Spillovers from Multinationals to Heterogeneous Domestic Firms: Evidence from Hungary

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Abstract

Firms cluster their economic activities to exploit technological and informational spillovers from other firms. Spillovers through the entry of multinational firms can be particularly beneficial to domestic firms because of their technological superiority. Yet, the importance of foreign firm’s spillovers might depend on two key features of domestic firms: their productivity level and its export status. In line with theories and empirical evidence on the absorptive capacity of firms, we argue on the basis of an empirical analysis of Hungarian firms that larger and more productive firms are more able to reap spillovers from multinationals firms than smaller firms. The export status, in contrast, is of minor importance.

Keywords: FDI, multinationals, productivity.

JEL classification: F23, F14, D21, R12, R30


1 Introduction

The large number of bilateral investment treaties between Central and Eastern European countries and OECD countries agreed on during the nineties as well as various investment support schemes carried out since the early nineties suggests that political actors in the participating countries view multinational firms as welfare increasing and growth enhancing. It is widely believed that multinational firms increase competition, transfer technology and help to achieve more efficient allocation of resources. A major argument in this line of reasoning is that inward Foreign Direct Investment (FDI) increases domestic firms’ productivity (and thus, enhances economic development) by creating linkages among domestic and foreign firms.

Domestic firms can benefit from the presence of multinationals in the same industry through horizontal spillovers that might for instance arise through the movement of workers within industries. In addition, there may be vertical spillovers from multinationals operating in other industries. This type of external effect is usually attributed to buyer-supplier linkages. There are two types of vertical spillovers: backward spillovers are generated through serving customers in downstream industries; forward spillovers are generated through sourcing from upstream industries.

Spillovers from foreign firms are measured through foreign firms’ effect on domestic firms’ total factor productivity (TFP). The TFP of a firm is the firm-specific component of the firm’s technology. A higher TFP of a firm is the result of several factors, such as better use of inputs, more sophisticated sales methods, superior internal organizational structure or simply more knowledge and information. When explaining TFP by spillovers, we make the assumption that the presence of foreign firms creates additional information and opportunities and thereby enhances this firm-specific component of domestic firms’ technology. In the literature several channels of positive spillovers have been identified, including labor mobility, supply chains, and face-to-face communication. Yet, while proximity to other producers, customers and suppliers can create a cost advantage or an increase in productivity for a domestic firm, it may also lead to increased competition and to the exit of domestic firms.¹

The empirical literature on FDI spillovers finds mixed support for the positive impact of multinational entry on domestic firms’ TFP (Görg & Greenaway 2004). A large part of literature investigates the extent of horizontal productivity spillovers. Damijan et al. (2003), for instance, use firm level data for

¹See Kosova (2006) for a study on the impact of FDI on exit of Czech firms
several transition countries, including Hungary, and find some evidence for positive spillovers only for Romania. For other countries, the spillover effect is either statistically insignificant or negative. Bosco (2001) analyzes the direct and spillover effects of foreign ownership on firms’ TFP in Hungary for the period 1992-1997. She finds that horizontal spillovers are either insignificant, or negative. According to Aitken & Harrison (1999) and Konings (2001), negative horizontal spillovers arise when multinational firms attract demand away from domestic firms. This lack of sizable horizontal spillovers from multinationals to domestic firms might be explained by the lack of absorptive capacity (i.e. the ability to assimilate and apply new knowledge) of the latter (Girma et al. 2001). Domestic firms may be unable to learn from multinational firms if the technological gap between the two groups is wide.

Javorcik (2004) extends the spillover approach to backward linkages. Using firm level panel data for Lithuania from 1996 to 2000, she finds evidence of backward linkages. There is, however, no robust evidence from her analysis that domestic firms benefit from horizontal spillovers from multinational firms. Blalock & Gertler (2005) find the same evidence using Indonesian plant-level data. Driffield et al. (2003) examine the relative importance of horizontal, backward and forward spillovers using an industry-level data for UK manufacturing during 1984 - 1992. They show evidence for positive spillovers through forward linkages. There are however no statistically significant effects from horizontal spillovers or from backward linkages.

In this paper, we examine the impact of multinational firms’ presence on local firm productivity and size. We assume that the presence of multinational firms generates spillovers which are more important when geographical distance between multinational and domestic firms is small D.B. (1998). For Hungarian firms, this stance is supported by Halpern & Murakőzy (2005) who found strong positive spillovers that operate only on small distances (i.e. broadly at the county level) for domestic-owned firms. At the national level, backward spillovers are found significantly positive suggesting that foreign customers make domestically owned firms more productive (Halpern & Murakőzy 2005).

Our aim with this paper is to show how firm level heterogeneity may affect the nature of spillover from the multinational firms to domestic ones. To do this, we run spillover regressions for various types of firms and compare coefficients. We consider two sorts of heterogeneity.

First, we analyze whether more productive and larger firms are able to reap more benefit from spillovers of multinational firms. Many studies find that the degree of technology gap is negatively associated with spillover absorption. For
example, Sabirianova et al. (2005) argues that greater technology gap allows
for swifter convergence. Similarly, Sjöholm (1999) finds that FDI spillovers
are greater in sectors with a high-technology gap in Indonesia. However, the
sign may be the other way around, as suggested by the experience of UK
establishments, where spillover strength rises in productivity (Girma & Görg
2005). There is also a possibility for hump-shape pattern of the impact, as large
gap implies more room for improvement, but also a possibly low capacity to
carry out developments.

Our emphasis is on absorptive capacity, a set of organizational routines and
processes by which firms acquire, assimilate, transform, and exploit knowledge
to produce a dynamic organizational capability. (Zahra & George 2002, p.186.)
or in other words, firms ability to recognize valuable new knowledge, integrate
it into the firm and use it productively (Cohen & Levinthal 1990). We argue
that identification, acquisition and exploitation may all depend on the firms
development, i.e. its level of productivity.

Second, spillovers effect might also differ with respect to the export status of
the domestic firm. Exporters’ experience in export markets might explain why
they deal better with the spillovers of foreign multinational firms (Bernard
& Jensen 1999). However, it might also be that the foreign multinationals’
spillovers at home are less important to exporters, because they also learn
from firms in the foreign market.

We use a large and extensive data set on Hungarian manufacturing firms. The
data set crucially entails information on domestic and export sales as well as
ownership. Further, we have information on employment, capital and other
firm-level characteristics that enable us to compute the TFP of each domestic
firm. We work with an unbalanced panel of manufacturing firms for the period

Our empirical analysis makes use of three variables which have to be con-
structed in a first step. (i), we compute the TFP of domestic firms using the
semi-parametric Olley & Pakes (1996) methodology. (ii), we construct the hor-
izontal and vertical spillovers variables following Javorcik (2004). We depart
from her analysis by taking the extreme view that spillovers from multina-
tionals can only be reaped by domestic firms located in the same county. (iii),
we quantify the net effects of spillovers by controlling for the degree of com-
petition. Therefore, we construct a Herfindahl index at sectoral and county
level.

