Imports and Productivity[1]

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Abstract

How do imports affect firm productivity? To answer this question, we estimate a structural model of importers using a panel of Hungarian firms. In our model with heterogenous goods, imported inputs improve productivity because (1) they are imperfect substitutes of domestic inputs; and (2) they have higher quality. This model yields a production function where output depends both on conventional factors and the number of product varieties imported. We estimate this import-augmented production function with the Olley and Pakes (1996) procedure, and find that increasing the fraction of product varieties imported from 0 to 100 percent leads to a productivity gain of 14 percent. About two thirds of this gain can be attributed to imperfect substitution, while the remainder is due to the higher quality of imports. We also compute the effects of a hypothetical tariff cut, and find that for small firms, it improves productivity through importing more product varieties, while for large firms it improves productivity through increasing existing imports.

1 Introduction

Many economists believe that trade has substantial effects on income, a view supported by a number of cross-country studies using aggregate data.[1] Less is known, however, about the exact mechanism through which the beneficial effects of trade are realized at the level of the firm. Two important mechanisms identified in theoretical work are access to a greater number of product varieties (as in Krugman (1979)) and importing more high-quality foreign inputs (e.g., Grossman and Helpman (1991)). As Hallak and Levinsohn (2004) emphasize, understanding the contribution of different mechanisms through which trade affects growth is important for industrial and trade policy. For example, to evaluate the effect of a tariff change on consumer welfare, the policymaker may want to know which industries and firms are likely to be affected, as well as the effect on the product structure of these industries, the distribution of factors across firms, and tariff revenues.

Our goal in this paper is to explore the effects of trade on productivity at the firm level. Specifically, we ask whether imports increase the productivity of importing firms, and if so, through what mechanism. To answer this question, we build a simple model of importer-producers and estimate it structurally using a panel of Hungarian firms. Our structural model makes it possible to measure the contribution of different mechanisms through which imports affect productivity. Firm level panel data has an econometric advantage as well: we can make use of the Olley and Pakes (1996) procedure to deal with endogeneity problems that often plague macro level estimates.

In our model, importer-producers use differentiated intermediate goods to produce a final good. Each intermediate good has a domestic as well as a foreign variety, and producers may choose to import the foreign variety in exchange for a fixed cost. The domestic and foreign varieties within each good are imperfect substitutes, and the foreign variety has a quality advantage. As a result, importing foreign goods increases firm output through two channels: (1) a love-of-variety effect due to imperfect substitution; (2) a quality effect, because foreign goods are better than their domestic counterparts. Firms differ both in the fixed cost of acquiring foreign varieties and in their productivity, and hence make different choices about the number of varieties they import. Hence 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 leads to a firm level production function where output depends on the usual factors of production and an additional term related to the number of intermediate goods that the firm chooses to import. The key variable of interest is this last term, which reflects a combination of the two channels described above. Note that in a traditional production function which does not explicitly incorporate the role of imports, this term would be sub-

[1]For example, see Romer (1987), Grossman and Helpman (1991), as well as Coe and Helpman (1995), Barro (1997) and Frankel and Romer (1999).

sumed into the firm's total factor productivity. Our model also predicts that the import demand of the firm is a function of firm size and the number of foreign varieties the firm has chosen to import. Combined with the production function, this second equation can be used to separately identify the role of the love-of-variety and product quality channels in improving productivity.

To measure the impact of imports on firm productivity, we estimate our model in firm level data. Estimating the effect of imports in the production function would be straightforward if imports were randomly assigned to firms. In the absence of such randomized experiment, we need to deal with the difficulty that imports may depend on unobserved productivity, which leads to reverse causality problems. We cope with this endogeneity problem using the empirical methodology developed by Olley and Pakes (1996) and Levinsohn and Petrin (2003).

We estimate our model on a sample of Hungarian manufacturing firms between 1992 and 2003. Our data comes from two sources. Product level information on exports and imports is from the Hungarian Customs Statistics, which collects trade data at the firm level for 6-digit Harmonized System product categories. Data on firm characteristics, including factors of production, ownership and other balance sheet information comes from firms' financial statements. Two key advantages of this data for our purposes are the detailed product level information on imports, and the long panel dimension.

Our baseline estimates imply that imports have a statistically significant and large effect on firm productivity. As we increase the fraction of product varieties imported from 0 to 100 percent, firm productivity increases by 14 percent. About two thirds of this effect comes from the imperfect substitution of domestic and foreign goods, while the remaining one third is explained by the higher quality of foreign goods.

Our estimated model can also be used to conduct policy experiments. We consider the effect of a 10 percent tariff reduction on all imported products in a given industry. Interestingly, the tariff cut results in different behavioral responses depending on the size of the firm. For small firms, that are at the 25th percentile in the distribution of imported products, the tariff cut leads to an 1.9 percent increase in productivity, of which 60 percent is due to entering new import markets. In contrast, for a large firm that is at the 75th percentile in the distribution of imported products, the same tariff cut leads to a 4.2 percent increase in productivity, and 90 percent of this is due to increasing existing imports. Intuitively, large firms already participate in most relevant import markets, and hence the gains from additional import markets are likely to be limited.

Our paper builds on a large theoretical and empirical literature in international trade. Most closely related to our work is Broda, Greenfield and Weinstein (2006) and Broda and Weinstein (2006), who estimate the effect of new product varieties on aggregate productivity and consumer welfare. One important difference is that these papers make use of country level data, while we have access to information at the firm level. As a result, we are able to estimate firm level production functions and identify the role of specific mechanisms in greater detail, which allows us to conduct policy experiments.

Also related are Amiti and Konings (2005) and Muendler (2004), who study the impact of trade barriers on productivity using micro data. Amiti and Konings (2005) use Indonesian plant-level data to analyze how changes in input and output tariffs affect productivity. They find that reducing tariffs on imported intermediate inputs implies a bigger productivity gain than reducing the tariff on the product the firm produces. This is in contrast with Muendler (2004), who finds that output tariffs are more important in Brazilian data. Kasahara and Rodrigue (2004) estimate a production function similar to ours, where the share of imported inputs contributes to output. All of these papers take an essentially reduced form approach. As a result, they do not identify the relative contribution of the intensive and extensive margins, and in the absence of a structural model, they do not conduct policy experiments.

