is no evidence for their existence.

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 for endogeneity may lead to biased parameter estimates. In the next section I take the possible endogeneity of input choices into account by applying a system GMM estimator.

5.4 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.[26]

In this section I consider the original model in the form:

$$(7)\ \ln Y_{it} = \alpha_1 + \alpha_2 \cdot \ln M_{it} + \alpha_3 \cdot \ln E_{it} + \alpha_4 \cdot \ln U_{it} + \alpha_5 \cdot \ln S_{it} + \alpha_6 \cdot \ln K_{it} + \alpha_7 \cdot FS_{it} + \alpha_8 \cdot Backward_{it} + \alpha_9 \cdot Forward_{it} + \beta_i + \varepsilon_{it},$$

where β_i denotes the firm-specific effect. I regard all right-hand side variables to be endogenous. I use the system GMM estimator of Blundell and Bond (1998, 1999) to

[26] See Griliches and Mairesse (1995).

estimate the model (7). The system GMM estimator is based on two sets of moment conditions. The first set of the moment conditions comes from the first differenced equations (to remove the firm-specific effect) with lagged levels of the variables as instruments (cf. 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. 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 $E[\alpha_i * D\varepsilon_{it}]=0$, which means that the unobserved firm-specific effects are not correlated with changes in the error term. 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 the 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 are presented in Table 13.[27] 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 second-order serial dependence.

[27] I employed the xtabond2 command in Stata, see Roodman (2005).

Table 13 - System GMM

Dependent variable in both specifications is ln (Output).

	Full Sample	**Czech-Owned**
Backward	0.348	0.658*
	(0.346)	(0.376)
Forward	0.333	0.151
	(0.374)	(0.339)
Foreign Share	0.18	
	(0.175)	
ln (Material)	0.489***	0.418***
	(0.101)	(0.116)
ln (Energy)	0.205*	0.237***
	(0.117)	(0.086)
ln (Unskilled)	0.144	0.157
	(0.128)	(0.152)
ln (Skilled)	-0.094	-0.134
	(0.175)	(0.188)
ln (Capital)	0.038	0.079
	(0.055)	(0.075)
P-value of Hansen test of overid. Restrictions	0.517	0.501
P-value of Arellano-Bond test for AR(2) in 1^{st} Δ	0.167	0.242
Number of Firms	103	70
Number of Obs.	712	447

Robust standard errors in parenthesis.
One-step system GMM results.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

The coefficients on Backward and Forward linkages are positive both for the full sample and the subsample of Czech-owned firms. However, only the coefficient on Backward linkages for the Czech-owned firms is statistically significant (p-value=0.08). A one-percent increase in the backward linkage of a Czech-owned firm leads to a 0.658 percent rise in its output. This provides further evidence that Czech-owned firms benefit from their interactions with their multinational customers.

There are a few alternative methods proposed to deal with the endogeneity of input choices apart from system GMM. Standard references are Olley and Pakes (1996) and Levinsohn-Petrin (2003). I apply both methods to check the robustness of my system GMM results.

5.5 Levinsohn-Petrin Estimator of Production Function

Olley and Pakes (OP) show the conditions under which an investment proxy controls for correlation between input levels and the unobserved productivity shock. Levinsohn-Petrin (LP) show how intermediate inputs, such as material and energy, can also be used to solve the simultaneity problem.

In this section I apply the LP procedure where I use consumption of material as a proxy variable. The LP 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 the revenue case. Value-added (VA) is defined as the difference between real output and real material and energy consumption. I estimate (8) using the nonlinear semi-parametric LP procedure on the subsample of Czech-owned firms.

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

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 has 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 a simultaneity problem in production function estimation. Demand for the material $m_{it} = \ln M_{it}$ is assumed to depend on the firm's state variables, capital k_{it} and ω_{it}, i.e. $m_{it} = m_{it}(k_{it}, \omega_{it})$.

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: $\omega_{it} = \omega_{it}(k_{it}, m_{it})$.