We then estimate the effect of multinationals’ spillovers on the average do-
mestic firm’s TFP using a firm fixed-effects panel model. The firm specific
effects allow the control of the firm’s technology and the isolation of the sec-
toral spillovers effects. Finally, we are interested in the difference in the effect
of spillovers on firms that differ in productivity. We therefore estimate simul-
taneous quantile regressions.

The remainder of this paper is structured as follow. In Section 2, we provide
information on the Hungarian dataset and the descriptive statistics. In Section
3, we present the estimation strategy. In Section 4, we discuss our results. We
conclude in Section 5.

2 Descriptive Statistics

In this section we present the data and analyze Hungarian firms’ productivity.
Our analysis is limited to manufacturing firms that meet the data require-
ments that will be described in the first subsection. In the second subsection,
we discuss the distribution of Hungarian firms with respect to size and pro-
ductivity. As documented for other economies as well, exporters are larger and
more productive than domestic firms over the whole size distribution. Foreign
multinational firms are larger and more productive than exporters. Hence, it
is possible that Hungarian firms (non-exporter and exporter) learn from more
productive foreign multinational firms. In the third subsection, we therefore
have a first look at our main interest: the relationship of productivity and the
number of foreign multinational firms active in a particular Hungarian county.

2.1 Data

We use a Hungarian corporate dataset, which is based on annual balance
sheet data submitted to APEH, the Hungarian Tax Authority\textsuperscript{2}. The dataset
contains information on all registered, double entry book-keeping firms. The
data include the information of a firm’s balance sheet and income statement.
It entails information on sales, employment, total assets, labor costs, and eq-
uity ownership. It also includes information on each firm’s sector classification
(NACE rev-1, two-digit level) and on the location of the firm’s headquarter.

In Hungary, economic transition has lead to the entry of new domestic and for-

\textsuperscript{2}See details in the Appendix
eign firms. The number of firms has risen substantially from 55,213 in 1992 to 226,072 in 2003. The sample used in this study is less comprehensive than the original APEH data for two reasons. First, we concentrate on manufacturing firms. Second, very small firm data are unreliable and no complete information exists on employment and fixed assets, which are required to compute the TFP variable. As a result, this sample contains 108,541 observations over 12 years, rising from 6,003 firms in 1992 to 11,208 in 2003. The dataset covers 42% of the total number of manufacturing firms and 73% of total turnover. We use the subsample of domestically-owned firms. It includes 66,470 observations from 11,767 firms for the period from 1993 to 2002.

In table (1), summary statistics for all domestically-owned firms in our sample are presented.

Table 1  
*Summary statistics of variables.* Domestically-owned firms only

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed assets (log)</td>
<td>8.324</td>
<td>1.967</td>
</tr>
<tr>
<td>Sales (log)</td>
<td>10.78</td>
<td>1.547</td>
</tr>
<tr>
<td>Materials (log)</td>
<td>9.468</td>
<td>1.579</td>
</tr>
<tr>
<td>Employment (log)</td>
<td>2.848</td>
<td>1.242</td>
</tr>
<tr>
<td>Domestic Sales (log)</td>
<td>10.80</td>
<td>1.562</td>
</tr>
<tr>
<td>Export Sales (log)</td>
<td>9.660</td>
<td>2.357</td>
</tr>
<tr>
<td>Export share</td>
<td>0.114</td>
<td>0.249</td>
</tr>
<tr>
<td>Exporter status (dum)</td>
<td>0.253</td>
<td>0.435</td>
</tr>
<tr>
<td>Horizontal Linkage</td>
<td>0.330</td>
<td>0.224</td>
</tr>
<tr>
<td>Backward Linkage</td>
<td>0.145</td>
<td>0.088</td>
</tr>
<tr>
<td>Forward Linkage</td>
<td>0.260</td>
<td>0.242</td>
</tr>
<tr>
<td>R&amp;D Linkage</td>
<td>0.119</td>
<td>0.117</td>
</tr>
<tr>
<td>Wholesale linkage</td>
<td>0.262</td>
<td>0.192</td>
</tr>
<tr>
<td>Herfindahl index</td>
<td>0.137</td>
<td>0.152</td>
</tr>
<tr>
<td>Private share</td>
<td>0.974</td>
<td>0.149</td>
</tr>
<tr>
<td>TFP (log)</td>
<td>1.815</td>
<td>0.598</td>
</tr>
</tbody>
</table>

2.2 *Total Factor Productivity, Domestic and International Activities*

The data at hand allows discrimination between firms according to their export status and their foreign ownership. We differentiate between four types of firms in the APEH database: domestic non-exporting firms (hence domestic firms), domestic exporters, foreign-owned non-exporting firms and foreign-owned exporters. We use the foreign ownership information to compute our horizontal and vertical spillover variables (see section 3.1) and focus on the
impact of multinationals’ spillovers on the productivity and size of domestic firms. We define an exporter as a firm that exports at least 5% of its total sales and a foreign owned firm as a firm with at least 10% foreign stake.

In 2002, the sample includes 8,650 domestically owned and 2,112 foreign owned firms. Exporters account for 27% of domestically owned firms and 74.0% of foreign owned firms. The foreign presence in Hungarian manufacturing is rather important, as domestic firms with foreign capital are responsible for 76.6% of total sales in our sample (total sales of foreign firms reached about 28.6 billion euros compared with about 8.7 billion euros by domestically owned ones).

Total factor productivity (TFP) of firms is proxied by an estimated firm-level Solow residual. We use the Olley & Pakes (1996) (OP) semiparametric method to estimate firm-level TFP, a method that takes into account the endogeneity of some inputs, the exit of firms as well as the unobserved permanent differences among firms. We consider the following Cobb-Douglas production function

\[ y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it} \]  

and denote the logarithm of output (total sales), fixed asset capital, labor (employment) and intermediate inputs (materials) with \( y_{it}, k_{it}, l_{it}, m_{it} \), respectively. Subscripts \( i \) and \( t \) stand for firm and time, \( \omega_{it} \) denotes productivity, and \( \epsilon_{it} \) stands for measurement error in output. For details, see the Appendix.

Figure (1) shows that the distribution of Hungarian firms’ TFP is right skewed. It is, however, not too far from log-normal. We have a closer look at the heterogeneity of Hungarian firms using the results of Table (2). We split the distribution of the logarithm of TFP in five intervals and report information on the corresponding number of domestic firms, export status and sales.

