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Distance to the Efficiency Frontier and FDI Spillovers

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October 2004

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ABSTRACT

Distance to the Efficiency Frontier and FDI Spillovers*

We establish that domestically owned firms in two alternative models of emerging market economies, the Czech Republic and Russia, have not been converging to the technological frontier set by foreign owned firms. In both countries, the distance of domestic firms to the frontier grew (in all parts of the distribution) from 1992-1994 to 1995-1997 and did not change from 1995-1997 to 1998-2000. However, the distance to the frontier is orders of magnitude greater in Russia than in the Czech Republic throughout 1992-2000. We also find in both countries that domestic firms in industries with a greater share of foreign firms are falling behind more than domestic firms in industries with a smaller foreign presence. However, in the Czech Republic this “negative spillover” effect is diminished over time, whereas in Russia it continues to cause domestic firms to fall further behind. On the other hand, we find in both countries that foreign firms experience positive spillovers from other foreign firms operating in the same product market. This evidence on the dynamics of efficiency is consistent with the view that economies (firms) need to be more technologically advanced and open to competition in order to be able to gain from foreign presence.

JEL Classification: C33, D20, F23, G32, L20, O33

Keywords: foreign direct investment, productivity, convergence, frontier, knowledge spillovers, Czech Republic, Russia

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1. Introduction

Are firms in the former communist economies converging to the world standard? This is the key question in the most challenging economic transformation of the start of this century. While expert opinions differ on what constitutes a successful and complete transition,¹ it is generally acknowledged that transition economies need to raise substantially their productivity in order to catch up with the advanced countries. In this paper, we show how much progress has been made in reducing the distance between the efficiency of domestic firms and the world technology frontier in two transition economies – the Czech Republic and Russia – and we assess whether the presence of foreign firms in these countries contributes to the reduction of the productivity gap (either through knowledge spillovers or competition).

Russia and the Czech Republic are desirable model economies because they share useful similarities in their initial conditions, yet they represent polar cases of the strategy and implementation of the transition. Unlike for instance Hungary and Poland, Russia and the Czech Republic maintained a relatively unreformed centrally planned system until the very end of the communist period, thus providing us with “authentic” initial conditions. During the transition, both countries privatized most of the state assets in a way that was both rapid and controversial. Otherwise these economies pursued different paths, becoming prototypes of two distinct patterns of the transition process. The Czech Republic exemplifies the Central European model. It opened up to trade and capital flows, developed a relatively functioning market economy and gradually established institutions, rules and regulations that made it eligible, together with other Central European countries, for accession to the European Union. Like the other Commonwealth of Independent State (CIS) countries, Russia has remained more closed to the world. It has changed its laws, regulations and institutions more slowly and without attempting

¹ See e.g. Brown (1999) for different views on the end of transition from the symposium on this topic.

to harmonize them with those of the European Union. Hence, to the extent that private corporate governance and competition are effective in strengthening performance, we should expect firms in the Czech Republic to be closing the productivity gap and converging to the frontier more rapidly than firms in Russia.

2. Evolution of the Productivity Gap and Distance to the Frontier

We start by estimating and comparing changes in the levels of productive efficiency of domestic and foreign-owned firms in each of these two countries over the 1992-2000 period. Specifically, we estimate the following augmented translog production function with panel data on medium-sized and large firms in the industrial sector (manufacturing, mining, and utilities) in the Czech Republic and in Russia for three consecutive periods: 1992-94 (early transition), 1995-97 (middle transition) and 1998-00 (mature transition):²

$$\ln y_{it} = X_{it} \beta + Z_{it} \rho + v_i + \varepsilon_{it}, \quad (1)$$

where y_{it} represents the output (revenue) of firm i in year t , X_{it} is a vector of inputs (in translog specification) and dummy variables for (two-digit level ISIC) industries and years, Z_{it} is a dummy for domestic ownership (with foreign ownership serving as the base), v_i are unobserved time-invariant firm-specific effects, and ε_{it} is an independently distributed error term, with $E(v_i) = E(\varepsilon_{it}) = E(v_i \varepsilon_{it}) = E(\varepsilon_{it} \varepsilon_{is}) = 0$ for $\forall t > s$. We treat domestic firms with private, mixed and state ownership as one category since we find in a companion paper that their efficiency is similar (Sabirianova, Svejnar and Terrell, 2004, henceforth SST, 2004).