Bernard, Jensen and Schott (2005) provide a descriptive study of globally engaged U.S. firms using a new data set. Eaton, Kortum and Kramarz (2004) document detailed trade patterns at the firm level using French data. Tybout (2003) summarizes earlier plant and firm level empirical work testing theories of international trade. One robust finding of this literature is that exporting firms are more productive than those selling only domestically (see Bernard and Jensen (1999), among others).

The rest of this paper is organized as follows. Section 2 describes our data and collects several stylized facts about importers in Hungary. Building on these stylized facts, Section 3 develops a simple model of importer-producers. Section 4 describes the estimation procedure and results. Section 5 conducts two simple policy experiments, and Section 6 concludes.

2 Data

2.1 Data description

Our data consists of a panel of Hungarian exporting companies from 1992 to 2003. This data comes from two sources, the Hungarian Customs Statistics and firms' balance sheets and earnings statements. The Customs Statistics data contains firms' annual exports and imports measured both in currency and in tons. This trade data is available at the disaggregate level of 6-digit Harmonized System (HS) product categories (5,200 categories). We aggregate the data up to the 4-digit level (1,300 categories) because the 6-digit classification is noisy.[2] Using the product level classification of Rauch (1999), these goods can be further broken down into homogenous and differentiated products. We will make use of this categorization in the empirical analysis.

[2]For example, firms often switch their main export product at the 6-digit level whereas this happens infrequently at 4 digits.

Our sample of firms is the universe of all Hungarian companies which exported more than 100 million forints (approximately 500,000 U.S. dollars) in any of the years between 1992 and 2003. There are 2,043 such companies, which are responsible for the bulk of Hungarian exports, ranging from 47% in 1992 to 76% in 1999.[3] Table 1 reports summary statistics for several key variables in our sample, and also compares our sample to a representative sample of Hungarian firms. The key differences are that firms in our sample are bigger, more capital-intensive, more export-oriented and more likely to be foreign-owned. None of these differences are surprising given the way the sample was selected. Interestingly, average labor productivity for the firms in our sample does not appear to be higher than for the representative sample of all Hungarian firms.[4]

Table 2 summarizes the main trends in the data over time. There is a marked shift towards greater international participation during our sample period. For example, the ownership composition of firms shifts away from state-owned firms towards foreign-owned firms. Similarly, both the share of imports in intermediate inputs and the average number of imported products increases over time.

One key limitation of the data is that we do not have product level information for domestic inputs used by the firms in our sample. As we explain below, the structural approach helps address this problem: in our model the effect of imports on productivity can be estimated even in the absence of product level breakdown for domestic inputs, as long as such data for foreign inputs is available.

2.2 Stylized facts about firm-level imports

We now turn to document some basic empirical facts about the importing behavior of firms in our data.

Fact 1. There is substantial heterogeneity in the import patterns of firms.

Heterogeneity in importing behavior is reflected by the fact that about $4-7$ percent of firms in our sample do not import at all. Figure 1 shows the relationship between importing behavior and size by plotting the number of imported products (HS4 categories) as a function of firm size for foreign and domestic firms. The lines correspond to nonparametric estimates of the relationship between product number and employment. The number of imported products sharply increases in size: doubling firm size would increase the number of imported products by 30 percent. However, even controlling for firm size, foreign firms tend to import about twice as many products as domestic ones.

This pattern is consistent with a model where entry in import markets entails a fixed cost, perhaps because it requires establishing and maintaining business connections. Larger

[3]We have data on firms' exports from two sources: their financial statement and disaggregated customs statistics. The correlation between these two measures across firms is 0.953.

[4]We discuss the effects of sample selection on our estimates in Section 4.8 below.

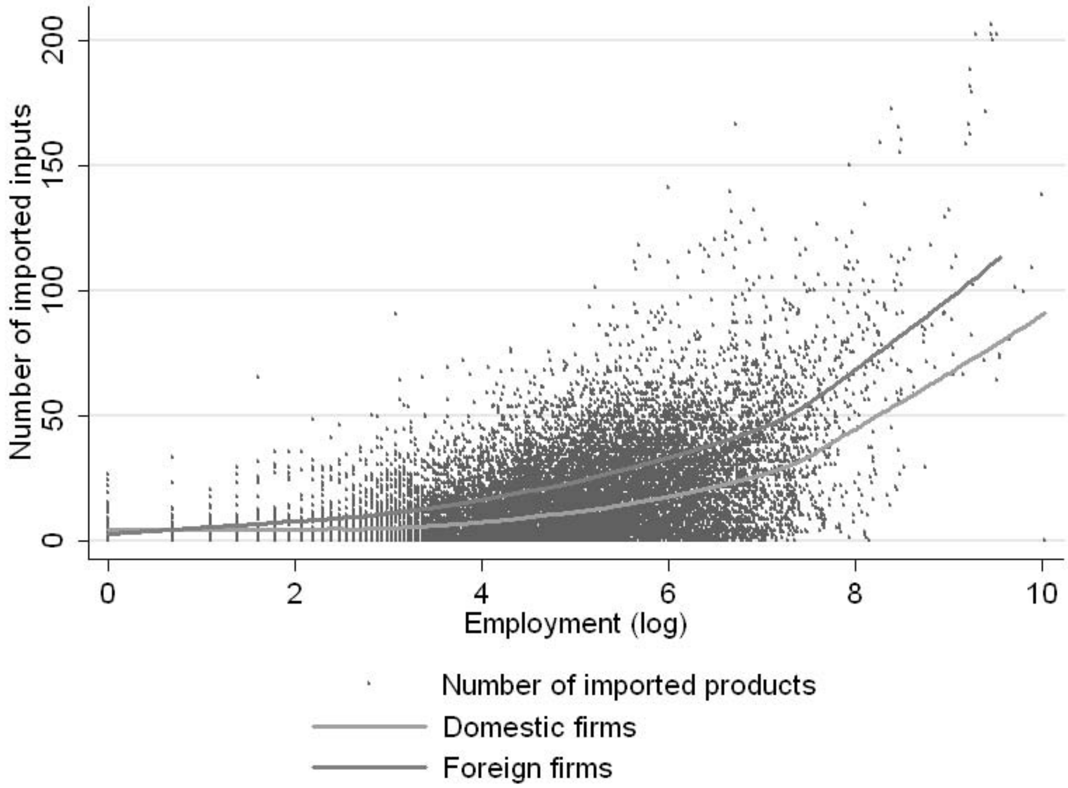

Figure 1: Number of imported inputs and firm size

firms profit more from buying the product and hence are more likely to overcome the fixed cost. This explanation is consistent with the finding that foreign firms import a greater number of varieties conditional on size, because these firms are likely to have a business network abroad, and hence their fixed costs are probably lower.

