Imports and Productivity*

László Halpern

Institute of Economics, Hungarian Academy of Sciences

CEU, CEPR, WDI

Miklós Koren

Institute of Economics, Hungarian Academy of Sciences

Ádám Szeidl

Department of Economics, University of California - Berkeley

Abstract

What is the effect of imports on productivity? To answer this question, we estimate a structural model of producers using product-level import data for a panel of Hungarian manufacturing firms from 1992 to 2001. In our model with heterogenous firms, producers choose to import or purchase domestically varieties of intermediate inputs. Imports affect firm productivity through expanding variety as well as improved input quality. The model leads to a production function where the total factor productivity of a firm depends on the share of inputs imported. To estimate this import-augmented production function, we extend the Olley and Pakes (1996) procedure for a setting with an additional state variable, the number of input varieties imported. Our results suggest that the role of imports is both statistically and economically significant. Imports are responsible for 30% of the growth in aggregate total factor productivity in Hungary during the 1990s. About 50% of this effect is through imports advancing firm level productivity, while the remaining 50% comes from the reallocation of capital and labor to importers.

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*June 29, 2005. E-mail addresses: `halpern@econ.core.hu`, `miklos.koren@post.harvard.edu` and `szeidl@econ.berkeley.edu`. We thank Andrew Austin, Péter Benczúr, Devra Golbe, Elhanan Helpman, Marc Melitz, Ariel Pakes, John Romalis and seminar participants at CERGE-EI, CEU, and the Empirical Investigations in International Economics conference for comments. This research was supported by a grant of the Global Development Network (RRC IV-061: The Microeconomics of Technology Spillovers: Theory and Evidence from Hungarian Product-Level Data) and of the Hungarian Scientific Research Fund (T048444: Productivity Spillover Through Trading Products).

1 Introduction

Does trade cause growth? Early work, including Coe and Helpman (1995), Barro (1997), and Frankel and Romer (1999) approached this question using aggregate data. While most of the evidence suggests that trade has a potentially large effect on income, using macro data to answer this question may not be satisfactory for two important reasons. First, such data do not speak about the exact mechanism through which trade affects income. Potential mechanisms range from R&D spillovers to import competition, and can have different policy implications. Second, aggregate correlations between trade and productivity are subject to omitted variable and reverse causality biases, and it is hard to think of instruments for trade that are not correlated with other determinants of productivity, like institutions or human capital. Such endogeneity makes it difficult to evaluate the magnitude of the causal effect of trade on output. These two problems call for caution in using the existing estimates for policy recommendations.

In this paper, we narrow the scope of the question, and ask: Do imports increase productivity? To provide an answer, we first build a theoretical model of producers who purchase intermediate inputs from both domestic and international markets, and then estimate it structurally using firm level panel data. In this framework, we are able to deal with both of the difficulties identified above. A structural model allows us to make specific statements about the relative importance of various channels. Moreover, with firm level panel data we can make use of recent developments in production function estimation to deal with the endogeneity of imports. In principle, our estimates can also be applied to explore the effect of various policy experiments such as a tariff change on aggregate output.

Motivated by a preliminary exploration of the data summarized in Section 2, in Section 3 we build a model where the decision to import a given variety from abroad involves paying a sunk cost. This assumption is motivated by the observation that in the data, firms almost never cease to import any given input variety. Because of the fixed cost, in our model the number of intermediate input varieties imported from abroad (N) is a state variable in the firm's dynamic problem. Firms also differ in their productivity levels, and hence will make different choices about the number of varieties they import. As a result, the model exhibits cross-firm heterogeneity in both the number of imported varieties and the share of imports in intermediate inputs, an observation borne out by the data as well. Our model explicitly identifies two channels through which imports impact firm level productivity: (1) access to foreign inputs can improve the product mix of intermediate inputs (horizontal differentiation); and (2) domestic inputs may be of inferior quality relative to foreign inputs (vertical differentiation). In addition, (3) imports can increase aggregate productivity through reallocation of capital and labor to importers.

Our model of importers generates a firm level production function where output depends on residual productivity, capital, labor, materials, and the share of intermediate inputs imported from abroad. The key variable of interest is the last term, which reflects a combination of channels (1) and (2). Note that in a traditional production function where the factors are capital, labor and materials, this term would be subsumed into the firm's total factor productivity. The main difficulty with estimating this parameter is that imports are endogenous to unobserved productivity. To deal with endogeneity, in Section 4 we estimate the production function by extending the empirical methodology developed by Olley and Pakes (1996) and Levinsohn and Petrin (2003). As in those papers, our estimation proceeds in two stages.

In the first stage, Olley and Pakes invert the firm's investment function conditional on capital to obtain a proxy for unobserved productivity. We follow an analogous procedure based on the observation that the change in the number of varieties imported (ΔN) is a monotonically increasing function of productivity conditional on the state variables capital and N. Effectively, we treat N as another form of capital, and ΔN as the investment in this form of capital. The benefit of using ΔN instead of investment as a proxy for productivity is that in our data, 25% of firms have investment equal to zero, and for them the investment function cannot be inverted. In contrast, only 4% of firms have ΔN equal to zero. Using ΔN in the place of investment, we follow Olley and Pakes and regress output on labor as well as a non-parametric function of ΔN and the two state variables capital and N. This yields a consistent estimate of the labor coefficient. An important lesson of our structural model is that failing to control for the second state variable N at this stage would yield inconsistent estimates for the labor share and plague the next estimation stage as well.

We then proceed to the second stage of the Olley-Pakes approach. Here, identification boils down to exploiting the panel nature of the data to create variation in factors of production that is orthogonal to innovations in productivity. A particularly important issue is exit, which is an endogenous choice of the firm conditional on the state variables capital and N. Not accounting for exit would bias our key import share coefficient towards zero. As in Olley and Pakes, we estimate an auxiliary model of exit and use the predicted probabilities as controls at the second stage. We then identify our coefficient of interest by instrumenting current import shares with lagged capital, lagged import shares and other lagged variables. Under the identification assumption that innovations in residual productivity at the firm level are not correlated with these variables, our approach yields a consistent estimate of the impact of import markets on firm output.

To implement this estimation procedure, we use a new panel data set of all Hungarian manufacturing firms employing more than 50 workers between 1992 and 2001. We obtained trade data at the firm level for very disaggregated product categories (at the 6 digit Harmonized System level) from the Hungarian Customs Statistics. To this data we merged balance sheet information from firms' financial statements. Information on product level inputs allows us to observe the number of imported varieties which is a key state variable in the model, making the data particularly suitable for our estimation. Another advantage of the data is the 10 year long panel dimension.

Our estimation results show that imports have a statistically as well as economically significant effect on firm level productivity. We find that a 10 percentage point increase in the share of imports increases firm productivity by 1.8%. To gauge the magnitude of this effect, note that the average firm in the data increased its import share from 23% to 50% between 1992 and 2001, implying that the effect of imports on productivity for the average firm has been 4.9% during this time. This finding suggests that imports have a powerful effect on productivity at the level of the firm.