² Our sample is comprised of industrial firms with more than 100 employees at any point in time. We use data on 1,537 to 2,970 firms a year for the Czech Republic and 15,035 to 19,209 firms in a given year for Russia. For a detailed description of the data and our methodology, see Sabirianova, Svejnar and Terrell (2004).

Next, for each firm i we calculate firm-specific productive efficiency in log points as $\varphi_i = \rho + v_i$, with $E(\varphi_i) = \rho$ and $E(v_i) = 0$, and we measure how far the productive efficiency of domestic firms is from that of the frontier firms.³ An important methodological question is how to define the world technology frontier. Since in SST (2004) we find that the efficiency of foreign firms is above the efficiency of domestic firms at all respective points of the two efficiency distributions, in this paper we use the average level of the estimated efficiency of the top third of foreign firms in a given two-digit industry as the benchmark for the frontier.⁴ We believe this is superior to the alternative of using firms operating in advanced market economies as the benchmark since the latter approach is plagued by comparison problems associated with wide exchange rate fluctuations and different shocks and institutions across countries.

We therefore estimate the (inverse) distance from the frontier as the ratio of each firm's efficiency to the mean productive efficiency of the frontier foreign firms within a two-digit industry in each period. The ratio indicates how far a firm is from the efficiency frontier. When the ratio is large (closer to 1), the firm is approaching the frontier. Since our measure of productive efficiency is in log form, we apply the following exponential transformation:

$$\alpha_i = \exp\left(\varphi_i - \bar{\varphi}_{k,FOR} |_{\theta > .66}\right), \quad (2)$$

where α_i is the firm-specific (inverse) measure of the distance to the frontier and $\bar{\varphi}_{k,FOR} |_{\theta > .66}$ is the mean productive efficiency of the top third of foreign firms (above the 66th percentile in θ) in

³ The idiosyncratic errors (ε_{it}) are excluded from the definition of firm-specific productive efficiency in order to reduce the effect of transitory productivity shocks and statistical noise. To allow for the time variation in productive efficiency, the estimates are performed within the 3-year consecutive sub-panels defined above.

⁴ The results are similar if one takes other percentage benchmarks (e.g., 20 or 10 percent). Note that smaller percentages, especially at the level of two-digit industries, are likely to contain more measurement error.

industry k . We use random effect (RE) estimates to obtain our measure of productive efficiency.⁵

In Figure 1 and Table 1 we show for each time period the distribution of the domestic firms' distance to the frontier (α_i). Two important findings emerge: a) in every period domestic firms in Russia are further away from the frontier than domestic firms in the Czech Republic; b) the distance from the frontier has grown from 1992-94 to 1995-97 and it did not change much from 1995-97 to 1998-2000. During the period 1998-2000 the efficiency of the median domestic firm in the Czech Republic was 37.4% of the frontier, whereas it was only 14.6% in Russia. While the top 5% of the Czech domestic firms operated at the level of the frontier, the best Russian firms were not even close to this level. Even more dramatic is the fact that the Russian firm at the 90th percentile was the same distance from the frontier as the median Czech firm.

In Table 1 we also show the distribution of the distance of foreign owned firms from the frontier. In both countries, the distribution of foreign firms lies closer to the frontier than the distribution of the domestic firms. Moreover, the distribution of the distance of foreign firms is fairly constant over the three periods, although in the Czech Republic there is a slight increase in the distance from the first to the second period. However, this increase is not as great as that of the domestic firms.