A final identification restriction concerns the development of productivity. LP (2003) follow OP (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 production function (8) can be written as

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

where $\phi_{it}(k_{it}, m_{it}) = \alpha_0 + \alpha_k \cdot k_t + \omega_{it}(k_{it}, m_{it})$. I follow Petrin, Levinsohn and Poi (2003)[28] in substituting a third-order polynomial approximation in k_{it} and m_{it} in place of $\phi_{it}(k_{it}, m_{it})$ and consistently 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

[28] Petrin, A., Levinsohn, J. and B.P. Poi (2003, pp. 3-5).

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:

$$\hat{\varepsilon}_{it} + \hat{\xi}_{it} = va_{it} - \hat{\alpha}_s \cdot s_{it} - \hat{\alpha}_u \cdot u_{it} - \hat{\alpha}_b \cdot Backward_{it} - \hat{\alpha}_f \cdot Forward_{it} - \alpha_k^* \cdot k_{it} - \hat{E}(\omega_{it} \mid \omega_{i,t-1})$$

The estimate of $\hat{\alpha}_k$ for 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 14, col. 1.

Table 14 - LP estimator and Comparison of Estimates of Production Function

Dependent variable in all specifications is ln (Value Added).

VARIABLE	LP	OLS	FE	LP
ln (Unskilled)	0.388***	0.570***	0.562***	0.463***
	(0.102)	(0.024)	(0.114)	(0.098)
ln (Skilled)	0.254**	0.253***	0.089	0.218***
	(0.115)	(0.032)	(0.091)	(0.070)
ln (Capital)	0.251*	0.171***	0.181***	0.294***
	(0.144)	(0.021)	(0.038)	(0.106)
Backward	0.608*			
	(0.312)			
Forward	0.122			
	(0.180)			
No. of Obs.	444	772	772	772
R-Squared	---	0.98	0.41	---
Sum of Coefficients	1.623	0.994	0.832	0.975

Robust standard errors in parenthesis. Within R-Squared reported with FE estimates. ***, ** and * denote significance level at 1%, 5% and 10% respectively. Results in the 1st column are estimated on a subsample of Czech-owned firms, other columns on the full sample.

The coefficient on the Backward variable is positive, statistically significant (p-value = 0.051), and its size (0.608) is economically meaningful and similar to the system GMM estimate (0.658).[29]

In the next section, I use the 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 and use it as a dependent variable in the basic model.

5.6 LP Residuals as a Measure of Total Factor Productivity

Javorcik (2004) studied inter-industry spillovers in Lithuanian manufacturing. She applied the Olley-Pakes estimator to consistently estimate the coefficients of the production function, 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 in the form:

(9) $va_{it} = \alpha_0 + \alpha_s \cdot s_{it} + \alpha_u \cdot u_{it} + \alpha_k \cdot k_{it} + \omega_{it} + \varepsilon_{it}$,

using the nonlinear semi-parametric LP procedure on the full sample of firms.

I assume that capital is the only state variable over which the firm has control.[30] For comparison, I also estimate equation (9) using the OLS and the fixed effects estimator.

Estimated coefficients of production function are presented in Table 14 (page 46), columns 2-4 above. The LP technique seems to work quite well. OLS estimates of

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[29] Notice that a ratio of the coefficient on the Backward variable and its standard error is almost 2 (0.608/0.321). Using a one tailed test the Backward variable would be significant at 5% level. In my case a one tailed test is more appropriate than two tailed test, since there is no theory predicting a negative coefficient on the Backward variable. I am indebted to Robert T. Masson for pointing this out.

[30] In section 1.5.7 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.

skilled and unskilled labor exceed the LP estimates, confirming the theoretical results 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. There is not enough within variation in the number of skilled workers to identify the coefficient well. The sums of coefficients are slightly less than one (0.994 in the OLS case and 0.975 in the LP case).

The residuals from model (9) become a measure of total factor productivity:

$$TFP_{it} = e^{va_{it} - \hat{\alpha}_s \cdot s_{it} - \hat{\alpha}_u \cdot u_{it} - \hat{\alpha}_k \cdot k_{it}}.$$

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:

$$(10) \quad \ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_t + \varepsilon_{it}.$$

I use both the fixed and the random effects estimator. Results for the full sample and the subsample of Czech-owned firms are presented in Table 15. A Hausman test suggests that the random effects model is more suitable than the fixed effect model.[31]

The estimated coefficients do not differ much. In all four regressions, I find a positive and significant coefficient on the Backward variable. The size of the coefficients is slightly larger in the case of the subsample of Czech-owned firms. This suggests that for Czech firms, linkages are especially important. A one-percent

increase in the backward linkage of a Czech-owned firm is associated with a 0.860 percent rise in its output.[32] Again, I do not find any evidence in favor of forward linkages.