What is the effect of imports on aggregate productivity? To answer this question, we aggregated our firm-level measures to compute an aggregate productivity index for manufacturing. With this index, we find that imports account for about 30% of the growth in aggregate productivity during 1992-2001. A decomposition of the index shows that approximately 50% of this growth is due to increased importing activity. The remaining 50% is coming from the reallocation of capital and labor to importing firms. Repeating the same exercise for the subsample of machinery, we find that the data tell a similar story. In particular, according to the estimates imports are responsible for 38% of the growth in total factor productivity in the machinery sector in Hungary during the 1990s.

Recently, Amiti and Konings (2005) and Muendler (2004) have explored the impact of tariffs on productivity in firm level data. The main difference between both of these papers and our work is that we follow a structural approach. Amiti and Konings, using data from Indonesia, estimate firm level productivity by implementing the Olley and Pakes procedure, and then run a reduced-form regression of the resulting estimates on tariff rates. Muendler estimates a reduced firm production function that is identical to ours using the Olley-Pakes approach. Because neither of these papers model the effects of import on productivity formally, they do not include the number of imported varieties N as a state variable in the first stage of the estimation. This can yield inconsistent estimates of the labor coefficient and plague the second stage of estimation. In addition, both papers use investment as a proxy for productivity in the first stage, which may be less satisfactory due to the problem of zero investment for a number of firms. A final difference relative to both of these papers is that we also explore the effect of productivity on imports due to reallocation.

Bernard, Jensen and Schott (2005) provide a descriptive study of globally engaged US firms using a new data set. Tybout (2003) summarizes earlier plant and firm level empirical work testing theories of international trade. An extremely robust finding of this literature is that exporting firms are more productive than those selling only domestically (see Bernard and Jensen (1999), among others).

2 Data

The dataset consists of a panel of Hungarian exporting companies from 1992 to 2001. It has three major dimensions: firms, products and time. Data were matched from the Customs Statistics and the firms' balance sheets and earnings statements.

The Customs Statistics dataset contains the annual export and import traffic of the firms, both in value (forints and U.S. dollars) and in tons. The traffic is divided into product cate-

Table 1: Definition of sectors

Machinery	All machinery except electric and data processing machines
Vehicles	Vehicles, (not railway, tramway, rolling stock); parts and accessories
Electronics	Household electronics (except "white goods")
Computers	Automatic data processing machines

Table 2: Number of firms: machinery

Year	Domestic	Foreign	Total
1992	131	90	221
1993	162	121	283
1994	165	145	310
1995	162	157	319
1996	186	187	373
1997	187	208	395
1998	185	218	403
1999	177	212	389
2000	184	198	382
2001	169	188	357
Total	*304*	*410*	

gories broken down to 6-digit Harmonized System (HS) level (5,200 categories). However, we aggregate the data up to the 4-digit level (1,300 categories) because the 6-digit classification of shipments seems to be very noisy.[1]

The sample consists of 2,043 large exporting companies which exported more than 100 million forints in any of the years. These were further broken down into two categories: domestic (less than 33% foreign ownership) and foreign-owned firms (foreign ownership exceeds 33%).[2] Tables 2 through 5 display how these firms are represented in each of the years of this unbalanced panel. The average spell in the sample is 5.38 years for domestic and 6.52 years for foreign firms.[3] During this decade, one of the most important developments in Hungary was the growing number and market share of foreign firms.

We assign firms into four sectors based on their main export products (see Table 1). Tables 6 through 9 display the average firm size over time for each of the sectors. Apart from computers, where foreign firms tend to be bigger, there is no clear difference between the size of foreign and domestic firms. Note that firms enter and exit the sample and change ownership status so the trends in firms size are affected by these composition changes.

[1]For example, firms very often switch their main export product at the 6-digit level whereas this happens much less frequently at 4 digits. There is certainly an element of arbitrariness in classifying shipments at such a finely disaggregated level.

[2]This roughly corresponds to the median foreign ownership. By far the most common levels of foreign ownership are either 0 or 100%, so the choice of cutoff does not influence our results.

[3]Note that some firms change ownership status during the sample. This typically means a domestic firm being bought by foreign investors. Hence the relatively short spell of domestic firms.

Table 3: Number of firms: vehicles

Year	Domestic	Foreign	Total
1992	30	27	57
1993	38	39	77
1994	44	41	85
1995	43	45	88
1996	41	60	101
1997	46	67	113
1998	47	72	119
1999	44	73	117
2000	47	70	117
2001	47	60	107
Total	*75*	*115*	

Table 4: Number of firms: electronics

Year	Domestic	Foreign	Total
1992	11	12	23
1993	11	15	26
1994	14	16	30
1995	13	18	31
1996	14	24	38
1997	14	27	41
1998	13	30	43
1999	11	33	44
2000	11	29	40
2001	10	33	43
Total	*23*	*49*	

Table 5: Number of firms: computers

Year	Domestic	Foreign	Total
1992	7	6	13
1993	10	11	21
1994	6	14	20
1995	9	15	24
1996	8	21	29
1997	9	23	32
1998	10	22	32
1999	10	22	32
2000	11	17	28
2001	11	17	28
Total	*16*	*34*	

Firms in our sample cover the bulk of Hungarian exports, ranging from 47% in 1992 to a top of 76% in 1999. We have data on exports for each firm from two sources: their financial statement and disaggregated customs statistics. The correlation between these two measures across firms is reassuringly high: 0.953. Foreign firms are more export oriented for obvious

Table 6: Average employment: machinery

Year	Domestic	Foreign
1992	508	208
1993	406	197
1994	317	197
1995	313	192
1996	263	202
1997	231	224
1998	213	240
1999	209	254
2000	189	267
2001	190	288

Table 7: Average employment: vehicles

Year	Domestic	Foreign
1992	973	140
1993	821	132
1994	564	146
1995	502	190
1996	444	219
1997	426	243
1998	416	262
1999	332	289
2000	276	325
2001	256	332

Table 8: Average employment: electronics

Year	Domestic	Foreign
1992	765	423
1993	363	301
1994	469	301
1995	474	362
1996	439	311
1997	502	333
1998	657	367
1999	617	574
2000	731	720
2001	897	859

reasons. The export orientation of the average Hungarian firm increased substantially over the sample period. There are three channels through which this took place: firms already in the sample increased their market share, entered new product markets, and new, more export oriented firms entered the sample.

Table 9: Average employment: computers

Year	Domestic	Foreign
1992	343	300
1993	209	220
1994	132	280
1995	176	284
1996	200	255
1997	145	364
1998	387	430
1999	266	614
2000	256	780
2001	255	1159