Overall, in both countries domestic firms diverged from the frontier set by foreign firms during the first half of the transition and they stabilized this enlarged gap but did not succeed in diminishing it during the second half.

⁵ The results are not very different from those that would be obtained with fixed effect or two-stage least square random effect estimators (SST, 2004).

3. Effect of Foreign Presence on the Productivity Gap

If domestic firms are not catching up to the world efficiency standard in general, is it the case that they are converging to this standard in industries with a greater foreign presence and falling behind in industries with a smaller foreign presence, or vice versa? In this section we explore these propositions. Moreover, since foreign owned firms are more technologically advanced and globally accustomed to absorbing knowledge, we test if greater foreign presence has a positive effect on these firms and a less positive or negative effect on the domestic firms.

Part of the FDI literature argues that foreign firms have beneficial “spillover” effects on the productivity of domestic firms by allowing the latter to observe and learn from the introduction of new products and processes to the domestic market (horizontal spillovers).⁶ Foreign firms may also act as a new and large source of demand for inputs, thus stimulating new production in upstream activities (vertical spillovers). On the other hand, foreign firms can have a negative effect on domestic firms’ output and productivity, especially in the short run, if they compete with domestic firms and “steal their market”. This may force domestic firms to cut back production and experience a higher average cost as fixed costs are spread over a smaller scale of production (Aitken and Harrison, 1998). The question is which effects dominate.

Studies of the effect of foreign presence on the productivity of domestic firms use data on domestic firms and include as an explanatory variable some measure of foreign presence, usually the share of foreign firms in a given industry’s output or employment. The evidence from this research is mixed. Studies of the same industry (horizontal spillovers) suggest that the effect is negative in developing countries such as Morocco (Haddad and Harrison, 1993) and Venezuela (Aitken and Harrison, 1999) as well as in transition economies such as Bulgaria and Romania

⁶ Domestic firms can learn about the foreign firms’ management style, technology, and marketing techniques in many ways: through observation, from employees that have worked in these firms, etc.

(Konings, 2000), the Czech Republic (Djankov and Hoekman, 1998; Kosova, 2004) and Russia (Yudaeva *et al.*, 2003). However, Damijan *et al.* (2003) detect positive horizontal spillovers in five of the ten transition countries they examine. The negative effect is usually attributed to a low “absorptive capacity” of domestic firms in the less developed countries. It is argued that the larger the technology gap between the domestic and foreign firms, the less likely the domestic firms will be able to gain from the spillovers and the implication is that positive spillovers should be found in more technologically advanced sectors or in the more industrialized countries.⁷ This latter hypothesis receives some support as Kinoshita (2000) finds positive horizontal spillovers in the R&D sector in the Czech Republic, while Haskel *et al.* (2002) find evidence of positive spillovers on the productivity of domestic plants in the UK.

Unlike the existing studies in this area, we combine data on domestic and foreign owned firms and test whether foreign presence in a given industry affects productive efficiency of domestic and foreign firms differently. In particular, we hypothesize that foreign presence in emerging market economies affects positively the efficiency of foreign firms, which are more advanced and have a globally developed absorptive (learning) capacity, while having a smaller positive or a negative effect on the efficiency of domestic firms, which are less efficient and may not yet have developed their absorptive capacity. In order to implement this test, we augment the production function specified in equation (1) by including as explanatory variables the interaction of foreign presence with the dummy variables for domestic ownership and foreign ownership. We measure foreign presence as the lagged share of foreign firms in total output in a given two-digit ISIC industry ($FS_{(-i)t-1}$).⁸ This measure is firm-specific because for each firm we

⁷ The reverse hypothesis, that spillovers increase with a larger technology gap, was put forth by Findlay (1978).