Table (2) shows two interesting facts. First, the most productive firms are not necessarily the largest with respect to sales. As for both the fifth ([2,3]) and the forth ([3,6.3]) intervals, the share of the interval sales in total sales is below their shares in total number of firms. We expect sector differences behind this finding. Second, export participation increases with productivity. The share of exporters in total firms in the interval increases from 26.2% in the first interval to 41.2% in the fifth. The increase is even more impressive if export activities are measured in export sales instead of number of exporters. Both measures suggest that exporters are more productive than non-exporting domestic firms. The qualitative results of Table (2) are robust to change in
Fig. 1. Distribution of Hungarian firms’ TFP

<table>
<thead>
<tr>
<th>( \ln TFP_{it} ) interval</th>
<th>Number of firms</th>
<th>Number of exporters</th>
<th>Total Sales</th>
<th>Export Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>([-8.2, 0])</td>
<td>61</td>
<td>16</td>
<td>4.E+06</td>
<td>6.45E+05</td>
</tr>
<tr>
<td></td>
<td>(0.69)</td>
<td>(26.2)</td>
<td>(0.05)</td>
<td>(16.1)</td>
</tr>
<tr>
<td>([0, 1])</td>
<td>395</td>
<td>107</td>
<td>2.E+08</td>
<td>7.51E+07</td>
</tr>
<tr>
<td></td>
<td>(4.46)</td>
<td>(27.1)</td>
<td>(2.36)</td>
<td>(37.5)</td>
</tr>
<tr>
<td>([1, 2])</td>
<td>5249</td>
<td>1738</td>
<td>5.E+09</td>
<td>3.07E+09</td>
</tr>
<tr>
<td></td>
<td>(59.26)</td>
<td>(33.1)</td>
<td>(64.14)</td>
<td>(61.4)</td>
</tr>
<tr>
<td>([2, 3])</td>
<td>2995</td>
<td>1232</td>
<td>3.E+09</td>
<td>1.99E+09</td>
</tr>
<tr>
<td></td>
<td>(33.82)</td>
<td>(41.1)</td>
<td>(32.49)</td>
<td>(66.3)</td>
</tr>
<tr>
<td>([3, 6.3])</td>
<td>157</td>
<td>65</td>
<td>8.E+07</td>
<td>5.90E+07</td>
</tr>
<tr>
<td></td>
<td>(1.77)</td>
<td>(41.4)</td>
<td>(0.95)</td>
<td>(73.8)</td>
</tr>
</tbody>
</table>

Source: APEH, authors’ computation. Sales figures in HUF million.

In Figure (2), we show the cumulative distribution of TFP and sales of Hungarian firms according to their export status. Panel (a) of Figure (2) points to first-order stochastic dominance of exporters with respect to sales. Exporters
are selling more than domestic firms over the whole distribution. The first-order stochastic dominance of exporters with respect to TFP is, however, not obvious from Panel (b) of Figure (2).

**Fig. 2. Cumulative Distribution of:**

(a) Sales  
(b) Total Factor Productivity

Source: APEH, authors’ computation.

We use the non-parametric Kolmogorov-Smirnov test (KS-test) to determine whether the sales and TFP distributions between the two groups differ significantly. The KS-test calculates the largest difference between the observed and expected cumulative frequencies, which is called D-statistics. These statistics are compared against the critical D-statistic for the sample size. The results of the two-sided KS-test are shown in Table (3).

**Table 3**  
**KS-Test of Differences between Exporters and Domestic firms, Sales and TFP, 2000**

<table>
<thead>
<tr>
<th>Group</th>
<th>Largest Difference</th>
<th>P-value</th>
<th>Corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H_0: \text{Exp} - \text{Dom} \leq 0)</td>
<td>0.3034</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>(H_0: \text{Dom} - \text{Exp} \leq 0)</td>
<td>-0.0005</td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td>Combined K-S</td>
<td>0.3034</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Concerning the sales distribution, the largest difference between the distribution functions is 0.3034, which is statistically significant at 1%. Thus, the
null hypothesis that both sales distributions are equal is rejected. From the left hand-side of the KS-test we can reject the hypothesis that domestic firms are larger than exporters with respect to their sales. The largest difference between the distributions functions is 0.3034, which is statistically significant at 1% level of significance. From the right hand-side of the KS-test, we accept the hypothesis that exporters are larger than domestic firms. The largest difference between the distributions functions is -0.0005, which is not significant. Therefore, we cannot reject the stochastic dominance of exporters’ sales distribution over domestic firms’ sales distribution. However, we can reject the stochastic dominance of domestic firms’ sales distribution over exporters’ sales distribution.

We find qualitatively similar results using the TFP distributions. Exporters’ TFP cumulative distribution with respect to TFP dominates stochastically domestic firms’ TFP cumulative distribution.

As result, the KS-test of stochastic dominance suggests that exporters are more productive than domestic firms and larger in size$^3$.

2.3 TFP and Spillovers

Having documented that exporters are more productive than domestic firms, we now turn to the most productive firms in Hungary: foreign multinational firms.

Some transition countries, and Hungary in particular, offer a laboratory environment for studying spillover effects as the presence of foreign firms is rather overwhelming. This is true, even if transition started before our sample period of 1992-2003, and foreign firms entered the market as early as the 1989 via joint ventures and greenfield investment. This is how the foreign share in manufacturing sales reached as much as 30% in 1992.

There is substantial sectoral as well as regional disparity in terms of foreign presence. While in Vas, a Western county, foreign firms were responsible for two-third of sales in 1992, this share was just over 10% in Hajdu-Bihar county, in the South-East of the country. In 2002, almost 90% of manufacturing production was carried out by non-domestic firms, and the lowest share of multinationals in a county rose to half this value (42%-48% in Bekes, Bacs-Kiskun, Veszprem). The picture is similarly diverse in terms of industries. In the production of motor vehicles, non-domestically owned firms were responsible for $^3$Note that the KS-test results are qualitatively similar for each year of the sample.
over 98% (*sic!*) of output in 2002 compared with just over 17% in press and 57% in raw materials and over 65% in machinery and equipment.

We are interested to see whether Hungarian firms (non-exporters and exporters) can learn from foreign multinational firms or use their proximity in another way to increase their productivity. We therefore first look at the productivity gap. A productivity gap is the first necessary condition for positive spillovers. Then we look at multinationals’ geographic location relative to Hungarian firms. Geographic proximity is the other necessary condition for spillovers.

Fig. 3. **Regional distribution of foreign owned firms**

Source: APEH, authors’ computation, share in percent.

We use again the KS-test to determine whether the sales and TFP distributions of foreign owned and domestically owned firms differ significantly. We present the comparison of foreign owned firms and the group of Hungarian exporters, which are more productive than Hungarian non-exporters. The results of the two-sided KS-test are shown in Table (4). The KS-test reveals that the size of the distribution of foreign multinational firms stochastically dominates those of Hungarian exporters. Thus, the first necessary condition
for positive spillovers is met.