Taken together, the evidence on import heterogeneity suggests that firms have nontrivial import demand, implying that they do not view domestic products as perfect substitutes for imports.

Fact 2. Imports are concentrated on a few products, and firms spend little on the remainder of products.

The expenditure on additional imported product varieties declines sharply with the number of goods imported: for example, the average firm spends 45% of its import budget on the largest product category and only 4% on the fifth largest category. Figure 2 illustrates this pattern for a randomly selected large firm in the data by plotting the log of spending on an imported good against the log rank of the good among goods imported by the firm. Analogous figures for other firms in the data look almost identical.

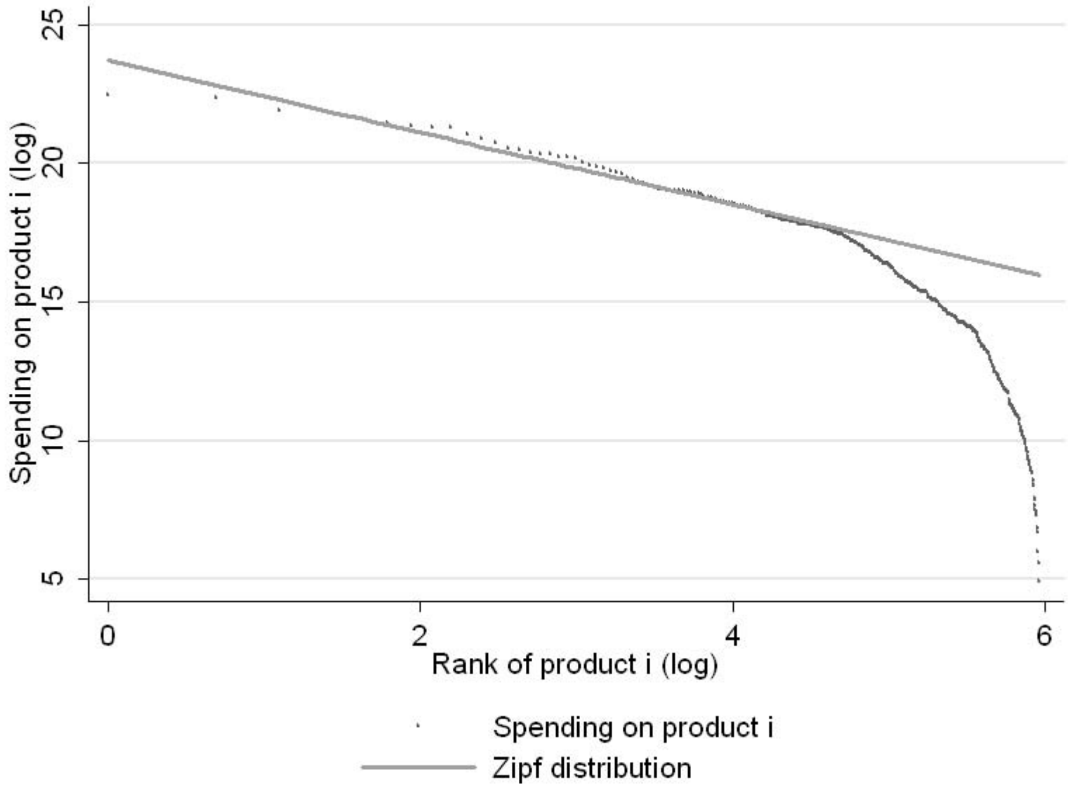

Figure 2: The distribution of spending across products

The plot shows a remarkably linear relationship in much of the sample, except for products with a very low rank where log spending declines even more sharply with additional varieties. The linear pattern means that the budget share of additional imported varieties declines according to a power law for much of the sample.

This figure suggests that the returns to additional imported products diminish quickly, since many of the imported products contribute only a small amount to overall material costs. This finding implies that we cannot treat product categories symmetrically as in a Dixit-Stiglitz model; we need to take into account diminishing demand for additional imported varieties in our structural model.[5]

Fact 3. Growing firms enter new import markets and shrinking firms exit their existing import markets.

Figure 3 plots the change in the number of products (relative to the number of products last year) against sales growth. Growing firms increase the number of products imported,