⁸ We use the lagged value of foreign presence since spillovers may take time to materialize. Moreover, by using the lagged value we avoid the potential problem of endogeneity, i.e., that foreign firms are attracted to industries with

exclude its own output in calculating $FS_{(-i)t-1}$. Such a specification helps capture what each firm learns from others rather than from itself and it also avoids the bias induced by having the firm's own output on both sides of the equation. In addition to estimating the average effects over the 1993-2000 period, we also examine how these effects change over time by introducing the interaction of the above variables with time trend.⁹

In Table 2 we present the summary statistics related to foreign presence in the two economies. As may be seen from the table, the three measures of foreign presence that we report – share of the number of industrial firms, share of output, and share of employment – are highly correlated and they all indicate that foreign firms started from a very low share of total economic activity and increased their share over time. Moreover, the three variables show that throughout the period of our analysis the share of foreign firms is much smaller in Russia than in the Czech Republic. For example, the Russian share of industrial firms in 2000 is approximately one-fifth of the corresponding share in the Czech Republic.

The estimated average (time invariant) and dynamic (time-varying) effects of foreign presence on productive efficiency of domestic and foreign firms in a given industry are reported in Panels A and B of Table 3, respectively.¹⁰ In order to assess the sensitivity of the estimates to the estimation method, we report coefficients from pooled OLS, random effects (RE), fixed effects (FE), and the two-stage least squares random effect estimator (2SLS-RE).

highly productive domestic firms. The panel estimates that control for unobserved firm heterogeneity are also likely to reduce a potential endogeneity bias.

⁹ Since we are using a lagged variable, we exclude the 1992 data from the analysis.

¹⁰ Due to space constraints, we present only the coefficients of the variables of interest. The underlying coefficients on inputs of the translog production function display concavity and monotonicity at the geometric means of the variables.

The last estimator exploits information on supervisory ministries under central planning in treating the potential endogeneity of ownership, i.e., that unobserved firm-specific productivity could determine the type of ownership by influencing the governments' decisions to privatize or investors' decisions to acquire the firm. Since the ministries had significant control over the extent and process of privatization, the ministry dummy variables are correlated with (and hence are good predictors of) the ownership variables. We use ministry categories and the one-year lagged X 's and Z 's to estimate the binary (probit) ownership model for each ownership type:

$$P(Z_t^j = 1 | X_{t-1}, Z_{t-1}, M) = G_j(X_{t-1}, Z_{t-1}, M), \quad (3)$$

where j indicates the ownership type (domestic and foreign) and M is a vector of ministry categories. We next use the fitted probabilities from the probit, \hat{G}_{ij} , as instruments for ownership categories in the two-stage least squares random effects estimator. These predicted probabilities have several useful properties as instruments for binary endogenous variables (e.g., Wooldridge, 2002, pp. 621-633). The IV estimator is asymptotically efficient, the fitted probabilities stay within [0,1] range, and the first stage equation need not be correctly specified.

As may be seen from panel A of Table 3, all four methods yield the same pattern of key results with respect to the average effect of foreign presence over the 1993-2000 period: productive efficiency of domestic firms declines with greater presence of foreign owned firms in both countries and the negative spillover is much larger in Russia than in the Czech Republic. Over this period, a 10 percentage point increase in the foreign share of output in an industry reduces efficiency of domestic firms between 10.6% and 13.7% in the Czech Republic and between 47.1% and 50.1% in Russia, depending on the estimate.¹¹ Conversely, foreign owned

¹¹ We have converted the coefficients in Table 3 into percentages with the formula: $\exp(\beta-1)$.

firms experience positive spillovers from greater presence of foreign owned firms in their industry in both the Czech Republic (around 30.5% to 42.5%) and Russia (around 44.3% to 54.0%).

The time-varying effects, reported in panel B, indicate that the underlying dynamics varies across the two countries. Except for some OLS estimates, the effect of greater foreign presence on domestic firms is (a) negative but becoming less so over time in the Czech Republic, and (b) negative initially and becoming increasingly negative over time in Russia. The time-varying effects on foreign firms suggest that greater foreign presence has (a) an insignificant initial effect that becomes positive over time in the FE and RE estimates but remains insignificant in the OLS and 2SLS-RE estimates in the Czech Republic, and (b) a negative initial effect that becomes positive over time in Russia.