Table 4
KS-Test of Differences between foreign multinational firms and Hungarian Exporters. TFP, 2000

<table>
<thead>
<tr>
<th>Group</th>
<th>Largest Difference</th>
<th>P-value</th>
<th>Corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0: MNE - Exp \leq 0$</td>
<td>0.0474</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>$H_0: Exp - MNE \leq 0$</td>
<td>-0.0111</td>
<td>0.809</td>
<td></td>
</tr>
<tr>
<td>Combined K-S</td>
<td>0.0474</td>
<td>0.041</td>
<td>0.037</td>
</tr>
</tbody>
</table>

Concerning the second necessary condition, we look at the regional distribution of foreign owned firms. Figure (3) shows that Western counties have a higher share of foreign firms, while the Eastern and South-Eastern counties have a rather low share of foreign owned firms.

Next, we look at the relationship of the share of multinational firms in total firms in a particular county and the TFP of Hungarian firms in that county. We regress the logarithm of firm level TFP of domestic firms on the share of multinational firms in sector $j$ of county $l$, $N_{jlt}$.

$$TFP_{it} = 0.0692^{***}N_{jlt} + \nu_j + \nu_l + \nu_t$$  \hspace{1cm} (2)

From this very crude first inspection, we find a positive correlation between a higher share of multinational firms and firm-level TFP. The share of multinational firms and the fixed effect explains 49.67% of the TFP’s cross variation.

3 Empirical Analysis

In this section, we describe measurement of productivity, detail the spillover variables and give an account of our estimation strategy.

3.1 Horizontal and Vertical Spillovers

The total factor productivity of a firm reflects its own technology. Apart from its own technology, the productivity of a firm might also be affected by sectoral linkages and local competition. In this study, we examine the effect of horizontal spillovers, of backward and forward linkages and of local and sectoral competition on firm-specific productivity. Thereby, we describe the logarithm
of the TFP of a domestic firm $i$, in sector $j$ located in a county $l$ at time $t$, $TFP_{ijlt}$, as follows

$$
TFP_{ijlt} = \alpha H_{jlt} + \beta_1 B_{jlt} + \beta_2 F_{jlt} + \gamma C_{jlt} + \chi Psh_{it} + \nu_i + \nu_j + \nu_t \quad (3)
$$

$TFP_{ijlt}$ has been computed using the semi-parametric estimation suggested by Olley & Pakes (1996). The methodology is developed in Appendix A. It allows to take into account the endogeneity of the inputs in the production function. The endogeneity issue arises because inputs are chosen by a firm based on its productivity. $H_{jlt}, B_{klt}, F_{klt}$ and $C_{jlt}$ represent local Horizontal spillovers, local Backward and Forward linkages and local and sectoral Competition, respectively.  

We focus on spillovers and competition within a specific county and assume that they arise from the presence of multinational firms in the same county. The variable $Psh_{it}$ stands for the Privatization share at firm-level (that may change year by year). Since we want to quantify the impact of spillovers at sectoral level on firm-specific total factor productivity, we control for the technology of the firm by introducing firm-specific effects, $\nu_i$. Since the firm specific TFP might also be driven by unobserved sectoral specific shocks, we include a set of sector dummy variables, $\nu_j$. We also assume that firm-specific TFP is affected by macroeconomic shocks and include a set of time dummy variables $\nu_t$ to control for it. In addition, the time dummy variables control for the average change of productivity that is not due to the spillovers.

Horizontal spillovers occur when entry or presence of multinational firms lead to an increase in productivity of domestic firms active in the same industry. This results, for instance, in intra-sectoral movement of workers who take some industry-specific knowledge with them. As in Javorcik (2004), we assume that horizontal spillovers increase with the foreign presence in sector $j$ at time $t$. We assume, however, that horizontal spillovers are county-specific. We proxy the potential for spillovers by the share of multinational firms in total activities. For each county $l$, $H_{jlt}$ is defined as foreign equity participation averaged over all firms in the sector, weighted by each firm’s share in sectoral output. We proxy horizontal spillovers by $H_{jlt}$ defined as

$$
H_{jlt} = \left[ \sum_{i \in j,l} \text{share}_{it} \times Y_{it} \right] / \sum_{i \in j,l} Y_{it} \quad (4)
$$

where $\text{share}_{it}$ is the share of firm’s total equity that is foreign owned. $Y_{it}$ is

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4 Competition as an influential force on productivity was used e.g. in Nickell (1996).
the output of firm $i$ at time $t$.

Vertical spillovers occur when multinational firms’ presence in backward or forward industries increases the efficiency of a firm through vertical input-output linkages with suppliers and customers. We calculate the backward linkage with multinational firms (i.e. domestic firms supplying to foreign firms) as

$$B_{jlt} = \sum_{k \neq j,l} \theta_{jk} H_{klt} \quad (5)$$

where $\theta_{jk}$ is the proportion of industry $j$’s output shipped to sector $k$. This information is taken from the 1998 input-output table at the two-digit NACE level. All results to follow are robust to the use of revised 2000 version. As in Javorcik (2004), the output delivered within the sector is excluded in the computation since this effect is already captured by the horizontal spillovers variable. In other words, the diagonal of the input-output matrix is ignored. By this assumption we acknowledge that the horizontal linkage variable will refer to several sorts of interactions - including the trade otherwise captured by vertical spillover variables. (Of course, a finer sectoral classification would improve upon the problem.)

The forward linkage (i.e. domestic firms purchase goods from foreign firms) is defined as the weighted foreign share in output in the supplying industries.

$$F_{jlt} = \sum_{m \neq j,l} \theta_{mj} H_{mlt} \quad (6)$$

$\theta_{jm}$ is the share of inputs purchased by industry $j$ from industry $m$ in total inputs purchased by industry $j$. We again exclude the input purchased within the sector because these linkages are captured by the horizontal spillovers variable.

We approximate a potential competition effect by the Herfindahl index. We calculate the Herfindahl indices for all year, sector and county combinations and denote it $C_{jlt}$. We expect competition to exert a positive effect on TFP. The mode of ownership might also influence the TFP of domestic firms. According to Brown et al. (2006), privately owned firms are more efficient than state-owned firm. We therefore control for the mode of ownership at firm level by including the privatization share.
3.2 Estimation Strategy

The heterogeneity in the firm-level data is large. This suggests that we must take it explicitly into account when studying the effects of multinational spillovers on domestic firms. We deal with this large heterogeneity in our empirical analysis in two ways. First, we look at the average impact of spillovers and competition on domestic firms. Therefore, we use a firm fixed-effects panel model. While firm heterogeneity is collected in the firm fixed effects, coefficients of $H_{jlt}$, $B_{jlt}$, $F_{jlt}$ and $C_{jlt}$ give the average effects of spillovers and competition. Thus, we first ignore differences in the effect of spillovers and competition among firms. Second, we allow spillovers and competition effects to differ between well defined groups of firms but not among firms within each group. We do this by estimating a simultaneous quantile regression model. Unlike the least squares estimator that assumes covariates shifting the location of the conditional distribution only, quantile regression allows us to analyze the possible effects on the shape of the TFP distribution.