Table 15 - TFP (Value Added Case) and Backward and Forward Linkages

Dependent variable in all specifications is a logarithm of total factor productivity, ln (TFP).

	FE	**RE**	**FE**	**RE**
Backward	0.732*** (0.165)	0.718*** (0.144)	0.875*** (0.229)	0.860*** (0.181)
Forward	-0.044 (0.138)	-0.0002 (0.116)	0.068 (0.150)	0.043 (0.131)
FS	0.129 (0.129)	0.252*** (0.083)		
Year Dummies	YES	YES	YES	YES
Industry Dummies	---	YES	---	YES
No. of Obs.	709	709	444	444
Number of Firms	103	103	70	70
R-Squared (within)	0.074	0.071	0.074	0.073
Hausman test Prob>chi^2 for Hausman		8.70 0.65		0.47 (1.00)

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively

[32] Based on random effects estimate for the subsample of Czech-owned firms.

As an alternative to the fixed effects estimator, I estimate model (10) in first differences. I would like to compare results from first differencing with fixed effects. First, I use contemporaneous and then one-period lagged linkages variables. I estimate:

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

and

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

Results for the full sample and the subsample of Czech-owned firms are presented in Table 16.

Table 16 - TFP (Value Added Case), 1st Differences of Linkage Variables

Dependent variable in all specifications is Δ ln (TFP).

VARIABLE	Full Sample	Full Sample	Czech-Owned	Czech-Owned
Δ Backward (t)	0.378 (0.275)		0.208 (0.299)	
Δ Forward (t)	0.102 (0.134)		0.136 (0.154)	
Δ Backward (t-1)		0.466*** (0.178)		0.493* (0.258)
Δ Forward (t-1)		-0.127 (0.196)		-0.052 (0.197)
Δ FS (t)	-0.081 (0.095)	-0.083 (0.089)		
Δ Year Dummies	YES	YES	YES	YES
No. of Obs.	602	509	373	314
R-Squared	0.04	0.05	0.04	0.07

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively

The coefficients on the Backward variable are positive in all specifications. They are statistically significant only for the differences of lagged controls for backward linkages. This suggests that it takes some time before spillovers through backward linkages increase productivity. Coefficients on the Backward variable are smaller than corresponding coefficients estimated with the fixed effects estimator. However, they are still economically significant. I find evidence for spillovers through backward linkages and no evidence for spillovers through forward linkages.

When I estimated the production function in the value-added form (9), I used the whole sample of firms due to data limitations. 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 select the industry for which I have the most data, which is the machinery and equipment industry, and re-estimate models (10)-(12).

Table 17 contains OLS, FE, and Levinsohn-Petrin estimates of the production function in the value-added form (9) for firms in machinery and equipment industry only.

Table 17 - Machinery and Equipment Industry – Production Function

Dependent variable in all specifications is ln (Value Added).

	OLS	**FE**	**LP**
ln (Unskilled)	0.643*** (0.039)	0.718*** (0.117)	0.567*** (0.148)
ln (Skilled)	0.240*** (0.039)	-0.108 (0.124)	0.257** (0.113)
ln (Capital)	0.088*** (0.028)	0.204*** (0.039)	0.113 (0.158)
No. of Obs. R-Squared Sum of Coefficients	371 0.98 0.971	371 0.32 0.814	371 --- 0.947

Robust standard errors in parenthesis. Within R-Squared reported with FE estimates.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

Table 18 below presents the results of model (10) for all firms in machinery and equipment and for a subsample of Czech-owned firms belonging to machinery and equipment industry. Results confirm the previous findings.

Table 18 - Machinery and Equipment Industry – Backward and Forward Linkages

Dependent variable is a logarithm of total factor productivity, ln (TFP).