4. Concluding Remarks

Neither the Czech (Central European) nor the Russian (CIS) model of transition has enabled domestically owned firms to converge to the technological frontier set by the most efficient foreign owned firms. In both countries, the distance of domestic firms to the frontier grew from 1992-1994 to 1995-1997 and remained about the same from 1995-97 to 1998-2000. On the other hand, the average distance was much greater in Russia than in the Czech Republic.

In both of these economies, greater presence of foreign firms in a given industry is estimated to have a negative average effect on productive efficiency of domestic firms in that industry but the effect is positive on the efficiency of other foreign owned firms. This result parallels the finding of SST (2004) that, both in the Czech Republic and Russia, foreign firms that are closer to the technological frontier have a higher probability of improving their performance than foreign firms that lag further behind, but that domestic firms have about the

same probability of moving closer or farther from the frontier irrespective of their initial position.

Our dynamic estimates of the spillovers indicate that in the Czech Republic the negative spillover effect on domestic firms is alleviated over time, while in the Russia the negative spillover effect becomes stronger over time. These findings suggest that in emerging market economies the hypothesized positive spillover (a) applies to foreign owned firms, which are relatively more efficient and prepared in terms of their absorptive capacity than local firms, (b) is negative but reversible among domestic firms in countries that open up and gradually adopt market-oriented and enforceable institutional and legal framework, and (c) is increasingly more negative on domestic firms in countries that are more technologically backward, have opened up less to trade and foreign competition, and have not carried out fundamental legal and institutional reforms.

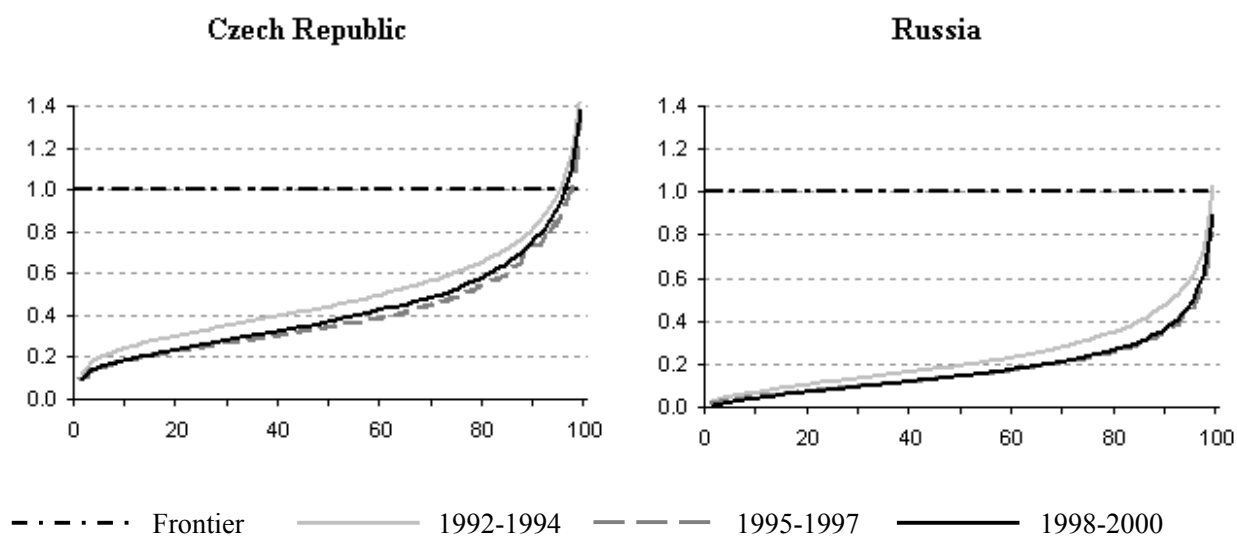
The implication of our findings may be extended further if one takes into account the findings of a parallel study of UK manufacturing by Griffith, Redding, and Simpson (2002), whose estimates suggest that there is convergence to the frontier and that increased foreign presence within an industry raises the speed of convergence to the technological frontier. Taken together, these findings for the Czech Republic (CEE), Russia (CIS) and the UK (EU) are consistent with the notion that the spillovers from foreign presence are positive for all firms in relatively advanced economies, but that in the less developed economies they are positive only for foreign owned firms and may be (increasingly) negative for domestic firms. Overall, our results suggest that future research needs to examine carefully the differential effects that globalization may have on local and foreign owned firms in both the advanced and emerging market economies.