In the fixed-effects specification, heteroscedasticity and serial correlation are always potential problems. The bias is larger the longer the time horizon. Since we have short time-series and a large cross-section, it is appropriate to use cluster-sample methods (Wooldridge 2003) to estimate the fixed-effects model. Cluster-sample methods are a generalization of White’s (White 1980) robust covariance matrices Arellano (1987). The obtained robust variance matrix estimator is valid in the presence of heteroscedasticity and serial correlation provided that, as in our case, $T$ is small compared to the number of groups (Wooldridge 2002, 2003). The fixed effects panel estimation allow to control for the unobserved domestic firm heterogeneity in the sample. Since our endogenous variable is an estimate itself, we bootstrap the standard errors in a robustness check. This does not alter the significance of the estimated coefficients.

As we have shown in Section 2.2, exporting firms are more productive than non-exporters. That might on the one hand decrease the potential for learning from foreign multinational firms, because more productive firms are already closer to the most efficient technology. On the other hand, learning might be easier because the absorptive capacity of more productive firms is larger. Hence, exporters might be affected differently by foreign multinational firms’ spillovers than non-exporting domestic firms. Moreover, there is a second dimension why exporters might reap spillovers to a larger degree: their international experience. Being used to interactions with partners in foreign
countries might also ease interaction with foreign multinational firms at home. We therefore test whether spillovers have a different effect on exporters than on non-exporting domestic firms.

The simultaneous quantile regression methodology allows a closer look at the impact of the spillovers on the productivity of domestic firms. We split the firms into twenty groups sorting them with respect to their productivity. We assume firms in each group are affected identically by spillovers and by competition. The bootstrapped variance-covariance matrix takes into account the errors correlation between the different quantiles and allows us to compare coefficients of the explanatory variables in the different quantiles (Koenker & Hallock 2001). Hence, we test whether spillovers and competition have different impact in different groups. We estimate a simultaneous quantile regression model, which is specified as

\[ \text{Quant}_\Theta (\text{TFP}_{ijlt}|X_{ijlt}) = X'_{ijlt}\beta_{ijlt} \]  

where \( X_{ijlt} \) is the vector of independent variables specified in equation (3) and \( \text{Quant}_\Theta (\text{TFP}_{ijlt}|X_{it}) \) the conditional quantile of TFP. The distribution of the error term \( \nu_{ijlt} \) is left unspecified so the estimation method is essentially semiparametric. Koenker & Bassett (1978), introducing this technique, show that \( \beta_{ijlt} \) can be estimated by

\[ \min_{\beta} \left\{ \sum_{ijlt: TFP \geq X'_{ijlt}} \Theta|TFP_{ijlt} - X'_{ijlt}| + \sum_{ijlt: TFP < X'_{ijlt}} (1 - \Theta)|TFP_{ijlt} - X'_{ijlt}| \right\} \] 

The main advantage of the quantile regression approach is that it allows different slope coefficients for different quantiles of the conditional distribution of the TFP variable to be estimated. Since \( \Theta \) varies from 0 to 1, we trace the entire distribution of TFP conditional on the set of independent variables. As emphasized in Girma et al. (2004), quantile regressions provide a robust alternative to OLS when as in our case the error terms are non-normal. The tests of normality of the TFP distribution, as well as a skewness and kurtosis test, reject the log-normal distribution of TFP. Tests of normality reject a log-normal distribution of establishment-level TFP for any given year and for all domestic-owned firms.\(^5\)

\(^5\)The Shapiro and Francia (Shapiro & Francia 1972) test, designed for a smaller sample size, yields a p-value of 0.000 to 0.013 for any given year and a p-value of 0.000 for all but two sectors, while the skewness and kurtosis test of D’Agostino et al. (1990) for the whole sample gave a p-value of 0.000.
4 Results

Discussion of the estimation strategy is now followed by a presentation of main results attained by both fixed effect panel and quantile regressions.

4.1 Average Impact of Spillovers on Domestic Productivity

First, we estimate the average impact of the spillover variables on the domestic firm using a firm fixed effects panel model. Since a firm does not change its sector and its county over time, the firm fixed-effects are perfectly collinear with the sector and county fixed-effects. We thus estimate equation (3) without introducing sector and county fixed-effects. The results are presented in Table (5). In the first specification (S1), we show the results of the average spillovers and the competition effect on domestic firms and exporters. In the second specification (S2), the relative average impact of spillovers on TFP with respect to the exporting status of the firm is analyzed. We separate the effect of spillovers from multinational firms on exporters and non-exporting domestic firms by additionally including an interaction term between the spillovers variables and an exporter dummy variable, Exp, and an interaction term between the spillovers variables and a non-exporter dummy variable, Dom.

Specification (S1) of Table (5) shows that the average impact of horizontal spillovers is positive and significant. Therefore, the potential technology transfer from multinationals to domestic firms in the same sector overwhelms the competition effect that arises from the multinational presence. The average impact of forward spillovers is positive but remains statistically insignificant. The coefficient of the backward spillovers variable is very close to zero and insignificant. Both the significant positive effect of horizontal spillovers and the insignificant effect of vertical spillovers differ from Javorcik’s results on Lithuanian firms. Turning to the average impact of competition on total factor productivity, we find that a higher Herfindahl index reduces the productivity of domestic firms. Thus, as expected, more competition yields more productive firms. Moreover, as found in Brown et al. (2006), the firm-level privatization share has a positive and significant impact on TFP.

The coefficients of the Herfindahl index and the privatization share variables are robust to the inclusion of the interaction term between the spillover variables and the export status dummy variables (specification (S2) of Table (5)). We do not find any statistically significant impact of horizontal spillovers from
multinational firms to exporters, while the coefficient of the interaction term between the horizontal spillovers variable and the domestic firms is statistically significant. For backward linkages, the average impact is positive and statistically significant for the exporters only. Thus, while the results for Hungarian exporters are similar to Javorcik’s findings. The results for non-exporters, in contrast, differ.
4.2 Impact of Spillovers on Heterogenous Domestic Firms

The results of the fixed effects estimation suggest that no vertical spillovers exist from multinational firms to domestic firms. A close look at domestic firm-level heterogeneity might reveal that spillovers from multinationals affect different firms differently depending on their productivity.