	Full Sample	**Czech-Owned**
	FE	**FE**
Backward	0.947***	1.176***
	(0.206)	(0.290)
Forward	0.038	0.056
	(0.191)	(0.202)
Foreign Share	0.081	
	(0.196)	
No. of Obs.	337	236
R-Squared	0.10	0.12

Robust standard errors in parenthesis. Within R-Squared reported.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

Models in the first differences (11) and (12) estimated using only firms in the machinery and equipment industry are presented in Table 19. This time contemporaneous differences of backward linkages are statistically significant while lagged differences are not. The insignificant differences of lagged linkages variables are likely caused by a decrease in the number of observations caused by lagging and differencing linkage variables and by restricting to firms in the machinery industry.

Table 19 - Machinery and Equipment Industry – 1st Differences

Dependent variable in all specifications: Δ ln (TFP).

VARIABLE	Full Sample	Full Sample	Czech-Owned	Czech-Owned
Δ Backward (t)	0.965*** (0.353)		0.818*** (0.460)	
Δ Forward (t)	0.122 (0.202)		0.06 (0.228)	
Δ Backward (t-1)		0.429 (0.265)		0.525 (0.463)
Δ Forward (t-1)		-0.032 (0.246)		0.197 (0.186)
Δ FS (t)	-0.088 (0.132)	-0.008 (0.094)		
Δ Year Dummies	YES	YES	YES	YES
No. of Obs.	286	243	201	172
R-Squared	0.08	0.07	0.08	0.09

Robust standard errors in parenthesis. Within R-Squared reported.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

When estimating the production function (9) from which I recovered residuals as a measure of TFP, I assumed that capital was the only state variable over which firms had control. However, firms that receive a positive productivity shock may decide to become suppliers to multinationals and/or purchase inputs from multinationals. In the next section, I include these factors as additional state variables in the Olley-Pakes

(OP) procedure to correct for potential biases in the estimation of TFP.

5.7 OP Residuals as a Measure of Total Factor Productivity

To test the hypotheses of productivity spillovers through backward and forward linkages, I consider model (10) again:

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

However, I use residuals as a measure of TFP recovered from a production function estimated using the 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 the OP estimator as follows. I consider the production function given in (9) again: $va_{it} = \alpha_0 + \alpha_s \cdot s_{it} + \alpha_s \cdot u_{it} + \alpha_k \cdot k_{it} + \omega_{it} + \varepsilon_{it}$.

In each period the firm has to decide about its inputs (skilled and unskilled labor) and investment. Investment (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 the standard OP model, the investment decision depends on the capital stock and on firm productivity. To take into account that suppliers to multinationals and purchasers of inputs from multinationals may face the different market and operating conditions when they make decisions about investment, I include two dummy variables into the 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 (9), I obtain:

$va_{it} = \alpha_s \cdot s_{it} + \alpha_u \cdot u_{it} + \phi_{it}(k_{it}, i_{it}, b_{it}, f_{it}) + \varepsilon_{it}$, 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 (9) become a measure of total factor productivity: $TFP\_OP_{it} = e^{va_{it} - \hat{\alpha}_s \cdot s_{it} - \hat{\alpha}_u \cdot u_{it} - \hat{\alpha}_k \cdot k_{it}}$. I denote this total factor productivity as TFP_OP to distinguish it from TFP obtained in the section 5.6.

I estimate model (10):

$\ln TFP\_OP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_t + \varepsilon_{it}$, using the fixed effects estimator to control for fix firm-specific effects. Results are presented in Table 20.

I find positive and highly significant coefficients on backward linkages for both the full sample and the subsample of Czech-owned firms. Coefficients on forward linkages are not statistically significant. These findings correspond to results from the

section 5.6 where the dependent variable (lnTFP) in the model (10) was obtained using LP method without controlling for the supplier and the purchaser status (see Table 15).

Table 20 - Modified Olley-Pakes Estimator, TFP and Linkages

Dependent variable in both specifications is ln (TFP-OP).

VARIABLE	Full Sample	Czech-Owned
	FE	FE
Backward	0.574*** (0.167)	0.654*** (0.226)
Forward	0.057 (0.147)	0.128 (0.155)
Foreign Share	0.073 (0.131)	
Year Dummies	YES	YES
No. of Obs.	630	379
R-Squared	0.141	0.097

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively.
Within R-Squared reported.