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

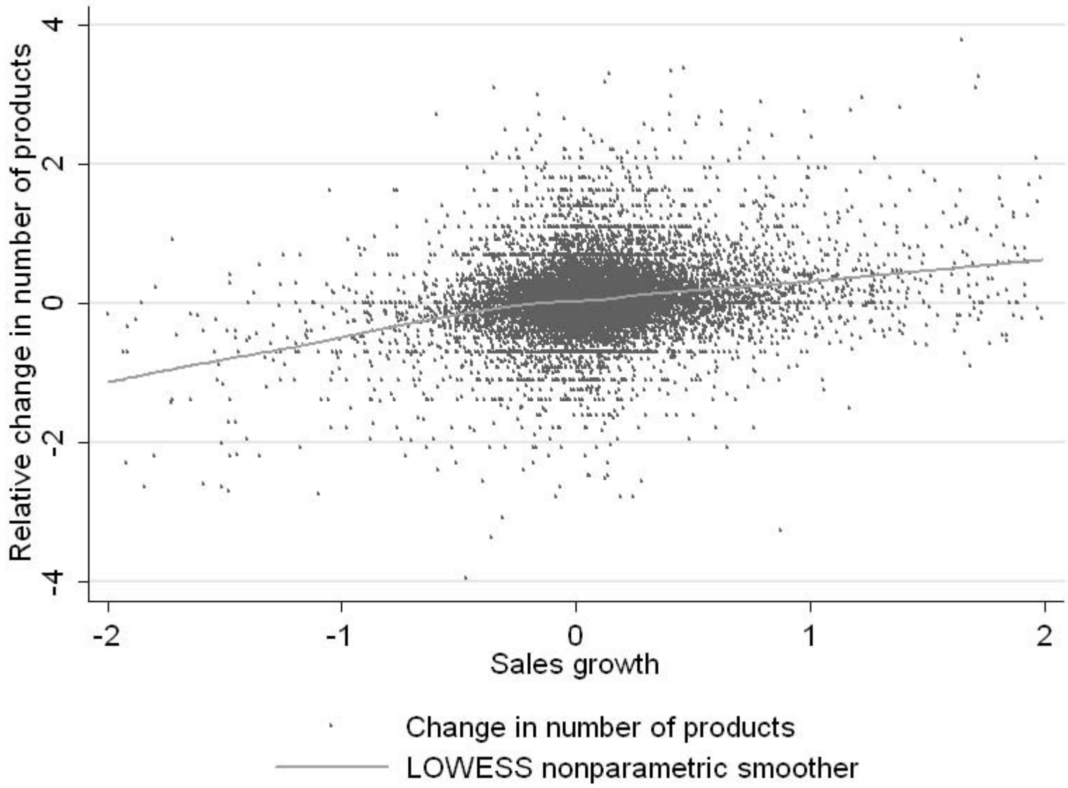

Figure 3: Product market entry and firm growth

perhaps because it becomes easier for them to overcome the entry cost. Similarly, shrinking firms exit their current import markets. This finding suggests the costs of participating in import markets are best modelled as fixed costs and not sunk costs: firms who want to continue importing a particular good need to pay the cost every period.

3 A Model of Imports and Productivity

This section introduces our model of heterogenous importers, based on the stylized facts documented above.

3.1 Production technology

Firms use capital, labor and materials in their production process. Total output is determined by the following production function

$$Y = \Omega K^{\alpha} L^{\beta} \prod_{i=1}^{\mathcal{N}} X_i^{\gamma_i}, \tag{1}$$

where K denotes capital inputs, L labor inputs, X_i is the amount of composite good i and Ω is Hicks neutral total factor productivity (TFP). Here γ_i is the Cobb-Douglas weight of composite good i in the production process. We denote the total weight of all intermediate goods by $\gamma = \sum_i \gamma_i$.

Each good X_i is assembled in the firm from a combination of two varieties, a foreign and a domestic one:

$$X_i = \left[(AX_{iF})^{\frac{\theta-1}{\theta}} + X_{iH}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{2}$$

where the quantity of foreign and domestic inputs are denoted by X_{iF} and X_{iH}, and θ is the elasticity of substitution between them. Both X_{iF} and X_{iH} are measured in dollars (after proper normalization) so that $(X_{iF} + X_{iH})$ is total spending on good i. The parameter $A \geq 0$ measures the quality difference of foreign goods and their domestic counterparts.[6] More specifically, one dollar's worth of the foreign good is A times as productive as \$1 of the domestic good. Because A measures price-adjusted quality, any changes in the relative price of foreign and domestic inputs will be reflected in A. For example, a 5 percent reduction in tariffs increases A by 5 percent.

Note that even if $A \leq 1$, it is worth to buy foreign goods, because they imperfectly substitute for domestic goods. Similarly, as long as $\theta < \infty$, it is never optimal to buy only foreign goods.[7]

Two features of the production technology (1) are noteworthy. First, to increase flexibility, this production function does not necessarily exhibit constant returns to scale. Second, the Cobb-Douglas specification allows for a certain level of substitution between different intermediate inputs as well as capital and labor. Such substitutability is commonly assumed in the literature, and can reflect the trade-off between in-house production versus outsourcing of intermediate products: the former requires greater labor inputs but smaller purchases of intermediate inputs. The Cobb-Douglas specification also implies that all inputs are essential in the production process: if the use of any factor or intermediate good falls to zero, total output also becomes zero.

3.2 The productivity gains from importing

We now develop a measure of productivity that captures the productivity gains from the love-of-variety and differential product quality channels discussed earlier. Because the set and composition of intermediate inputs varies across firms depending on their access to

[6] It is plausible that $A > 1$ in our empirical application, since Hungary is a developing country with a majority of its imports from advanced economies. Also note that it is not restrictive to assume one variety both home and abroad. If the number of foreign and domestic varieties substantially differ, that will be reflected in A.

[7] In this discussion we assume that the parameters A and θ are constant across firms and products. In the estimation, we allow them to depend on broad product categories. We discuss the implications of firm-specific A in Section 4.8.

import markets, computing productivity is not straightforward. The approach we take here is to measure productivity by looking at the marginal cost schedule of the firm. Intuitively, firms with higher productivity should produce an additional unit of the final good at a lower marginal cost for a given set of input prices.

The marginal cost function of the firm, ignoring constants, is

$$C(Y, R, W, \{P_i\}) = Y^{1/(\alpha+\beta+\gamma)-1}\Omega^{-1/(\alpha+\beta+\gamma)}R^{\alpha/(\alpha+\beta+\gamma)}W^{\beta/(\alpha+\beta+\gamma)}\prod_{i=1}^{\mathcal{N}} P_i^{\gamma_i/(\alpha+\beta+\gamma)} \tag{3}$$

where R is the cost of capital, W is the wage rate, and P_i is the cost-minimizing price of the bundle X_i conditional on the entry decision in import markets. More specifically, given that the prices of both domestic and foreign intermediate inputs are normalized to one, $P_i = 1$ if the firm only uses domestic inputs. However, if the firm uses both domestic and foreign inputs for a given good X_i, we have $P_i < 1$, because combining the two inputs results in the same composite X_i at a lower cost. Given the decision to import, P_i can be computed by finding the optimal combination of domestic and foreign goods as

$$P_i = \begin{cases} \left[1 + A^{\theta-1}\right]^{1/(1-\theta)} & \text{if } i \text{ is imported,} \\ 1 & \text{otherwise.} \end{cases} \tag{4}$$

We denote by a the percentage decrease in the cost of bundle i if it uses imported products,

$$a = \frac{1}{\theta - 1} \ln\left[1 + A^{\theta-1}\right], \tag{5}$$

and introduce the indicator variable χ_i that takes the value one if product i is imported and zero otherwise.