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Figure 1: Distance of Domestic Firms to the Frontier by Period



Notes: The frontier is defined as the mean productive efficiency of the top third of foreign owned firms in a 2-digit ISIC industry. The efficiency estimates are obtained from the translog production function (specified in equation 1) estimated with a random effect estimator for each period separately. The (inverse) measure of the firm's distance to the frontier is calculated as the ratio of the firm's efficiency to the frontier in its industry. Percentiles are constructed from the distribution of the firm-specific distance to the frontier for each ownership type.

Table 1: Distance to the Frontier by Ownership and Period

| Czech Republic | | | | | | |
|-----------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Percentile | Foreign | | | Domestic | | |
| | 1992-1994 | 1995-1997 | 1998-2000 | 1992-1994 | 1995-1997 | 1998-2000 |
| 10 | 0.286 | 0.218 | 0.205 | 0.250 | 0.186 | 0.189 |
| 25 | 0.414 | 0.350 | 0.346 | 0.329 | 0.249 | 0.263 |
| 50 | 0.612 | 0.574 | 0.556 | 0.445 | 0.345 | 0.374 |
| 75 | 0.912 | 0.856 | 0.835 | 0.609 | 0.493 | 0.531 |
| 90 | 1.125 | 1.118 | 1.109 | 0.829 | 0.732 | 0.766 |

| Russia | | | | | | |
|-------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Percentile | Foreign | | | Domestic | | |
| | 1992-1994 | 1995-1997 | 1998-2000 | 1992-1994 | 1995-1997 | 1998-2000 |
| 10 | 0.079 | 0.077 | 0.092 | 0.072 | 0.048 | 0.043 |
| 25 | 0.158 | 0.156 | 0.167 | 0.122 | 0.085 | 0.083 |
| 50 | 0.278 | 0.322 | 0.338 | 0.195 | 0.144 | 0.146 |
| 75 | 0.717 | 0.673 | 0.699 | 0.317 | 0.230 | 0.240 |
| 90 | 1.349 | 1.350 | 1.324 | 0.482 | 0.353 | 0.371 |

Note: See notes in Figure 1 for definitions.

Table 2: Descriptive Statistics of Foreign Presence for Selected Years

| Foreign Firms': | Czech Republic | | | Russia | | |
|-----------------------------|-----------------------|------------------|------------------|------------------|------------------|------------------|
| | 1992 | 1996 | 2000 | 1992 | 1996 | 2000 |
| Share of industrial firms | 0.035 (0.184) | 0.126 (0.332) | 0.307 (0.461) | 0.001 (0.026) | 0.034 (0.182) | 0.056 (0.229) |
| Share of total output | 0.077 (0.266) | 0.214 (0.410) | 0.511 (0.500) | 0.001 (0.031) | 0.030 (0.171) | 0.196 (0.397) |
| Share of total employment | 0.026 (0.159) | 0.121 (0.326) | 0.336 (0.473) | 0.001 (0.036) | 0.019 (0.137) | 0.115 (0.319) |
| No. of observations (firms) | 1537 | 2283 | 2084 | 16633 | 17138 | 15035 |

Note: Standard deviations are in parentheses.