The results presented in Table 20 are estimated using fewer observations than results in Table 15 where the LP residuals are used as the dependent variable. 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 the estimation.[33] Therefore, in the rest of my paper if I use TFP, it is the TFP obtained using Levinsohn-Petrin technique in section 5.6.

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 provide several robustness checks in chapter 6.

6. Robustness Checks

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 by self-selection?

6.1 Self-Selection (Reverse Causality)

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 "the positive association between exporting and efficiency is explained by the self-selection of the more efficient firms into the export markets."[34] 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.

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[33] This is due to an invertibility of the investment function, the monotonicity condition does not hold for zero-investment observations.
[34] Clerides, Lach and Tybout (1998, p. 903).

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. I would like to know 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 empirical evidence that shows that it is not necessarily more demanding to start to supply multinational firms compared to Czech-owned firms.

When asked whether it is more demanding to start to supply multinationals, less than 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 summarizes these reasons.

On the other hand, 70 percent of suppliers to multinationals say they needed an ISO certification to be eligible to supply them.[35]

[35] ISO stands for the International Organization for Standardization, see http://www.iso.org/iso/en/ISOOnline.frontpage.

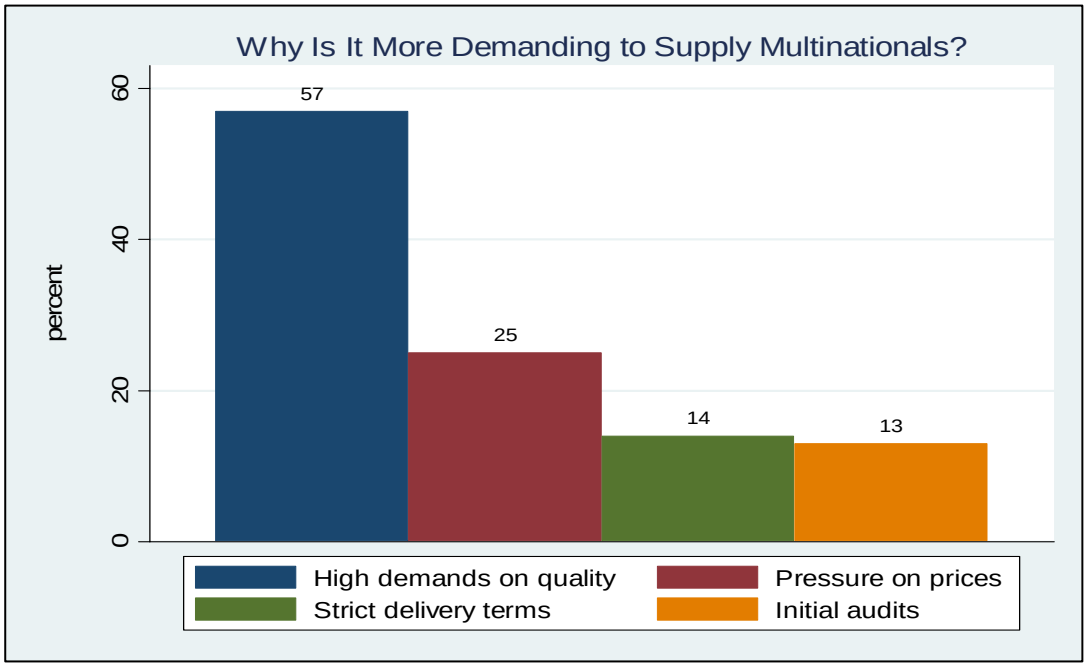

Figure 9 - In What Regard Are Multinational Firms More Demanding Buyers?

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.

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 for the whole period for which I have them in my database. These are firms that were able to overcome a productivity threshold and became suppliers to multinationals located in the Czech Republic. The restriction of the sample to these (possibly ex ante more productive) firms should mitigate the self-selection problem.

I re-estimate the model (10) 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 5.6.[36]

Results are presented in Table 21. The fixed effects and random effects estimates do not differ much in size. 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 15).

Table 21 - Robustness Check: Restriction of Sample on Czech-Owned Suppliers to Multinationals

Dependent variable is a logarithm of total factor productivity, ln (TFP).