With this notation, the log of the cost function (3) can be written as

$$\ln C = \frac{1}{\alpha+\beta+\gamma}\left[(1-\alpha-\beta-\gamma)y - \omega + \alpha r + \beta w - a\sum_{i:\chi_i=1}\gamma_i\right].$$

This equation suggests that firm total factor productivity can be measured by

$$\omega + a\sum_{i:\chi_i=1}\gamma_i, \tag{6}$$

where the efficiency gains due to imports are captured by $a\sum_{i:\chi_i=1}\gamma_i$, while ω represents "residual" productivity. The intuition for this decomposition is straightforward: if the firm uses foreign inputs for a larger set of intermediate goods, it enjoys efficiency gains due to both the love-of-variety and product quality channels. The productivity gain from importing variety i is proportional to the cost saving from imports, a, as well as the Cobb-Douglas weight of product i in the total output, γ_i.

We now show that the productivity measure (6) can also be used to obtain a more standard expression for the production function of the firm. Define $M = \sum_i P_i X_i$ as the total dollar spending on intermediate inputs. Given our Cobb-Douglas production function, M must equal the price index of all inputs times the Cobb-Douglas aggregate of the inputs:

$$M = \prod_{i=1}^{\mathcal{N}} P_i^{\gamma_i/\gamma} \prod_{i=1}^{\mathcal{N}} X_i^{\gamma_i/\gamma},$$

where $\gamma = \sum_{i=1}^{\mathcal{N}} \gamma_i$ is the overall importance of intermediate inputs in production. Using the expression for the cost-minimizing price P_i and taking logs

$$m = -\frac{a}{\gamma} \sum_{i:\chi_i=1} \gamma_i + \frac{1}{\gamma} \sum_{i=1}^{\mathcal{N}} \gamma_i x_i.$$

This last expression can be substituted into the production function (1) to obtain the following reduced form expression for log output:

$$y = \alpha k + \beta l + \gamma m + a \sum_{i:\chi_i=1} \gamma_i + \omega. \tag{7}$$

This equation has the form as a standard production function, where log output depends on various factors. The first three terms on the right hand side measure the contribution of capital, labor and intermediate inputs to total output. The novelty lies in the last two terms, which, by equation (6) decompose total factor productivity into the effect of imports and residual productivity.

3.3 The decision to import

Equation (7) shows that participating in import markets has a positive effect on output. Therefore, absent other considerations, firms would find it optimal to import a positive amount of all foreign input varieties. But it is clear from the data that most firms only import only a few product varieties and some firms do not import at all.

One plausible reason for this empirical pattern is that importing any given product variety i has an associated fixed cost each period. For example, importing a product might require maintaining a business connection, and that has a certain cost even if the purchased quantity is small. A fixed, rather than a variable cost of entry is also consistent with the stylized facts reported in Section 2, where we showed that small firms tend to import fewer categories of products or even have no imports at all. These fixed costs likely to be recurring every period, because, as Section 2 established, there is substantial variation over time in the set of products each firm imports. This suggests that when firms are hit by negative shocks, they may decide to stop importing some products to save some fixed costs.

Motivated by these observations, we introduce a fixed cost associated with entering each import market. These fixed costs are assumed to be constant across products, but may vary across firms, because some firms, such as foreign-owned companies, might find it cheaper to enter import markets. We assume that the costs are due every period when a given variety is imported.

We now formalize the firm's choice of entering import markets. Suppose, without loss of generality, that intermediate products are ordered by decreasing γ_i, and let G_k denote

$$G_k = \sum_{i=1}^{k} \gamma_i,$$

with $G_0 = 0$. This is an increasing, concave function that asymptotes to γ. Recall from (5) that a denotes the proportional decrease in the cost of a given product i if the associated foreign variety is imported. By the Cobb-Douglas specification, total spending on good i is $\gamma_i Y$, where Y is total output. Hence the firm will find it optimal to import variety i if and only if

$$\gamma_i a Y \geq f, \tag{8}$$

that is, if the cost saving in production exceeds f, the firm's fixed cost of entry to import market i.

It follows that the firm will import those products X_i that have the highest γ_i values. Let n denote the number of foreign varieties that the firm chooses to import. Then the total expenditure on these varieties is

$$\sum_{i=1}^{\mathcal{N}} X_{iF} = sY \sum_{i=1}^{n} \gamma_i = sYG_n, \tag{9}$$

where $s = A^{\theta-1}/(1 + A^{\theta-1})$ is the optimal share of foreign inputs in a given product i.

4 Estimation

4.1 Estimating equations

Our goal is to estimate the structural parameters of the production function α, β, $\{\gamma_i\}$, A and θ, as well as the firm-specific fixed cost $\tilde{f}$, which governs the entry into import markets. To identify these parameters, we estimate three equations derived from our theoretical model.

Our first estimating equation is the production function (7). It will be convenient to introduce the notation $V_n = G_n/\gamma$ which measures the relative contribution of those product varieties that are imported in the composite of all intermediate goods. Thus V_n is an increasing function of n and always falls between zero and one. With this notation, the production function becomes

$$y = \alpha k + \beta l + \gamma m + \delta V_n + \tilde{\omega}, \tag{10}$$

where $\delta = a\gamma$ and $\tilde{\omega}$ is residual productivity, part of which may be observable by the firm before making input choices. The intuition for this equation is simple: firms that import a greater number of product categories, so that their V_n is higher, have higher output conditional on traditional inputs, including overall spending on intermediates (m).

The second estimating equation is for the import demand of the firm. Equation (9) yields

$$\frac{X_F}{Y} = s\gamma V_n + \tilde{u} \tag{11}$$

where X_F is the total expenditure on foreign varieties, and the error term $\tilde{u}$ captures measurement error and other unmodelled variation in imports. Firms that import a greater number of products spend a larger fraction of their output on imported inputs.