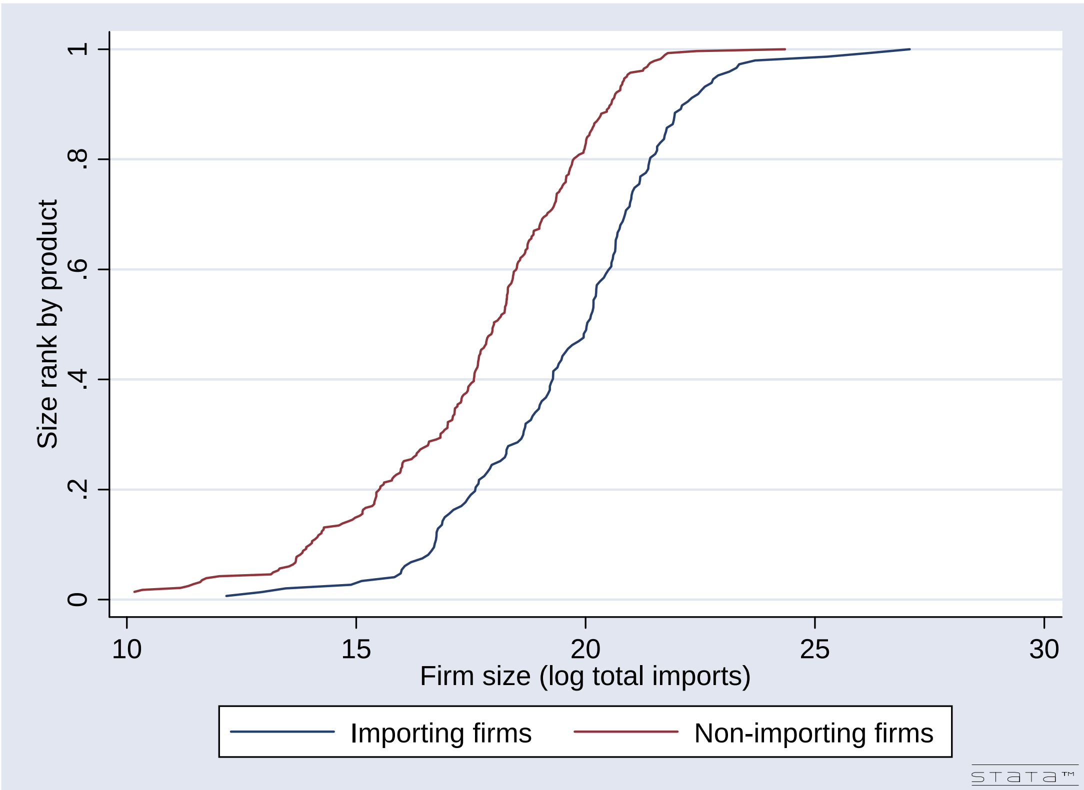

Figure 1: Size distribution of importing vs non-importing firms

2.1 Stylized Facts of Firm-Level Imports

This section documents some empirical regularities concerning the import patterns of firms.

Fact 1. There is substantial heterogeneity in the import patterns of firms within a sector. About $4 - 7\%$ of firms do not import at all. Importing firms are 2-3 times as big as nonimporting ones.

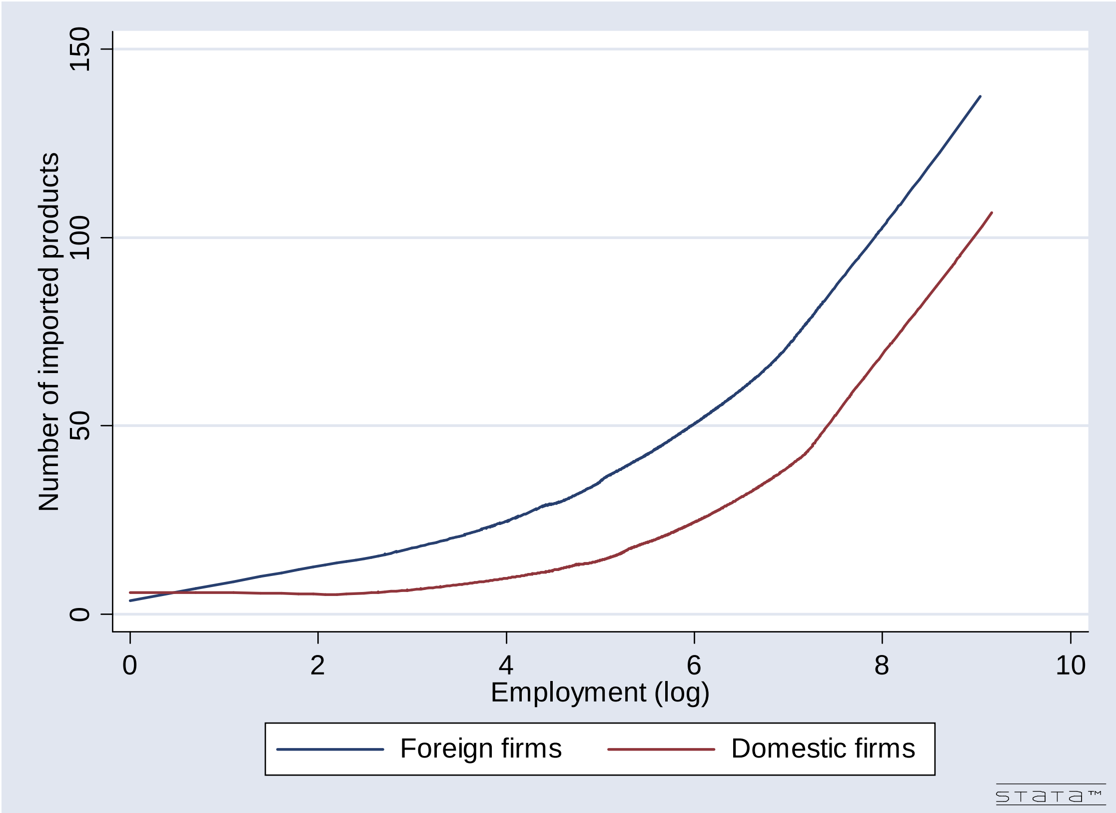

Figure 2: Number of products and firm size

Figure 1 displays the size distribution of firms in machinery that do and do not import a typical product, "gaskets and joints of metal sheeting." The distribution of importing firms is shifted to the right, firms that import the product are 7 times as large as firms that do not.

Note that our sample is restricted to *big exporting* firms. Firms that have never exported more than 100 million HUF are excluded. Such firms are likely to be smaller and rely less on imports.

Fact 2. Foreign firms import more (both more product categories and as a share of total materials) and imports increase in size.

Figure 2 shows the number of imported products (HS4 categories) by firm size for foreign and domestic firms. The lines correspond to the LOWESS nonparametric estimate of the relationship between product number and employment. Product number sharply increases in size: doubling firm size would increase the number of imported products by 30%. However, even controlling for firm size, foreign firms tend to import 170% more products than domestic ones.

This pattern is consistent with a model where importing products entails a fixed cost (one needs to establish business connections, shop for the product abroad). Larger firms