VARIABLE	**Czech-Owned Suppliers to Multinational Firms**	
	FE	RE
Backward	0.778***	0.776***
	(0.239)	(0.207)
Forward	-0.071	-0.019
	(0.207)	(0.139)
Year Dummies	YES	YES
No. of Obs.	287	287
R-Squared	0.04	0.08

Robust standard errors in parenthesis.
Within R-Squared reported.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

[36] An estimation using TFP_OP measure obtained in the section 1.5.7 leads to exactly the same conclusions.

2. Dynamic Panel Model

In this section I try to shed more light on the competing hypotheses of productivity spillovers from multinationals to local firms versus the self-selection of ex ante more-productive firms into supplying to multinationals by considering a model in the form:

$$(13) \qquad \ln TFP_{it} = \alpha_0 + \alpha_1 \cdot \ln TFP_{i,t-1} + \alpha_2 \cdot Backward_{i,t-1} + \alpha_3 \cdot Forward_{i,t-1} + \alpha_t + \varepsilon_{it}.$$

I include one-period lagged TFP as a regressor to capture the persistence in total factor productivity. More importantly, if firms improve their productivity by supplying to multinationals or by purchasing inputs from multinationals, the coefficients on the Backward and Forward variables should be positive and significant. Linkage variables are included with a one- period lag to reduce the simultaneity problems. Time dummies are included and denoted as α_t. I use the system GMM estimator proposed by Blundell and Bond (1998, 1999) to estimate model (13). 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 the linkage variables are endogenous, i.e. $E[Backward_{it}*\varepsilon_{is}]\neq 0$ for $s\leq t$ but $E[Backward_{it}*\varepsilon_{is}]=0$ for all $s>t$ and similarly that $E[Forward_{it}*\varepsilon_{is}]\neq 0$ for $s\leq t$ but $E[Forward_{it}*\varepsilon_{is}]=0$ for all $s>t$.

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 the first two columns of Table 22.

Table 22 - Robustness Check: Dynamic Panel Data Model (System GMM)

Dependent variable in all specifications is lnTFP (t).

VARIABLE	Full Sample	Czech-Owned	Czech-Owned
lnTFP (t-1)	0.446***	0.366***	0.371***
	(0.075)	(0.096)	(0.103)
Backward (t-1)	0.704*	0.726†	0.753*
	(0.365)	(0.447)	(0.453)
Forward (t-1)	-0.378	-0.469	-0.372
	(0.400)	(0.429)	(0.346)
Real Export Ratio (t-1)			0.205
			(0.219)
Year dummies	YES	YES	YES
P-value of Hansen test of over-identifying restrictions	0.601	0.557	0.690
P-value of Arellano-Bond test for AR(2) in 1^{st} Δ	0.552	0.681	0.494
Number of Firms	103	67	67
No. of Obs.	603	373	361

Robust standard errors in parenthesis.
One-step system GMM results.
***, ** and * denote significance level at 1%, 5% and 10% respectively.
† P-value=0.105

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 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 indicate that the backward linkage has a significant effect on the firm's productivity. This provides further evidence in favor of productivity spillovers through backward linkages. Firms in the Czech Republic indeed improve their productivity by supplying to multinationals. There is no evidence for productivity spillovers through forward linkages.

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 omitted variable bias in my previous specifications.

6.2 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.[37] 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

[37] See e.g. Bernard and Jensen (1995), Tybout and Westbrook (1995), Clerides, Lach and Tybout (1998) and Blalock and Gertler (2004b)

location within the European Union. With information on the value of exports, I construct a measure for exporting experience, the Real Export Ratio.

I define the 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. These 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 as an additional control and estimate a model in the form:

$$(14) \quad \ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_4 \cdot RER_{it} + \alpha_t + \varepsilon_{it},$$

where RER stands for the Real Export Ratio.

I use a fixed effects estimator to control for any fixed firm-specific unobservable heterogeneity. Results are presented in Table 23 for the full sample and the subsample of the Czech-owned firms, columns 1 and 3, respectively. The Backward variable is still positive and significant at 1% in both specifications. The Real Export Ratio does not have a significant impact on total factor productivity.