Finally, we look at endogenous entry to import markets. The inequality (8) implies that if the firm imports exactly n foreign varieties, then

$$a\gamma_n Y = \tilde{f} \tag{12}$$

must hold, where $\tilde{f}$ is the firm specific fixed cost of entry in import markets, which can vary across firms and over time.

Before proceeding with the estimation, we need specify our identifying assumptions about the error terms in equations (10), (11) and (12). Estimating (10) is difficult, because the unobserved error term $\tilde{\omega}$ is likely to be correlated with all variables on the right hand side, for example due to reverse causality problems. As a result, simple ordinary least squares estimates will bias the point estimate of our key import share coefficient. To deal with this problem, we use the estimation strategy originally proposed by Olley and Pakes (1996). The key identification assumptions required for this procedure are the following: (1) $\tilde{\omega}$ can be written as a sum of two terms, a deterministic, monotonic function of observables such as investment, and an innovation orthogonal to other variables on the right hand side of (10). (2) The first term in this decomposition of $\tilde{\omega}$ follows a first-order Markov process.[8]

To estimate equation (11), we assume that $\tilde{u}$ is classical measurement error, orthogonal to the decision to enter import markets and hence the number of imported inputs n. This identifying assumption allows us to estimate (11) using an ordinary least squares regression. One important case where this assumption is violated is when there is cross-firm heterogeneity in s, which would result in a nonzero correlation between $\tilde{u}$ and G_n. Section 4.8 discusses the robustness of our estimates to allowing for such heterogeneity. Finally, our estimating procedure requires no assumptions about the error term $\tilde{f}$ in equation (12).

Given the above identifying assumptions, equations (10) and (11) allow us to estimate all parameters of the model. We can then use equation (12) to back out the firm specific fixed costs. We now turn to describe our estimating procedure in more detail.

[8]See Olley and Pakes (1996) for a discussion of the validity of these assumptions.

4.2 Estimating the input weights γ_i

We begin with estimating the parameters γ_i which summarize the role of different intermediate goods in the firm's production process. As we discussed in Section 2, import spending is heavily concentrated on a few big products. To capture this pattern with the γ_i coefficients, we assume that the cross-product distribution of γ_i follows a Zipf distribution (which is the discrete version of the Pareto distribution), so that

$$\gamma_i = \gamma i^{-\xi} \frac{1}{H_{\mathcal{N},\xi}}, \tag{13}$$

where $H_{\mathcal{N},\xi}$ is a constant ensuring that the γ_i parameters sum up to γ.

The power coefficient ξ in equation (13) can be estimated by regressing the log import share of product i on the log rank of product i within the firm.[9] (See Figure 2.) When we run this specification on our sample of firms, we find a point estimate of $\hat{\xi} = 1.7$ with an R^2 of 0.88, suggesting that the Zipf distribution very precisely describes the distribution of import shares across products. The coefficient $\hat{\xi}$ can be used to back out γ_i/γ, that is, the relative contribution of each intermediate good in the composite of all intermediate goods. To estimate the actual γ_i values, we need to use an estimate of γ, which we obtain in the next section.

Since the production function (10) has V_n on the right hand side, we also need a way to express this quantity. Given specification (13) for γ_i, V_n can be written as

$$V_n = \frac{H_{n,\xi}}{H_{\mathcal{N},\xi}},$$

where $H_{n,\xi}$ is called the generalized harmonic number given n and ξ. Generalized harmonic numbers can be computed numerically, but a simple analytic approximation can also be derived by considering the continuous counterpart of G_n and V_n, where the summation over γ_n is replaced by an integral that can be solved in closed form. This yields the approximate identity

$$V_n \approx \left[1 - \frac{n^{1-\xi}}{(\xi - 1)H_{\mathcal{N},\xi}}\right]. \tag{14}$$

We use our estimate of ξ to compute V_n from this expression, thus obtaining the key import term in the right hand side of the production function (10).

4.3 Estimating the production function

We estimate (10) using the Olley and Pakes (1996) method to account for unobserved heterogeneity in $\tilde{\omega}$. As Olley and Pakes, we conjecture that, conditional on the observable state

[9] This follows from our assumption that s is the same across products. Hence the relative import spending of any two products i and j coincides with the relative total spending, γ_i/γ_j.

variable k, investment I is a monotonic function of productivity,

$$I_{jt} = f(\omega_{jt}, k_{jt}), \tag{15}$$

where j denotes firms and t stands for time. Assuming that (15) is invertible in its first argument we obtain

$$\omega_{jt} = g(I_{jt}, k_{jt}).$$

Combining this with (10) leads to

$$y_{jt} = \alpha k_{jt} + \beta l_{jt} + \gamma m_{jt} + \delta V_{njt} + g(I_{jt}, k_{jt}) + \varepsilon_{jt}, \tag{16}$$

where ε_{jt} is the part of productivity that is not observable to the firm, i.e., the part that is orthogonal to firm decisions.

Equation (16) has the advantage that the error term ε_{jt} is orthogonal to all right hand side variables. Therefore, estimating (16) in ordinary least squares allows us to obtain consistent estimates of β, γ and, most important, the key coefficient δ. The only difficulty is the presence of the unobserved function $g(I_{jt}, k_{jt})$, but we can approximate that using nonparametric functions of I_{jt} and k_{jt}.[10]

The next step is to obtain a consistent estimate of α, which is not identified in regression (16). To facilitate the estimation of α, we assume that unobserved productivity ω follows a first-order Markov process conditional on observed state variables, which we approximate with an AR(1) process that has autocorrelation ρ:

$$\mathrm{E}_t\, \omega_{j,t+1} = \rho\omega_{jt}.$$

For any given α and ρ, we can subtract ρ times $\omega_{j,t-1}$ from the current estimated ω_{jt} to obtain productivity innovations

$$u_{jt} \equiv [y_{jt} - \alpha k_{jt} - \beta l_{jt} - \gamma m_{jt} - \delta V_{jt}] - \rho g(I_{j,t-1}, k_{j,t-1}).$$

These innovations are orthogonal to all information available at time $t-1$, i.e., $\mathrm{E}(u_{jt}|\mathbf{Z}_{j,t-1}) = 0$. This orthogonality condition can be used in a generalized method of moments estimation with instrument set Z. To implement this estimate, we use as instruments current and lagged capital, lagged employment, lagged material cost, lagged number of products, and the lagged import share.