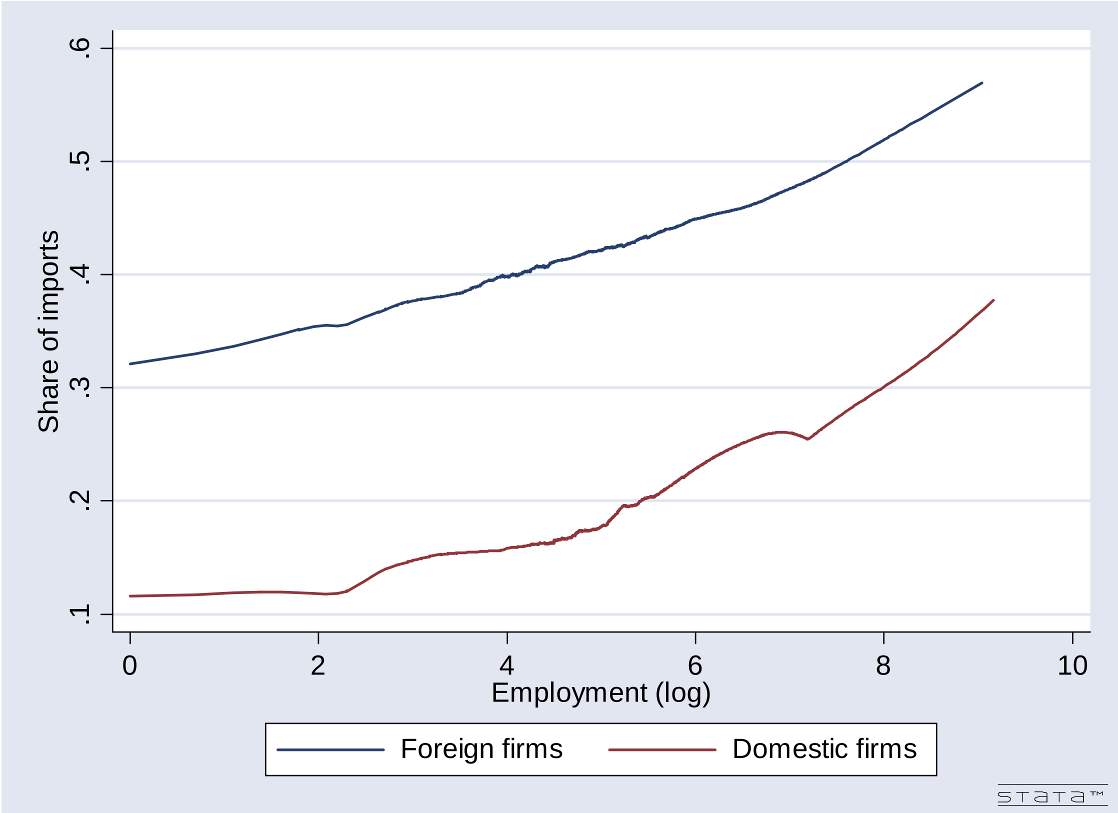

Figure 3: Import share and firm size

profit more from buying the product and are more likely to overcome the fixed cost. It is also plausible that such a fixed cost is considerably lower for foreign firm as they already have their business networks abroad. Hence they import more products even at the same size.

We identify a product being imported if the total import shipment in the given HS4 category was positive. Note that the value of shipments is given in units of HUF (not rounded) so we do no underestimate the number of imported products.

Fact 3. Import intensity increases with firm size and foreign ownership.

The heterogeneity of imports with respect to firm size is further illustrated in Figure 3, which shows the *share* of imported inputs in total material costs. Bigger firms spend a bigger fraction of their intermediate input budget on imports. This is consistent with the fixed cost explanation: larger firms are already present in many import markets and they hence have the ability to spend a bigger fraction on imports. Again, foreign firms spend a much larger proportion on imports.

This means that there is a nontrivial demand for imports; firms do not view it as perfect substitute for domestic inputs.

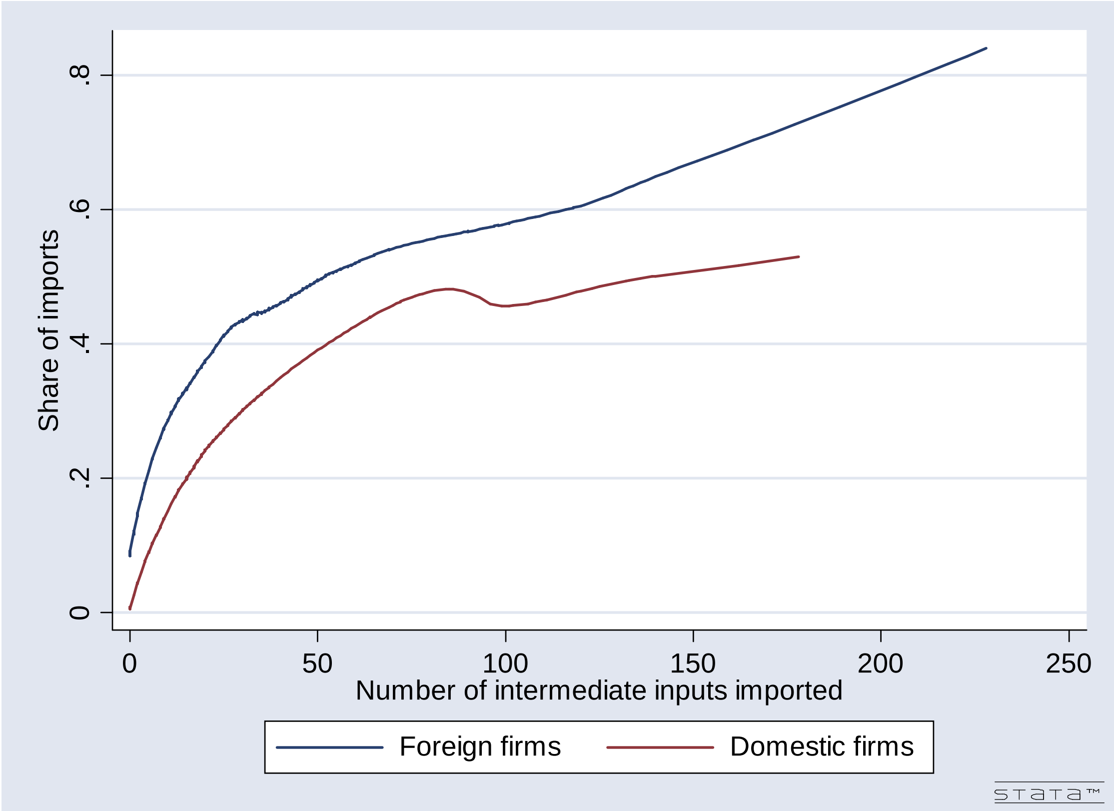

Figure 4: Import share and the number of imported products

Fact 4. Imports are concentrated on a few products, firms spend very little on the remainder of products.

The average firm spends 45% of its import budget on the largest product category and only 4% on the fifth largest category. (Some firms import less then five products.)

Figure 4 plots import intensity as a function of the number of imported products. Two observations stand out. First, the returns to additional imported products sharply diminish. This is because many of the products are small components with little contribution to overall material costs. This implies that we cannot treat product categories symmetrically as in a Dixit-Stiglitz model, we have to account for a diminishing love of variety.[4]

Second, foreign firms have a somewhat higher demand for imports, even controlling for the number of products they import. This may be because they are better at using the imported inputs in production so they purchase relatively more of each product category.

Fact 5. There is a ranking of products by "importance": if a product is imported by a firm, it is also likely to be imported by larger firms.

[4] See Hummels and Lugovskyy (2004) for a model (and supporting evidence) where the marginal utility of additional varieties declines.

If the average firm imports a given product then about 40-65% of larger firms within the same industry will also import that product (depending on the industry considered). The narrower the definition of an industry, the higher the proportion of importing larger firms.

This implies that a model with a size cutoff, where firms with sizes above the cutoff all import the product whereas firm below it do not, is a reasonable approximation.

Fact 6. Conditional on industry and firm size, import structures are similar.