To check whether my results from model (13) are robust to the omission of the export control, I estimate a model on the subsample of Czech-owned firms in the form:

$$(15) \quad \ln TFP_{it} = \alpha_1 \cdot \ln TFP_{i,t-1} + \alpha_2 \cdot Backward_{i,t-1} + \alpha_3 \cdot Forward_{i,t-1} + \alpha_4 \cdot RER_{i,t-1} + \alpha_t + \varepsilon_{it}.$$

I employ the system GMM estimator by Blundell and Bond (1998, 2000) again.

Table 23 - Robustness Check: Controlling for Export and Import Channels of Spillovers, Fixed Effects Estimator

Dependent variable in all specifications is a logarithm of total factor productivity, ln (TFP).

VARIABLE	Full Sample	Full Sample	Czech-Owned	Czech-Owned
Backward	0.700***	0.715***	0.888***	0.600***
	(0.206)	(0.249)	(0.259)	(0.259)
Forward	0.025	-0.138	0.076	-0.097
	(0.140)	(0.154)	(0.150)	(0.186)
Foreign Share	0.155	0.185		
	(0.131)	(0.146)		
Real Export Ratio	0.014	0.007	0.007	-0.243
	(0.103)	(0.120)	(0.215)	(0.241)
Material Import Ratio		0.148		0.914***
		(0.218)		(0.182)
Year Dummies	YES	YES	YES	YES
No. of Obs.	680	518	432	326
Within R-Squared	0.08	0.08	0.07	0.17

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

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 also assume that $E[Backward_{it}*\varepsilon_{is}]\neq 0$ 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 $s>t$ and $E[RER_{it}*\varepsilon_{is}]\neq 0$ for $s\leq t$ but $E[RER_{it}*\varepsilon_{is}]=0$ for all $s>t$. These two assumptions imply that for the first-difference equations, lagged levels dated t-2 and earlier of firm performance, linkages and the real export ratio can be used as instruments and for the levels equations, first-differences of firm performance, linkages and the 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 22, column 3. They confirm previous findings.

6.3 Import Channel of Productivity Spillovers

Another potential channel for productivity spillovers acknowledged in the literature is imports of intermediate inputs.[38] Embodied technology in intermediate goods might be a source for spillovers. Especially for Czech-owned firms, imported inputs might be important. With information about the value of imported material, I define a Material Import Ratio as the share of real imported material to real material consumption, defined as:

$$\text{Material Import Ratio} = \frac{\dfrac{\text{Imported Material}}{\text{Import Deflator}}}{\dfrac{\text{Imported Material}}{\text{Import Deflator}} + \dfrac{\text{Material Consumption-Imported Material}}{\text{Material Deflator}}}$$

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

[38] See e.g. Keller, W. (2004, p. 765).

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 use an overall import deflator.

I estimate a model of the form:

(16)

$$\ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot FS_{it} + \alpha_4 \cdot RER_{it} + \alpha_5 \cdot RIR_{it} + \alpha_t + \varepsilon_{it}$$

where RER stands for the Real Export Ratio and RIR for the Real Import Ratio. Results from the fixed effects estimation are presented in Table 23 in columns 2 and 4 for the full sample and for Czech-owned firms, respectively. The coefficients on the Backward variable are still positive and statistically significant at 1% level. Results suggest that imports of material may be important for productivity of Czech-owned firms.

Lastly, I re-estimate models (14) and (16) on the subsample of Czech-owned suppliers to multinational firms to mitigate the possible influence of self-selection. Results from the fixed effects estimator are presented in Table 24 and confirm previous findings: 1) Czech firms benefit from supplying to multinationals. 2) There is no evidence for spillovers through forward linkages.

6.4 Labor Mobility

Another potential source of spillovers from foreign direct investment is labor mobility.[39] Workers trained at multinational firms might acquire specific knowledge

[39] See e.g. Fosfuri, A., Motta M. and T. Ronde (2001).

about production technology and management. I do not have data about mobility of workers between firms. I have information about the background of CEOs. I know whether CEOs have worked at multinational firms before and, if so, if it was in a firm in the same industry. However, this information is time-invariant. Thus, whenever I use the fixed effects estimator, I also control for the past experience of CEOs.