We split the distribution of the logarithm of TFP in twenty quantiles and estimate a simultaneous quantile regression. We assume therefore that spillovers and competition effects differ between groups of firms but not within each group. The estimation results are presented in Figure (4). In each subfigure, we present the estimated coefficient of each variable on the vertical axis and the corresponding quantile of $\ln TFP_{ijlt}$ on the horizontal axis. The first quantile of the distribution contains information on the least productive firms, while the last quantile contains information on the most productive firms.

Fig. 4. Simultaneous Quantile Regression: Dependent Variable $\ln TFP_{ijlt}$

Estimated coefficient on the vertical axis. Quantile of $\ln TFP_{ijlt}$ on the horizontal axis. Source: APEH, authors’ computation.

The results show that horizontal spillovers have a negative impact on the least productive firm. This impact is, however, positive and significant for the most productive firm. Moreover, the impact is larger, the more productive is the domestic firm. There is no straightforward explanation, but we suspect
there may be two possible reasons for this finding. First, the negative effect on the least productive firm stems from their low level of absorptive capacity. Second, competition from multinational firms, which leads to exit of the least productive firms, stimulate innovation among domestic firms that have high level of productivity (Aghion et al. 2005). Hence, we argue that the larger the productivity gap between the domestic and foreign firms, the less likely is the domestic firms to gain from foreign multinational firms in its own sector.

We find a negative impact of backward spillovers on the least productive firm, whereas this impact is positive and significant for the more productive firms. The positive impact of backward linkages is increasing with the productivity of the domestic firm. Multinational firms might have a higher incentive to transfer knowledge to more productive firms in their downstream sectors in order to obtain higher sales through higher quality or less expensive goods. Moreover, the increase in foreign presence in the upstream sectors redirects intermediate inputs supply to the downstream sectors away from least productive firms toward more productive firms in the downstream sector. This explains the negative coefficient of backward spillovers on the TFP of least productive firms. The increasing horizontal and backward spillovers with domestic firms’ productivity is in line with Girma et al. (2004) findings on UK establishment.

Contrary to Javorcik (2004), we find a positive although small impact of forward spillovers on the productivity of domestic firms. The effect is larger for the least productive firms and insignificant for the most productive firms. The positive effect might stem from a higher quality of inputs purchased from multinational firms.

Turning to the Herfindahl index, it has a positive but insignificant impact on the least productive firms and a negative impact on TFP of more productive firms. Finally, the data suggest a positive correlation between the privatization share and the level of productivity of domestic firms. The impact of privatization is larger the less productive the domestic firm.

Similarly to the location choice problem, it can be argued that spillovers take time to exercise impact. For example, an extension of output by foreign firms may lead to increased interaction with domestic firms at time $t$, but it is only in time $t+1$ when this relationship bears fruit. Thus, we ran our basic regression with all spillover variables lagged by one year. Results are hardly different. As for the heterogeneity of impact, the ”slope” of the backward spillover variable seems slightly stronger now.
As a robustness check, we split the distribution of the logarithm of TFP in 10 deciles and run fixed effect panel regressions for each decile. Basic results (presented in Figure (6) with a production function and firm-level fixed effects confirm that more productive firms reap greater benefit from backward and to a less extent horizontal spillovers than less productive firms. However, when the OP and firm fixed effects is introduced the image becomes rather blurred.

4.3 Impact of Spillovers on Exporters and Non-exporters

We separate the effect of spillovers from multinational firms on exporters and non-exporting domestic firms by additionally including an interaction term between the spillovers variables and an exporter dummy variable and an interaction term between the spillovers variables and non-exporter dummy variable.

The results are reported in Figure (8). The upper panel of Figure (8) show that the coefficients of spillovers from multinational firms to all domestic firms
Fig. 6. **Fixed effect panel regression by deciles**: Dependent Variable $lnTFP_{ijlt}$

Estimated coefficient on the vertical axis. Quantile of $lnTFP_{ijlt}$ on the horizontal axis. Source: APEH, authors’ computation.

are mainly driven by spillovers to non-exporting firms. Figure (4) and the upper panel of Figure (8) are very similar. The middle panel shows the coefficients of the spillovers effect on exporters. The bottom panel shows the coefficients of Herfindahl index and of the privatization share variables.

We can statistically distinguish the impact of spillovers from multinational firms by the export status of domestic firms for some quantiles. Most non-exporting Hungarian firms receive horizontal spillovers from multinational firms. The effect of spillovers on TFP increases in productivity.

As for backward linkages, non-exporters gain from positive spillovers if their productivity places them at least in the third decile. The exporters pattern has a slight hump shape, but significant gain from productivity takes place in the upper third of the distribution only. Forward spillovers are very similar for the two categories, slightly positive or zero, for both groups.

The productivity advantage of exporters which we reported in Section 2 therefore does not result from higher spillovers that exporters as such receive from multinational firms relative to non-exporters.

In line with the results from the fixed effects regression, the quantile regres-
Fig. 7. **Simultaneous Quantile Regression**: Dependent Variable $lnTFP_{ijlt}$

Estimated coefficient on the vertical axis. Quantile of $lnTFP_{ijlt}$ on the horizontal axis. Source: APEH, authors’ computation.

Estimations revealed no larger spillovers for exporters than for non-exporting domestic firms. Hence, larger spillovers from multinational firms are not part of the explanation why exporters have higher total factor productivity. Thus, while exporters might receive additional spillovers in the foreign market which increases their TFP, we did not find support for higher spillovers received by exporters at home.

There are three explanations for these findings. First and probably most important, the higher TFP of exporting firms relative to non-exporters is explained by the fact that more productive firms self-select into exporting (as in Melitz 2004) Thus, exporting status *per se* gives no reason for a difference in impact. Second, exporters might receive additional spillovers in the foreign market which increase their TFP. Third, exporters might learn from foreign owned firms active in the Hungarian wholesale sector because they share a common "trade technology".

For the first two points have been examined in literature, we now test the validity of the third assertion by looking at the impact of the share of foreign-owned firms in the Hungarian wholesale sector. Therefore, we construct a
wholesale spillover variable, $W_{jlt}$, that is the share of foreign ownership among firms that operate in the wholesale sector and are exporters:

$$W_{jlt} = \left[ \frac{\sum_{i \in j, \text{exp}=1, l} \text{share}_{it} \ast Y_{it}}{\sum_{i \in j, \text{exp}=1, l} Y_{it}} \right]$$

Fig. 8. **Simultaneous Quantile Regression**: Dependent Variable $lnTFP_{ijlt}$

Estimated coefficient on the vertical axis. Quantile of $lnTFP_{ijlt}$ on the horizontal axis. Source: APEH, authors’ computation.