In other words, most of the within-sector heterogeneity in import patterns is due to the heterogeneity in firm size. Other sources of heterogeneity may include differences in the technology used or differences in the prices faced by importers.[5]

To provide evidence on this regularity, we first sort firms by size and then predict a counterfactual import share for each product as a nonparametric function of firm size. More specifically, we take a local average of import share from firms with similar sizes. This size-predicted import share explains 51-58% of all the variation in import shares.

Fact 7. Growing firms enter into more new product markets whereas shrinking firms do not exit their existing markets.

Figure 5 plots the share of newly added products (relative to the number of products last year) and the share of products dropped from the product line against employment growth. Growing firms add more and more products. This is expected because it becomes easier for them to overcome the entry cost. Whether shrinking firms drop products depends on the nature of market entry costs. If entry costs are sunk and cannot be recovered upon exit (e.g., establishing business connections), firms will keep on importing their existing products even if they are shrinking in size. As shown in the Figure, very few products are dropped, even by firms that are drastically contracting.

Fact 8. Firms importing a bigger fraction of their inputs are less likely to exit.

Around 4% of firms exit each year. Exiting firms import on average 20% less than surviving firms. Import share significantly (negatively) predicts exit even after controlling for physical capital (low-capital firms are less likely to exit), employment and employment growth in the past two years (shrinking firms are more likely to exit). This is again consistent with the irreversibility of importing: firms already present in many import markets will sit out productivity troughs rather than exiting the market.

3 A Model of Imports and Productivity

Here we introduce a partial equilibrium model consistent with the above stylized facts.

Firms use capital, labor and materials in their production process, where output is determined according to the production function

$$Y = \Omega K^{\alpha} L^{\beta} X^{\gamma}, \tag{1}$$

[5]Halpern and Koren (2004) document how import prices vary across buyers.

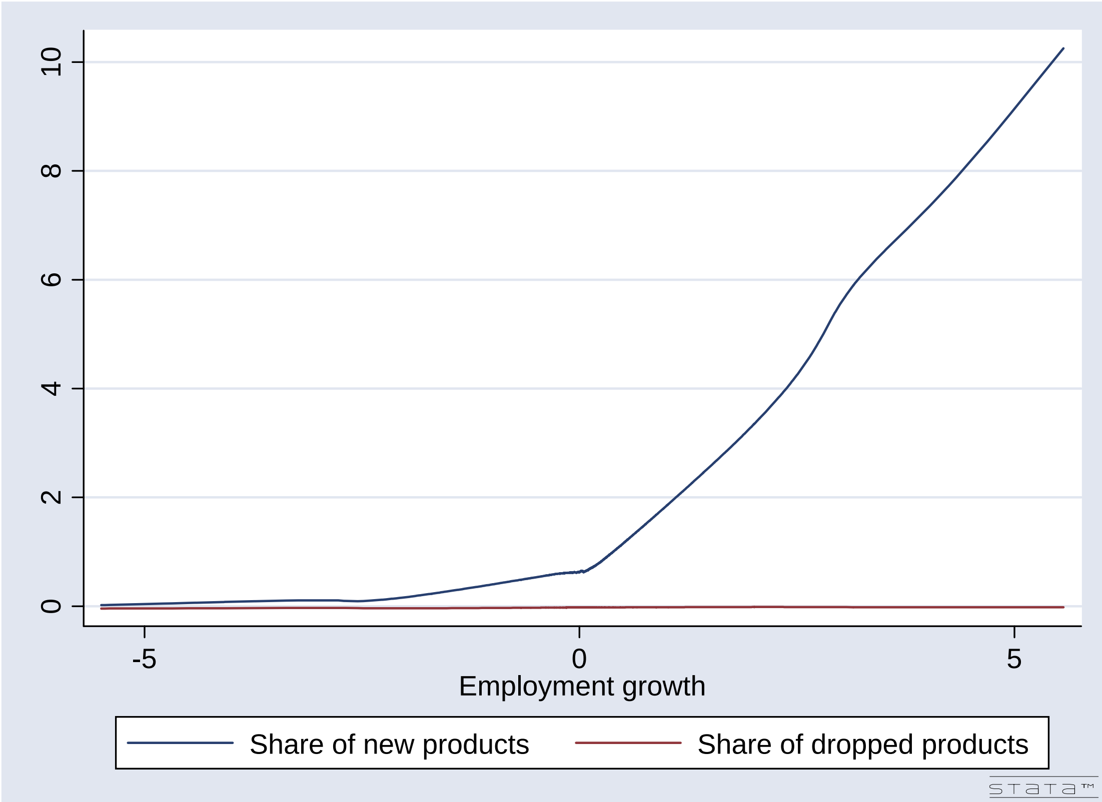

Figure 5: Product market entry and exit

with K denoting capital inputs, L labor inputs, X materials and Ω is total factor productivity (TFP). We assume that materials is a fixed-coefficient aggregate good composed of a number of different intermediate products

$$X = \min_i \{X_i/B_i\}. \tag{2}$$

It takes B_i units of good i to produce a unit of X. Each good X_i is assembled in the firm from a combination of two varieties, a foreign and a domestic one:

$$X_i = \left[(AX_{iF})^{\frac{\theta-1}{\theta}} + X_{iH}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}. \tag{3}$$

Here the quantity of the foreign and domestic inputs are denoted by X_{iF} and X_{iH}. Foreign goods are assumed to command an $A > 1$ quality advantage over domestic goods. We assume that this advantage is only partly reflected in prices, so the relative price of foreign and domestic goods is $p_{iF}/p_{iH} = A^\delta$, where $\delta \in [0, 1]$. A δ of 0 means that quality is not reflected in the price of the input so all the gains from quality are reaped by the buyer of the input. A δ of 1 means that prices are proportional to quality so there are no gains from quality to the buyer. Note that it is worth to buy foreign goods even in this case, because they imperfectly substitute for domestic goods.

Note that the production function does not necessarily exhibit constant return to scale. An alternative formulation could involve a Leontief aggregate of $K^\alpha L^\beta$ and X but here we allow for some substitution between input purchases and labor/capital. For example, if labor is very cheap, the firm may opt to make the input instead of buying it at arm's length. Without modelling the make or buy decision formally, we introduce a Cobb–Douglas production function with unitary elasticity of substitution.

The firm can only import positive amounts of X_{iF} if it has paid a fixed cost of f for product i. (Later on, we may model it as a *sunk* cost, payable only once. We will probably not have closed-form solutions for that case.)

As stated, the relative price of foreign and domestic goods depends on their relative qualities,

$$p_{iF}/p_{iH} = A^\delta. \tag{4}$$

If the firm only buys the domestic variant of good i, it pays a price of

$$p_i = p_{iH}. \tag{5}$$

On the other hand, if the firm buys both variants (note that they would always buy the domestic variant as it does not involve a fixed cost), the ideal price index of good i becomes

$$p_i^* = p_{iH}\left[1 + A^{(\theta-1)(1-\delta)}\right]^{1/(1-\theta)}. \tag{6}$$

The proportional decrease in the cost of acquiring one unit of good i is a function of A,

$$\frac{p_i - p_i^*}{p_i} = 1 - \left[1 + A^{(\theta-1)(1-\delta)}\right]^{1/(1-\theta)} \equiv a. \tag{7}$$

This cost advantage is increasing in A (the quality advantage), and decreasing in δ (the price difference) and θ (the elasticity of substitution). Intuitively, if domestic variants are good substitutes of foreign variants, the benefit of using imports is lower. The ideal price index for the whole set of intermediate inputs is

$$P = \sum B_i \tilde{p}_i, \tag{8}$$

where $\tilde{p}_i$ is either p_i^* (if good i is imported) or p_i (if it is not). For tractability, we assume that the gain from foreign inputs, a is the same across goods. Then the ideal price index is

$$P = P^{(0)}\left[1 - a\sum_{i\in\text{imp}} B_i p_i / P^{(0)}\right] \equiv \left[1 - a\sum_{i\in\text{imp}} b_i\right]. \tag{9}$$

The term $b_i \equiv B_i p_i / P^{(0)}$ is the share of good i in total intermediate expenditure if none of the products are imported. If all firms use the same technology (B_i) and face the same prices (p_i) then b_is are the same across firms, too.