Table 24 - Robustness Check: Restriction of Sample on Czech-Owned Suppliers to Multinationals with Controlling for Export and Import Channel

Dependent variable is a logarithm of total factor productivity, ln (TFP).

VARIABLE	Czech-Owned Suppliers to Multinational Firms	
	FE	FE
Backward	0.839***	0.808**
	(0.282)	(0.313)
Forward	-0.043	-0.167
	(0.203)	(0.242)
Real Export Ratio	0.453*	0.319
	(0.270)	(0.313)
Material Import Ratio		0.635*
		(0.352)
Year Dummies	YES	YES
No. of Obs.	277	211
Within R-Squared	0.09	0.13

Robust standard errors in parenthesis.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

6.5 Autocorrelation

When dealing with panel data in which observations are repeated along a time dimension, autocorrelation might be a concern. Therefore, in this section, I re-estimate the key specifications allowing for AR(1) shocks in disturbances.[40]

I consider models:

(17)

$$\ln Y_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot \ln M_{it} + \alpha_4 \cdot \ln E_{it} + \alpha_5 \cdot \ln U_{it} + \alpha_6 \cdot \ln S_{it} + \alpha_7 \cdot \ln K_t + \alpha_t + \alpha_i + \varepsilon_{it},$$

where $\varepsilon_{it} = \rho \cdot \varepsilon_{i,t-1} + u_{it}$.

(18) $\ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_t + \alpha_i + \varepsilon_{it}$,

where $\varepsilon_{it} = \rho \cdot \varepsilon_{i,t-1} + u_{it}$ and

(19) $\ln TFP_{it} = \alpha_1 \cdot Backward_{it} + \alpha_2 \cdot Forward_{it} + \alpha_3 \cdot RER_{it} + \alpha_4 \cdot RIR_{it} + \alpha_t + \alpha_i + \varepsilon_{it}$,

where $\varepsilon_{it} = \rho \cdot \varepsilon_{i,t-1} + u_{it}$.

I estimate models (17)-(19) on a subsample of Czech-owned firms that were suppliers to multinationals to simultaneously mitigate the self-selection issue apart from autocorrelation. Moreover, in specification (19) I control for both export and import channels of technological diffusion to avoid omitted variable bias. I use the fixed effects estimator or the random effects estimator, depending on the results of Hausman test, to control for fixed-firm specific heterogeneity. Results are presented in Table 25. They confirm previous findings.

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[40] Notice that the AR(1) coefficients reported in Table 25 are low in all three specifications. This suggests that the fixed effects estimates presented in chapter 5.3 should be more efficient than the first difference estimates that are presented in the same chapter.

Table 25 - Robustness Check: Autocorrelation, AR (1)

Dependent variable in the first column is ln (Output) and ln (TFP) in the second and third column.

VARIABLE	Czech-Owned Suppliers to Multinational Firms		
	FE	**RE**	**RE**
Backward	0.233*	0.750***	0.845***
	(0.127)	(0.222)	(0.269)
Forward	-0.032	0.03	-0.075
	(0.106)	(0.206)	(0.236)
Real Export Ratio			0.344*
			(0.207)
Real Import Ratio			0.421*
			(0.234)
ln (Material)	0.568***		
	(0.043)		
ln (Energy)	0.137***		
	(0.050)		
ln (Unskilled)	0.296***		
	(0.079)		
ln (Skilled)	0.054		
	(0.081)		
ln (Capital)	-0.037		
	(0.040)		
No. of Obs.	237	287	211
R-Squared	0.81	0.08	0.13
Year dummies	YES	YES	YES
Hausman test		9.95	7.04
Prob>chi^2		0.54	0.90
AR(1) coefficient	0.37	0.16	0.04

Standard errors in parenthesis. Within R-Squared reported.
***, ** and * denote significance level at 1%, 5% and 10% respectively.

7. Conclusions

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

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.

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 even other countries should provide incentive packages to attract foreign direct investors. Productivity spillovers are just one, though a very important, part of a complex cost-benefit analysis of the provision of incentive packages. I strongly believe that researchers studying productivity spillovers between firms should work with firm-level panel data sets that contain detailed information about actual relationships between firms instead of relying on industry-level measures. By constructing firm-level measures, my paper improves upon the current methodology.

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