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

$$\mathrm{E}(u_{jt}|\mathbf{Z}_{j,t-1}, \text{survival}\ ) \neq \mathrm{E}(u_{jt}|\mathbf{Z}_{j,t-1}). \tag{17}$$

[10]In practice we approximate $g(I_{jt}, k_{jt})$ with third-order polynomials of I, k, and other control variables.

To correct for the bias in (17), we first obtain propensity scores for exit by running a linear probability regression on current and lagged capital and other controls. As expected, firms with more capital are less likely to exit. We then control for this propensity score nonparametrically in the instrumental variables regression.

Because of the linearity of the production function, the parameter α 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 our specifications, verifying that productivity innovations are indeed orthogonal to all of the instruments. This procedure yields estimates of the parameters α, β, γ, δ, and hence $a = \delta/\gamma$ as well.

4.4 Identifying structural parameters

We next estimate the import demand equation (11). Given estimates of γ and V_n, we can compute γV_n which is on the right hand side of (11), and an ordinary least squares regression can be used to identify the coefficient s given our exclusion restrictions.

Given our estimates of s and a, we can recover the structural parameters A and θ using the model. Identifying A and θ is important, because these parameters measure the importance of the quality and the variety channels in determining the overall effect of imports on productivity. The model implies the following expressions for A and θ:

$$\ln \hat{A} = \hat{a} \left[1 - \frac{\ln \hat{s}}{\ln(1 - \hat{s})} \right], \tag{18}$$

$$\frac{1}{\hat{\theta} - 1} = \frac{\hat{a}}{- \ln(1 - \hat{s})}. \tag{19}$$

These equations can also be used to gain intuition about the identification of the quality and the variety channels. The term $\ln \hat{A}$ in the first equation measures the magnitude of the quality channel, while $1/(\hat{\theta} - 1)$ is inversely related to $\hat{\theta}$ and hence is increasing in the importance of the variety channel. To interpret these equations, first note that both the quality and variety channels are proportional to $\hat{a}$, which is the measure of total benefits from importing. Intuitively, this is because both channels contribute positively to the overall productivity gain from imports.

To assess the relative importance of the two channels, note that changes in the import share parameter $\hat{s}$ have opposing effects on the estimated magnitude of the quality and variety channels: for a fixed $\hat{a}$, the quality effect is increasing while the variety effect is decreasing in $\hat{s}$. The intuition for this result is straightforward. A higher quality differential induces firms to spend more on imports relative to domestic inputs, leading to a higher s. In contrast, higher complementarity calls for keeping imports and domestic inputs in proportion to one another, resulting in a lower s.[11] For example, in the limit when foreign and domestic inputs are no longer substitutes ($\theta = 1$), the firm would spend equal amounts on both ($s = 1/2$), regardless of the quality differential.

To summarize, a high value of $\hat{a}$ results in higher estimates for both the quality and variety channels, while the relative contribution of these channels is governed by the magnitude of $\hat{s}$. We use this logic to identify the key parameters of the model and the contribution of the quality and variety channels to the total gains from importing.

4.5 Computing fixed costs

We now turn to estimate the firm specific fixed costs that govern the decision to enter import markets. The key idea here is that firms only import those varieties where the the improvement in productivity compensates for the fixed cost of entry. Given $\hat{a}$, which measures the productivity improvement from imports, data on the number of varieties imported by each firm allows us to back out an estimate of the firm specific fixed cost.

According to equation (8), $a\gamma_n Y$ is the improvement in output that results from entering the import market of good n. Thus the firm-specific fixed cost can be approximated as

$$f = \gamma_n a Y, \tag{20}$$

which is just an indifference condition stating that the benefit of entering the last (n-th) product market should be approximately equal to the fixed cost of entry. The intuition behind identifying fixed costs using (20) is straightforward: firms who import a large number of foreign varieties relative to their size are inferred to have small fixed costs.

Note that if the gap in the benefit between importing n or $n+1$ varieties is large, so that $\gamma_n \gg \gamma_{n+1}$, then equation (20) is only an approximation, as we can only identify an interval where the fixed cost must lie: $\gamma_n \geq f/(aY) \geq \gamma_{n+1}$. For large enough n, these intervals are tight and $f = \gamma_n aY$ is a good approximation. However, for small values of n, in particular, for firms who do not import at all ($n = 0$), this can be an important limitation of the above approach. For these firms, we can only identify a lower bound on their fixed cost: $f \geq \gamma_1 aY$.

4.6 Standard errors

We obtain standard errors of all parameters from a bootstrap. We bootstrap the estimates by sampling firms in the data with replacement, keeping the entire time series of a firm together. We do this because the estimation of the capital coefficient relies of past and future information about the firm because of the dynamics of productivity, the endogeneity of exit and the use of lagged variables as instruments, and hence we cannot treat time periods as independent observations.

[11] Note that as long as $A \geq 1$, s is never smaller than $1/2$, because conditional on importing a given product, the share of imports must be at least 50 percent if foreign goods are not worse than domestic goods.

The bootstrap procedure is as follows. First we create 200 random samples from the data. Then, for each new sample, we repeat the estimation steps described above to fan out the empirical distribution of all parameters. Our tables report the standard errors computed in this way, and, where the skewness of the distribution makes it necessary, the empirical 95-percent confidence interval of the parameter estimate as well. We do not report standard errors for fixed costs, because these are estimated with substantial noise, since there is a fixed cost estimate for each firm and year.

4.7 Estimation results

Table 3 shows the results from our estimation. Column 1 columns show the simple OLS estimates of the production function (10) for comparison. We expect the OLS coefficients of freely adjustable inputs, like labor, material, and imported inputs, to be upward biased due to reverse causality, while the coefficient of capital is likely to be downward biased because of exit. 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.