Because the set and composition of intermediate inputs varies across firms, the only meaningful measure of TFP can be derived from the inverse of marginal cost. The cost function is

$$\Omega^{-1}Y^{1/(\alpha+\beta+\gamma)}R^{\alpha/(\alpha+\beta+\gamma)}W^{\beta/(\alpha+\beta+\gamma)}P^{\gamma/(\alpha+\beta+\gamma)}.$$

If the firm can buy foreign products, it can provide the same composite of intermediate goods at a lower ideal price index, P. This decreases marginal cost for *given factor prices.*

Let $M = PX$ denote the total spending on intermediate inputs (observable from the earnings statement). Then, up to a constant $P^{(0)}$,

$$Y = c\Omega K^{\alpha} L^{\beta} M^{\gamma} \left[1 - a \sum_{i\in\text{imp}} b_i\right]^{-\gamma}. \tag{10}$$

That is, measured productivity is greater, the greater the set of imported products.

To express productivity as a function of observables, note that we can write the share of intermediate expenditure spent on imports as

$$S \equiv \frac{\sum_n p_{iF} x_{iF}}{\sum p_i x_i} = \left[(1-a) - (1-a)^{\theta}\right] \frac{\sum_{i\in\text{imp}} b_i}{1 - a\sum_{i\in\text{imp}} b_i}, \tag{11}$$

which implies

$$\left[1 - a \sum_{i\in\text{imp}} b_i\right]^{-1} = 1 + \frac{a}{(1-a) - (1-a)^{\theta}} S, \tag{12}$$

which is increasing in the import share (S) since $\theta > 1$ (foreign and domestic inputs are gross substitutes).

Taking logs of (10) and using the approximation $\ln(1+x) \approx x$,

$$y = c + \alpha k + \beta l + \gamma m + \delta S + \omega, \tag{13}$$

where $\delta = a\gamma/[(1-a) - (1-a)^{\theta}]$ is positive. That is, TFP is increasing in the share of imports.

In a standard specification one would estimate

$$y = \alpha k + \beta l + \gamma m + \omega,$$

where capital, labor and material cost can be thought of as "traditional inputs," and ω is total factor productivity (TFP). Here we go one step further and relate TFP to the share of imported inputs, S. The key parameter of interest is hence δ.

The main challenge of estimating (13) is a well known endogeneity problem: firms with higher productivity (ω) use more variable inputs (l and m) so the error term is not orthogonal to the explanatory variables. Moreover, high-productivity firms are also more likely to enter more import markets, as we will show next.

3.1 Endogenous entry into import markets

When choosing which product markets to enter, the firm minimizes the sum of variable and fixed costs,

$$\min_{\{n\}} \Omega^{-1} Y^{1/(\alpha+\beta+\gamma)} R^{\alpha/(\alpha+\beta+\gamma)} W^{\beta/(\alpha+\beta+\gamma)} P^{\gamma/(\alpha+\beta+\gamma)} + nf, \tag{14}$$

where n is the number of products imported and f is the per-product fixed cost (assumed to be the same across firms and products).

Assume without loss of generality that products are ordered by decreasing share, b_i. Then the first n products will be imported, where n is implicitly given by

$$\frac{\gamma Y a b_n}{1 - a\sum_{i=1}^{n} b_i} = f. \tag{15}$$

This follows directly from the FOC of the minimum problem. The left-hand side is monotonically declining in n, this defines a unique n that is increasing in Y (sales), a (benefit from imports), and decreasing in f (fixed cost). Large firms with lower fixed costs (e.g., foreign-owned firms) import more product varieties.

This implies that conditional on k, l, and m, TFP is positively correlated with the number of imported products and hence with the share of imports in material costs.

Moreover, as we argued above, there is enormous persistence in import market participation: once a firm starts importing a product, it very rarely stops. Hence we can assume that there are two observable firm specific state variables, capital k and the number of input varieties n. The latter is a state variable because the firm is required to pay the sunk cost associated with using any particular variety only once.

The dynamics of the industry is assumed to be standard, as specified in Olley and Pakes. In particular, at each point in time, an incumbent firm has three decisions to make. First, it needs to decide whether to exit or continue in the industry. If it continues, it has to choose its variable factors (labor, materials, share of high quality inputs) as well as its investment in capital, and the number of new varieties it wishes to use in production. These latter two decisions, together with the current capital stock and number of inputs, will determine the levels of k and n next period.

4 Estimation Framework

As is well known, there are two interrelated endogeneity problems that plague the OLS estimation of an equation like (13). First, input demand and unobserved productivity are correlated, because more productive firms are expected to use more variable inputs. Because of that, simple OLS estimates would yield inconsistent estimates for the coefficients of variable inputs, which in our case includes labor l, and material costs m. Relatedly, if productivity is persistent over time, then more productive firms tend to accumulate more capital and enter a larger number of import markets; thus higher k and S will be associated with higher unobserved productivity in the cross section. Because of that, in a cross sectional OLS regression, the coefficients of k and S would not be estimated consistently.

The second endogeneity issue is related to the fact that firms endogenously choose when to exit the market. Firms with more capital or a higher number of imported varieties can afford to stay in the industry at lower levels of productivity. This implies a negative correlation between K and Ω as well as between N and Ω conditional on staying in the industry and hence a downward bias in the coefficients of capital inputs.

To deal with these endogeneity problems, we implement an estimation methodology which is based on the approach followed by Olley and Pakes and Levinsohn and Petrin (2003).

Recall from (13) that for firm i in year t,

$$y_{it} = c + \alpha k_{it} + \beta l_{it} + \gamma m_{it} + \delta S_{it} + \omega_{it}, \tag{16}$$

and the endogeneity problem is that unobserved productivity, ω_{it}, is correlated with the explanatory variables.

However, we conjecture that, conditional on observable state variables (k and n), entry into new import markets (ΔN) is a monotonic function of productivity,

$$\Delta N_{it} = f(\omega_{it}, k_{it}, n_{i,t-1}), \tag{17}$$

which is invertible in its first argument to get

$$\omega_{it} = g(\Delta N_{it}, k_{it}, n_{i,t-1}).$$

Hence

$$y_{it} = \alpha k_{it} + \beta l_{it} + \gamma m_{it} + \delta S_{it} + g(\Delta N_{it}, k_{it}, n_{it}) + \varepsilon_{it}, \tag{18}$$

where ε_{it} is the part of productivity that is not observable to the firm (i.e. orthogonal to firm decisions).