We find a strong negative impact of foreign-owned importers on the least productive domestic firms whereas this impact is positive and significant for most exporters. While domestic firms might suffer from import competition, exporters might benefit from foreign-owned importers’ trade knowledge.
5 Conclusions

We examined the impact of the presence of foreign multinational firms in local Hungarian markets on Hungarian firms’ productivity. We searched for horizontal spillovers from multinational firms in the same sector, backward spillovers from multinationals that are customers of Hungarian firms and forward spillovers from multinationals that are input suppliers. We used a sample of 11,767 Hungarian firms and their activities between 1993 and 2002. For this sample, we found significant horizontal spillovers in a firm level fixed effect regression but no evidence of backward and forward spillovers.

Yet, the spillover effects are average effects over all firms which might not be very informative if Hungarian firms are very heterogeneous and this heterogeneity affects the size of the spillovers. We documented great heterogeneity among Hungarian firms with respect to their productivity and size and analyze whether more productive and larger firms are able to reap more benefit from spillovers of multinational firms than less productive smaller firms. We used simultaneous quantile regression to analyze group specific effects with groups defined with respect to productivity. We found significant differences among the groups with more productive firms receiving more horizontal and backward spillovers from foreign multinational firms but less forward spillovers than less productive firms.

There is a second obvious characteristic in which firms differ: their export status. Export status is not independent of productivity since only more productive firms generate profits in the export market. We expected export status to have an effect for two reasons. First, as argued above, exporters are more productive. That might increase the spillovers reaped since the absorptive capacity is larger or decrease the spillover effect because the gap to the most efficient firm is smaller. Second, exporters are used to interact with foreign firms and therefore able to gain more from the presence of foreign multinational firms in Hungary. In a fixed effects regression which separates the spillover effects on exporters and non-exporters, we found significantly positive backward spillovers of multinational firms on Hungarian exporters but no effect on Hungarian non-exporters. Horizontal spillovers in contrast were only significant for non-exporting firms. In line with the results from the fixed effects regression, the quantile regressions revealed no larger spillovers for exporters than for non-exporting domestic firms.

Overall, we found that heterogeneity in terms of productivity influences domestically owned firms’ capacity to absorb knowledge and achieve higher pro-
ductivity. This finding may have policy implications regarding FDI subsidies, a point left for future research. Another point for further research is related to the potential of omitted variable bias. We understand that it is rather difficult to disentangle several coinciding developments of transition: reallocation of resources, privatization, capital and knowledge inflow or institutional reform. Some of the factors are controlled for via dummy variables, but many must have been left outside of the analysis, potentially affecting spillover.
References


Blalock, G. & Gertler, J. (2005), How firm capabilities affect who benefits from foreign technology. Cornell University.


Javorcik, B. S. (2004), ‘Does foreign direct investment increase the produc-


6 Appendix

In the appendix, data cleaning is described in detail, and productivity estimation is discussed.

6.1 Data cleaning

First note, that the APEH data provide information of firms with non-consolidated accounts. Thus, a manufacturing firm can mostly be considered as an establishment: i.e. a headquarter and a plant. For details, see Békés (2005).

This version of the dataset comes from the Central European University – Labor Project and is based on a dataset managed by the Magyar Nemzeti Bank. Several steps have been made to improve the consistency of the dataset. The initial dataset were exhaustively cleaned by the CEU Labor Project and the authors.

Non-surprisingly in a transition economy, firms frequently changed their attributes. First, we had to define manufacturing firms and their sector classification to avoid firms appearing/disappearing based on their statistical status. A sector was defined based on the NACE 2-digit code a firm most often used. A firm was kept in manufacturing if it spent 75% of its time in the sample as a manufacturer. Second, longitudinal links for firms had to be improved using data provided by Hungarian statistics office KSH on corporate entry and exit. These are cases, when a firm changes its identification code but remains basically the same. This is especially frequent phenomenon in transition economies such as Hungary, see Brown et al. (2006). Other longitudinal links were investigated where firms did not simply appear under a new code but actually split up into several firms or were formed via a merger. These allowed keeping track of most but not all of firms under transformation. Further, small firms (ones that never had as many as 5 employees) had to be dropped for the well-documented lack of reliable data (see Katay & Wolf (2006)) We discarded 58% of firms for missing or unreliable data. Otherwise, no outliers were dropped.

We made several fixes, too. Obvious typing errors were corrected. In order to ensure that small firms are not dropped for missing data in employment or fixed assets, for missing years we replaced these variables with the mean of their (t-1) and (t+1) values. This was the case for 1175 occasions for employment and 206 cases for fixed assets. Ownership also had to be cleaned for the
large number of missing observations (filled in case of equality of the (t-1) and (t+1) values) and typos.

The capital variable was created and corrected following suggestions in Katay & Wolf (2004). Importantly, capital was recalculated by the perpetual inventory method (PIM). The reason for this is that capital stock should be registered at market prices. This is not the case in Hungary, where the stock enters the balance sheet on the book value. Without information on the composition of the capital, actual data represents a mixture of various kinds of assets in terms of age and readiness to use. Hence, the need to recompose the capital stock by the PIM using an initial condition (i.e. first year of investment) and a capital accumulation equation to reconstruct the stock of capital. As a result, investments are deflated by the investment price deflator, and then, the rate of depreciation is used to get K, the capital stock. Thus:

\[ K_{i,t} = K_{i,t-1} \times (1 - \text{Depreciation}_{i,t}) + \text{Investment}_{i,t} \]  

(10)

Description of variables are presented in table 6.

Note that one may consider various other variables for the productivity estimation, such as using labor productivity of output instead of TFP. However, a meta analysis of Diebel & Wooster (2006) suggests that there is no great difference in terms of results, with TFP being the hardest to find significance with. In terms of measuring foreign share, employment as a weight is more likely to yield higher impact than output (used here).

6.2 TFP Measurement

We use the Olley & Pakes (1996) (OP) semiparametric method to estimate firm-level TFP. This method allows robust estimation of the production function. It takes into account the endogeneity of some inputs, the exit of firms as well as the unobserved permanent differences among firms. The main assumption the OP technique relies on, is the existence of a monotonic relationship between investment and firm-level unobserved heterogeneity. Table (7) gives an account of estimated coefficients.