Table 3: The Effect of Foreign Presence on the Efficiency Gap, 1993-2000*Panel A: Time-Invariant Effects*

| | Czech Republic | | | | Russia | | | |
|----------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | OLS | RE | FE | 2SLS-RE | OLS | RE | FE | 2SLS-RE |
| Domestic | -0.275** (0.023) | -0.090** (0.018) | -0.017 (0.020) | -0.131** (0.029) | -0.820** (0.028) | -0.326** (0.021) | -0.124** (0.024) | -0.635** (0.029) |
| Domestic*FS _{t-1} | -0.090 (0.046) | -0.147** (0.038) | -0.137** (0.039) | -0.112** (0.041) | -0.637** (0.048) | -0.674** (0.035) | -0.686** (0.035) | -0.695** (0.035) |
| Foreign*FS _{t-1} | 0.119 (0.071) | 0.266** (0.047) | 0.354** (0.050) | 0.335** (0.055) | 0.199 (0.219) | 0.432** (0.102) | 0.481** (0.104) | 0.367** (0.115) |
| No. of obs. | 18434 | 18434 | 18434 | 15133 | 136769 | 136769 | 136769 | 125795 |
| R ² | 0.759 | 0.740 | 0.656 | 0.752 | 0.681 | 0.672 | 0.599 | 0.690 |
| No. of firms | 4313 | 4313 | 4313 | 3777 | 25594 | 25594 | 25594 | 23899 |

Panel B: Time-Varying Effects

| | Czech Republic | | | | Russia | | | |
|-------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | OLS | RE | FE | 2SLS-RE | OLS | RE | FE | 2SLS-RE |
| Domestic | -0.271** (0.024) | -0.110** (0.020) | -0.039 (0.021) | -0.130** (0.031) | -0.806** (0.028) | -0.286** (0.021) | -0.066** (0.024) | -0.584** (0.029) |
| Domestic*FS _{t-1} | -0.068 (0.088) | -0.371** (0.069) | -0.383** (0.070) | -0.342** (0.076) | -0.317** (0.066) | -0.209** (0.054) | -0.195** (0.054) | -0.210** (0.054) |
| Domestic*FS _{t-1} *t | -0.005 (0.016) | 0.041** (0.010) | 0.045** (0.010) | 0.040** (0.011) | -0.109** (0.024) | -0.165** (0.015) | -0.176** (0.015) | -0.177** (0.015) |
| Foreign*FS _{t-1} | 0.215 (0.207) | -0.205 (0.131) | -0.150 (0.134) | 0.267 (0.182) | -0.629 (0.393) | -0.794** (0.207) | -1.115** (0.215) | -0.998** (0.245) |
| Foreign*FS _{t-1} *t | -0.016 (0.032) | 0.070** (0.018) | 0.074** (0.018) | 0.011 (0.023) | 0.156* (0.069) | 0.211** (0.035) | 0.278** (0.037) | 0.234** (0.041) |
| No. of obs. | 18434 | 18434 | 18434 | 15133 | 136769 | 136769 | 136769 | 125795 |
| R ² | 0.759 | 0.740 | 0.657 | 0.752 | 0.681 | 0.672 | 0.598 | 0.689 |
| No. of firms | 4313 | 4313 | 4313 | 3777 | 25594 | 25594 | 25594 | 23899 |

Notes: FS_{t-1}=the lagged share of foreign firms in total output by 2-digit industry and year. Standard errors are in parentheses (robust in OLS); * significant at 5%; ** significant at 1%. The estimates are obtained from the translog production function specified in equation (1) and which includes industry dummies, year dummies. *t* is time trend, with *t*=0 in 1993. RE – random effects estimator, FE – fixed effects estimator, and 2SLS-RE – two stage least squares random effect estimator, with ministries under central planning as instruments for all ownership variables.