From (18), we can control nonparametrically[6] for ΔN_{it}, k_{it} and $n_{i,t-1}$ to obtain consistent estimates of β and γ. However, because S deterministically depends on n and we do not know the function $g(\cdot)$, we are unable to identify α and δ in the first stage.

We assume that unobserved productivity follows a first-order Markov process conditional on the observed state variables. In particular, we simplify by assuming that ω is an AR(1) process with autocorrelation ρ,

$$\mathrm{E}_t\, \omega_{i,t+1} = \rho \omega_{it}.$$

For any given α, δ and ρ, we can subtract ρ times the lagged TFP from the current estimated TFP to obtain TFP innovations

$$u_{it} \equiv [y_{it} - \alpha k_{it} - \beta l_{it} - \gamma m_{it} - \delta S_{it}] - \rho g(I_{i,t-1}, k_{i,t-1}, n_{i,t-1}).$$

[6] In our implementation, this involves running multivariate locally weighted regressions.

These innovations are orthogonal to all information available at time $t-1$, $\mathrm{E}(u_{it}|\mathbf{Z}_{i,t-1}) = 0$. We use current and lagged capital, lagged employment, lagged material cost, lagged number of products, and lagged import share as instruments.

An additional problem is that we do not observe u_{it} for exiting firms, so we can only calculate $\mathrm{E}(u_{it}|\mathbf{Z}_{i,t-1})$ conditional on firm survival,

$$\mathrm{E}(u_{it}|\mathbf{Z}_{i,t-1}, \chi_{it} = 0) \neq \mathrm{E}(u_{it}|\mathbf{Z}_{i,t-1}). \tag{19}$$

To correct for the bias (19), we first obtain propensity scores for exit by running a logit regression on physical capital and the number of inputs. As expected, firms with more capital and importing more inputs are less likely to exit. We then control for this propensity score nonparametrically in the instrumental variable regression.

Because of the linearity of the production function, the parameters α and δ can be estimated by a linear instrumental variables regression for any given ρ. The autocorrelation parameter, ρ is obtained from a grid search over $[0, 1]$ seeking to minimize the weighted squared sum of moments. The J-test of overidentification is not rejected in any of the specifications, meaning that TFP innovations are indeed orthogonal to all of the instruments.

Standard errors and significance levels are obtained from a 200-repetition bootstrap.

5 Results

Tables 11*a* and 11*b* display the estimation results. The "OLS" columns show the simple OLS estimates of (13) for comparison. Significance at 10, 5, and 1% are denoted by *, **, and ***, respectively. We expect the OLS coefficients of freely adjustable inputs (labor, material) to be upward biased. Firm fixed effects are included in the "FE" columns. Note that the dependent variable is total sales, not value added. Hence the large coefficients of material costs and the relatively small coefficients of capital and labor. The "GMM" columns report the results of the concentrated GMM procedure outlined in the previous section, when import share is treated as a capital good (state variable). We also report the significance level at which the coefficients differ from zero. These we obtain from 200-repetition bootstraps.

The OLS regressions indicate a highly significant positive association between import share and productivity: those spending 0.10 more on imports typically produce 1-2% more output with the same amount of inputs. However, the causal interpretation of this relationship is limited by the endogeneity problems mentioned earlier.

As suggested in the discussion of the directions of endogeneity, the OLS coefficients of the freely adjustable inputs (labor and materials) tend to be larger that the GMM estimates, although the bias is not large. (It is typically significant for the material coefficient but not for the labor coefficient.) Additionally, both the OLS and the FE estimates of the capital coefficient tend to be significantly (at 1%) lower than the GMM coefficient, suggesting that endogenous exit indeed biases this coefficient downward.

The import share is highly significant for the pooled sample with a point estimate of 0.182.[7] This means that a 0.10 increase in import share leads to a 1.8% increase in productivity. A one-standard-deviation increase in import share (0.33) leads to a 6% increase in TFP. We further discuss the quantitative importance of this coefficient by looking at the contribution of imports to aggregate productivity growth in the next subsection.

The sum of the capital, labor and material coefficients is 0.969, which corresponds to a 3% decreasing returns to scale. The coefficient is statistically significantly lower than 1.

We also report results for the subsamples of foreign and domestic firms, as well as the machinery industry. Because the sample sizes are considerably smaller, the bootstrapped standard errors tend to be larger in these specifications. However, the import share coefficient, as well as the other coefficients, remain close to their benchmark estimates. We find significantly positive import share coefficients for most subsamples, although not for the case of domestic firms.

We also check the temporal stability of the estimates by running the regressions separately for the time period $1992 - 1996$ and $1997 - 2001$ (not reported). The production function coefficients are not statistically different in the two sub-periods.

Once we obtained consistent estimates of the production function coefficients, we can estimate log TFP as the residual output, $\hat{\text{tfp}}_{it} = y_{it} - \hat{\alpha}k_{it} - \hat{\beta}l_{it} - \hat{\gamma}m_{it}$. We use the estimated TFP to carry out some specification diagnostics, as well as to analyze the dynamics of productivity.

First, we check whether the overidentifying restrictions are satisfied. We use six instruments to estimate three parameters (α, δ, and ρ). The $\chi^2(3)$-test of overidentification is never significant at any conventional significance level, suggesting that all of the instruments are orthogonal to TFP innovations.

Second, we look at how estimated productivity relates to the observable decisions of the firm to judge whether our modelling and estimation choices are justified. After controlling for capital stock and the number of last-year product markets as state variables, we find that more productive firms (1) enter more import product markets,[8] (2) use more variable inputs, (3) and are less likely to exit. All of these relationships are highly significant statistically.

Third, we test model misspecification by including lagged inputs in a regression of $y_{it} - \hat{\beta}l_{it} - \hat{\gamma}m_{it}$ on k_{it}, S_{it} and a nonparametric function of predicted productivity ($\hat{\omega}$) and predicted exit probability. The coefficients of lagged inputs are neither individually, nor jointly significant and the coefficients of k_{it} and S_{it} do not change significantly from $\hat{\alpha}$ and $\hat{\delta}$.

[7] Note that the boostrapped standard error is generally not sufficient to assess the significance of $\hat{\delta}$ because the estimates are not symmetrically distributed. We hence report the p-values separately.

[8] The relationship is strictly monotonic, validating our use of newly imported products as a proxy for productivity.

Table 10: Decomposing Aggregate TFP Growth

Machinery, vehicles, electronics, and computers

Year	Total TFP	Due to imports	Contribution
Within-firm growth	0.95%	0.47%	49%
Reallocation	1.57%	0.40%	25%
Net exit	0.64%	0.07%	11%
Total	*3.15%*	*0.94%*	*30%*

Machinery only

Year	Total TFP	Due to imports	Contribution
Within-firm growth	1.72%	0.62%	36%
Reallocation	1.11%	0.59%	53%
Net exit	0.95%	0.24%	25%
Total	*3.78%*	*1.45%*	*38%*

5.1 The dynamics of industry productivity

What is the effect of imports on aggregate productivity? To answer this question, we aggregated our firm-level productivity measures to compute an aggregate productivity index for manufacturing. For any firm i at time t, let us introduce the following measure of TFP (A_{it}) and an index of production inputs (X_{it}),

$$A_{it} = \exp(\delta S_{it} + \omega_{it}),$$
$$X_{it} = \exp(\alpha k_{it} + \beta l_{it} + \gamma m_{it}).$$

It is clear that the output of the firm is $Y_{it} = A_{it} X_{it}$.