We consider the following Cobb-Douglas production function

\[ y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it} \]

and denote the logarithm of output, capital, labor and intermediate inputs
### Table 6
Description of variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Details</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>Net sales by the firm, deflated by sectoral PPI deflators</td>
<td>APEH: income statements</td>
</tr>
<tr>
<td>Capital</td>
<td>Fixed assets capital generated and corrected by the perpetual inventory method, following suggestions in Katay and Wolf (2004, 2006)</td>
<td>APEH: income statements</td>
</tr>
<tr>
<td>PPI</td>
<td>Producer price deflator, sectoral level</td>
<td>KSH</td>
</tr>
<tr>
<td>Ownership</td>
<td>Foreign-owned firms: at least 10% of equity capital is owned by non-residents. (NB. Distribution of the status is bimodal, and results are insensitive to the threshold.)</td>
<td>APEH: balance sheets</td>
</tr>
<tr>
<td>Private share</td>
<td>Share of equity capital owned privately (i.e. non-state and non-municipal owners)</td>
<td>APEH: balance sheets</td>
</tr>
<tr>
<td>Export status</td>
<td>Exporter firm is defined if net export sales reached at least 5% of total net sales. (NB. Distribution of the status is bimodal, and results are insensitive to the threshold.)</td>
<td>APEH: income statements</td>
</tr>
<tr>
<td>Investments</td>
<td>Change in fixed assets, reduced by a sector specific depreciation rate calculated from the data, deflated by investment input prices. (NB. Results robust to flat depreciation rate)</td>
<td>APEH: income statements</td>
</tr>
<tr>
<td>Investment price deflator</td>
<td>Estimated by authors based on 80% machinery and 20% property price deflators</td>
<td>KSH, authors calc.</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>Directly is estimated from the APEH data. To see robustness of the APEH data, an average of 20% was used, without sizeable impact</td>
<td>authors calc.</td>
</tr>
<tr>
<td>Labor</td>
<td>Average annual employment in the given year</td>
<td>APEH: income statements</td>
</tr>
</tbody>
</table>

with $y_{it}$, $k_{it}$, $l_{it}$, $m_{it}$, respectively. Subscripts $i$ and $t$ stand for firm and time, $\omega_{it}$ denotes productivity, and $\epsilon_{it}$ stands for measurement error in output. It is assumed that $\omega_{it}$ follow an exogenous first order Markov process:

$$\omega_{it+1} = E[\omega_{it+1}|\omega_{it}] + \eta_{it+1}$$

where $\eta_{it}$ is uncorrelated with the productivity shock. The endogeneity problem stems from the fact that $k_{it}$ and $l_{it}$ are correlated with the $\omega_{it}$. This makes $\beta_{OLS}$ to be biased and inconsistent. Given that investment is strictly monotonic, it can be inverted as:
\[ \omega_{it} = h(i_{it}, k_{it}) \]

and substituting this function in the production function leads to

\[ y_{it} = \beta_l l_{it} + \beta_m m_{it} + \Phi(i_{it}, k_{it}) + \epsilon_{it} \]

where \( \Phi(i_{it}, k_{it}) = \beta_0 + \beta_h k_{it} + h(i_{it}, k_{it}) \). Since the functional form of \( \Phi(\cdot) \) is not known, we cannot estimate the coefficients of the capital and labor variable directly. Instead, we use a linear model that includes a series estimator using a full interaction term polynomial in capital and investment to approximate \( \Phi(\cdot) \). From this first stage, the consistent estimates of the coefficients on labor and material inputs as well as the estimate of the polynomial in \( i_{it} \) and \( k_{it} \) are obtained.

The second stage takes into account the survival of firms. These probabilities are given by

\[
Pr\{\chi_{t+1} = 1|\omega_{t+1}(k_{t+1}), J_t\} = Pr\{w_{t+1} \geq \omega_{t+1}(k_{t+1})|\omega_{t+1}(k_{t+1}), \omega_t\} \\
= \varphi\{\omega_{t+1}(k_{t+1}), \omega_t\} \\
= \varphi(i_t, k_t) \\
= P_t
\]

The probability that a firm survives at time \( t + 1 \) conditional on its information set at time \( t \), \( J_t \) and \( \omega_{t+1} \). This is equal to the probability that the firm’s productivity is greater than a threshold, \( \omega_{t+1} \), which in turn depends on the capital stock. The survival probability can be written as a function of investment and capital stock at time \( t \). Thus, we estimate a probit regression on a polynomial in investment and capital controlling for year specific effects. Now, consider the expectation \( y_{t+1} - \beta_l l_{t+1} \) conditional on the information at time \( t \) and survival at \( t + 1 \).

\[
E[y_{t+1} - \beta_l l_{t+1}|k_{t+1}, \chi_{t+1} = 1] = \beta_0 + \beta_h k_{t+1} + E[\omega_{t+1}|\omega_t, \chi_{t+1} = 1] \\
= \beta_h k_{t+1} + g(\omega_{t+1}, \omega_t)
\]

\( \omega_{it} \) follow an exogenous first order Markov process. We substitute the productivity shock in the above equation using the result from the first stage.

\[
y_{t+1} - \beta_l l_{t+1} = \beta_h k_{t+1} + g(P_t, \Phi_t - \beta_h k_t) + \eta_{t+1} + \epsilon_{it}
\]

The third step takes the estimates from \( \beta_l, \Phi_t \), and \( P_t \) and substitutes them
for the true values. The series estimator is obtained by running a non-linear least squares on the equation

\[ y_{t+1} - \beta_l l_{t+1} - \beta_m m_{t+1} = c + \beta_k k_{t+1} + \sum_{j=0}^{s-m} \sum_{m=0}^{s} \beta_{mj} (\hat{\phi}_t - \beta_k k_t)^m \hat{P}_t + e_t \]

where \( s \) is the order of the polynomial used to estimate the coefficient on capital.

**Table 7**

Productivity function coefficients

<table>
<thead>
<tr>
<th>Sector</th>
<th>Observations</th>
<th>Labor</th>
<th>Materials</th>
<th>Capital</th>
<th>Scale</th>
</tr>
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<tbody>
<tr>
<td>17</td>
<td>4883</td>
<td>0.32</td>
<td>0.66</td>
<td>0.07</td>
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<tr>
<td>18</td>
<td>6526</td>
<td>0.45</td>
<td>0.59</td>
<td>0.05</td>
<td>1.09</td>
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<tr>
<td>19</td>
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<td>0.41</td>
<td>0.57</td>
<td>0.07</td>
<td>1.04</td>
</tr>
<tr>
<td>20</td>
<td>6209</td>
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<td>0.82</td>
<td>0.03</td>
<td>1.04</td>
</tr>
<tr>
<td>21</td>
<td>1523</td>
<td>0.15</td>
<td>0.83</td>
<td>(0.02)</td>
<td>0.99</td>
</tr>
<tr>
<td>22</td>
<td>9010</td>
<td>0.18</td>
<td>0.80</td>
<td>0.06</td>
<td>1.04</td>
</tr>
<tr>
<td>24</td>
<td>2978</td>
<td>0.14</td>
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<td>0.03</td>
<td>1.02</td>
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<td>25</td>
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<td>0.06</td>
<td>1.04</td>
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*NB* Figures in brackets are not significant at one percent level of significance.