Let $x_{it} = X_{it} / \sum_j X_{jt}$ denote the share of firm i in the index of inputs. The average productivity in the industry is the weighted average of firm productivities, $\bar{A}_t = \sum_i x_{it} A_{it}$. Productivity growth can be decomposed into the following three components:

$$\Delta \bar{A}_t = \sum_{i \in \text{cont}} x_{i,t-1} \Delta A_{it} + \sum_{i \in \text{cont}} \Delta x_{it} A_{it} + \sum_{i \in \text{exit}} x_{it} (\bar{A}_{\text{cont},t} - A_{i,t-1}). \quad (20)$$

Average TFP increases if continuing firms improve their TFP, if more productive firms become relatively bigger, and if exiting firms have lower productivity than continuing firms. We decompose TFP growth into these three channels.

To assess the quantitative importance of imports in the dynamics of productivity, we construct the following counterfactual. We calculate residual TFP as $A_{it} / \exp(\delta S_{it})$. This is the part of TFP that is not due to imported intermediate inputs. Then we do the decomposition of equation (20) for this residual TFP. As this grows slower than overall TFP, the difference can be attributed to the increasing reliance on imports. Average import intensity increases because (1) firms increase their import share, (2) import-intensive firms become bigger, and (3) exiting firms are less import-intensive than average.

Table 10 decomposes the average annual growth rate of industry TFP. Between 1992 and 2000, aggregate TFP rose by 29%. This corresponds to an annual growth rate of 3.15%.

Around 30% of aggregate productivity growth is attributable to a change in the import exposure of firms.

Recall from equation (20) that aggregate TFP growth can be decomposed into the within-firm TFP growth of continuing firms, the reallocation of resources towards more productive firms, and the exit of less productive firms. The first column of the table shows this decomposition for total TFP. The majority of growth is coming from a reallocation across continuing firms (1.57%).

The second column shows the same decomposition for the role of imports in productivity growth. The biggest source of import-related TFP growth is that firms increase their import share over time (0.47%). However, the reallocation of resources towards import-intensive firms contributes a comparable magnitude to annual productivity growth (0.40%).

6 Conclusion

This paper asks whether firms importing more become more productive. To obtain an answer, we first build a model of importers where importing a given product variety has a fixed cost, hence the number of varieties imported is a state variable. Such a model captures many of the stylized facts we find in a panel of Hungarian manufacturing firms between 1992 and 2001. Our model leads to a production function where productivity depends on the import share of inputs.

We then estimate this production function by extending the Olley and Pakes (1996) procedure to allow for two state variables, using entry in import markets to back out productivity. We have two main lessons from the estimation. First, imports have a large and significant effect on productivity: they account for 30% of the increase in productivity during the 1990s in Hungary. Second, reallocation effects are large: about half of the productivity growth caused by imports is a consequence of the reallocation of factors to importers. In future research, we intend to use our model and estimates to study various policy experiments, such as the effects of tariff reduction on productivity.

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Table 11a: Production function estimates for all industries

	Pooled				
	OLS	**FE**	**GMM**	**s.e.**	**p**
Capital	0.044***	0.016**	0.089***	(0.014)	*0.00*
Labor	0.166***	0.170***	0.162***	(0.018)	*0.00*
Materials	0.747***	0.732***	0.718***	(0.022)	*0.00*
Import share	0.196***	0.205	0.182***	(0.181)	*0.00*
rho			0.19***	(0.205)	*0.36*
Observations	3615	3615	2908		
R-squared	0.95	0.88			
J-test of overid.			0.003	Chi2(3)	*0.95*

	Foreign firms				
	OLS	**FE**	**GMM**	**s.e.**	**p**
Capital	0.040***	0.017	0.074***	(0.029)	*0.00*
Labor	0.205***	0.167***	0.203***	(0.027)	*0.00*
Materials	0.728***	0.720***	0.705***	(0.026)	*0.00*
Import share	0.118***	0.340	0.090*	(0.721)	*0.06*
rho			0.000	(0.348)	*1.00*
Observations	1991	1991	1597		
R-squared	0.95	0.88			
J-test of overid.			0.010	Chi2(3)	*0.89*

	Domestic firms				
	OLS	**FE**	**GMM**	**s.e.**	**p**
Capital	0.027***	0.017*	0.057***	(0.024)	*0.01*
Labor	0.165***	0.168***	0.163***	(0.029)	*0.00*
Materials	0.754***	0.780***	0.740***	(0.034)	*0.00*
Import share	0.156***	0.256*	0.285	(0.871)	*0.45*
rho			0.460	(0.263)	*0.14*
Observations	1624	1624	1177		
R-squared	0.95	0.87			
J-test of overid.			0.002	Chi2(3)	*0.97*

Notes: Dependent variable is log sales. *,**, and *** denote significance at 10%, 5%, and 1%. The FE specification includes firm fixed effects. The GMM specification corresponds to the estimation procedure outlined in Section 5. Standard errors and two-tailed p-values for difference from zero are obtained from a 200-repetition bootstrap.

Table 11b: Production function estimates for machinery

	Pooled				
	OLS	**FE**	**GMM**	**s.e.**	**p**
Capital	0.038***	0.016**	0.095***	(0.017)	*0.00*
Labor	0.165***	0.170***	0.157***	(0.020)	*0.00*
Materials	0.755***	0.732***	0.719***	(0.025)	*0.00*
Import share	0.245***	0.205	0.258**	(0.254)	*0.03*
rho			0.280	(0.205)	*0.25*
Observations	2726	2726	2187		
R-squared	0.94	0.88			
J-test of overid.			0.003	Chi2(3)	*0.95*

	Foreign firms				
	OLS	**FE**	**GMM**	**s.e.**	**p**
Capital	0.045***	0.017	0.092***	(0.031)	*0.00*
Labor	0.194***	0.167***	0.185***	(0.031)	*0.00*
Materials	0.738***	0.720***	0.703***	(0.034)	*0.00*
Import share	0.194***	0.340	0.170*	(0.839)	*0.09*
rho			0.000	(0.325)	*1.00*
Observations	1426	1426	1145		
R-squared	0.95	0.88			
J-test of overid.			0.007	Chi2(3)	*0.91*

	Domestic firms				
	OLS	**FE**	**GMM**	**s.e.**	**p**
Capital	0.015*	0.017*	0.052**	(0.023)	*0.04*
Labor	0.165***	0.168***	0.161***	(0.029)	*0.00*
Materials	0.755***	0.780***	0.735***	(0.040)	*0.00*
Import share	0.195***	0.256*	0.280	(0.862)	*0.41*
rho			0.410	(0.286)	*0.14*
Observations	1300	1300			
R-squared	0.95	0.87			
J-test of overid.			0.001	Chi2(3)	*0.98*

Notes: Dependent variable is log sales. *,**, and *** denote significance at 10%, 5%, and 1%. The FE specification includes firm fixed effects. The GMM specification corresponds to the estimation procedure outlined in Section 5. Standard errors and two-tailed p-values for difference from zero are obtained from a 200-repetition bootstrap.