Column 2 reports the results of the GMM procedure outlined in the previous section. The control function $g(\cdot)$ used to take out variations in unobserved productivity in the first stage of the Olley-Pakes procedure contains third-order polynomials of investment, export share and capital, estimated separately for each year, ownership category and two-digit industry. We use capital, lagged capital and lagged imported capital goods as instruments in the second stage to identify the coefficient of k.

The OLS estimate shows a highly significant positive association between the Cobb-Douglas weight of imported products V_n and productivity: a 10 percentage point increase in V_n is associated with a 1.2% increase in output with the same amount of inputs. However, this relationship cannot be interpreted as a causal effect because of the endogeneity problems mentioned earlier.

Comparing columns 1 and 2, we find that the OLS coefficients of labor and materials do tend to be larger than the Olley-Pakes estimates, consistent with the reverse causality bias described above. However, the bias appears to be modest in practice. There is a larger difference for the capital coefficient, which is significantly lower in OLS than in the Olley-Pakes estimates, consistent with the bias introduced by endogenous exit.

The key import coefficient δ in column 2 has a point estimate of 0.136. This means that a 10 percentage point increase in the Cobb-Douglas weight of goods imported leads to a 1.4 percent increase in productivity. This estimate implies that the proportional benefit of importing a given product is $a = \delta/\gamma = 0.194$. In words, the foreign-domestic bundle in a given product variety is about 19 percent more productive than a domestic good of the same cost.

Our estimates can be used to back out the structural parameters A and θ as well. We find that the quality differential is $A = 1.068$ and significantly different from one. This means that foreign goods are of about 7 percent better quality than their domestic counterparts. Given that the total gain from importing a particular variety is 19.4 percent, the quality channel is about one third of the overall gain in productivity due to importing a foreign good. The remaining two thirds of the total gain must come from the fact that domestic and foreign inputs are imperfect substitutes. Consistent with this, we find that the elasticity of substitution between domestic and foreign goods is not too high at $\theta = 5.4$. We further discuss the quantitative importance of these parameters when we conduct two policy experiments in the next section.

One concern with these estimates is that they assume that the benefit from importing remains constant during the time period in our sample. However, the 1990s were a period of rapid change and economic development in Hungary, accompanied by increasing trade integration. As a result, it is possible that there was variation in the benefit from importing over time. To allow for this possibility, we next estimate an extended model where the parameter A is allowed to vary over time, but θ is held fixed at the unconditional estimate of 5.4. Table 4 reports the results from this estimation.[12]

Column 1 in Table 4 reports the productivity gain from importing in each year during our sample. This overall gain varies between 7 percent and 22 percent, and is significantly positive in all of the years. As above, this overall gain can be decomposed into a quality and a variety effect. The quality advantage of foreign goods, A, reported in column 2, varies between 0.77 and 1.12, and is rarely significantly different from one. This suggests that most of the productivity gain comes from the complementarity between domestic and foreign inputs. Both the total productivity gain and the quality advantage of foreign goods are particularly low in the years 1994, 1995, and 2000 through 2002. This is consistent with macroeconomic events in Hungary during these years. 1994-95 was a period of temporary protectionism and high tariffs, which can explain the low price-adjusted benefits of importing. The 2000-2002 period witnessed a global slowdown and simultaneous deterioration in domestic public finances in Hungary, which was accompanied by a slowdown in both imports and exports at the aggregate level.

We now turn to describe the estimated fixed costs of entering import markets. Table 5 reports the median fixed cost across firms for each year and ownership category. Costs are measured in 1995 dollars. Domestic firms have more than twice as high fixed costs as foreign-owned firms, and the fixed costs faced by state-owned firms are even higher. These findings are driven by the fact that conditional on size, foreign firms import substantially more product categories than domestic private or state firms. The results are consistent

[12]Because θ is held fixed, the model becomes overidentified, but can still be estimated using the generalized method of moments by minimizing an appropriate moment condition.

with foreign-owned firms finding it easiest to enter import markets due to their preexisting connections abroad.

4.8 Robustness

In this section we address the robustness of the estimates to heterogeneity in the key parameters of the model and related endogeneity concerns, as well as sample selection.

Heterogeneity in the benefit of imports. The model assumes that the benefits of importing, measured by A and θ, are identical across firms. It is important to note, however, that heterogeneity in these parameters may lead to endogeneity problems and possibly bias our estimates. Intuitively, firms who enjoy greater benefits from importing would both have higher productivity and import more. This omitted variable bias can introduce a spurious positive correlation between imports and productivity.

To assess the quantitative importance of this heterogeneity, consider an extension of our model where firms earn different quality gains from importing, so that A varies across firms, but the elasticity of substitution θ is constant. Then the productivity of firm j can be written as

$$\text{TFP}_j = a_j G_j + \omega = \frac{1}{\theta - 1} \ln\left(1 + A_j^{\theta-1}\right) G_j + \omega,$$

which is increasing in A_j. The optimal import share of this firm is

$$s_j = \frac{A_j^{\theta-1}}{1 + A_j^{\theta-1}},$$

which is also increasing in A_j. Substituting out A_j using the import demand equation, we can express firm productivity as a function of the import share as

$$\text{TFP}_j = \frac{1}{\theta - 1} \ln\left(\frac{s_j}{1 - s_j}\right) G_j + \omega.$$

This equation shows that productivity is an increasing, *convex* function of the import share s_j. Intuitively, the marginal gain from a unit increase in imports is higher for firms that already import a large amount, as these are the firms for whom imports yield the highest quality gains. The convex relationship between import share and productivity arises only because of heterogeneity in A: when A is constant across firms, the marginal gain from importing is also constant, and hence the relationship between productivity and the import share is linear.

This observation can be used to test for heterogeneity in A across firms. Figure 4 plots estimated productivity across firms against the share of imports in total cost.[13] The solid line is the result of a nonparametric regression used to capture any nonlinearities in the relationship between productivity and the import share.[14] The estimated relationship is remarkably

[13] Estimated productivity is defined as $y - \hat{\alpha}k - \hat{\beta}l - \hat{\gamma}m$, where $\hat{\alpha}$, $\hat{\beta}$, $\hat{\gamma}$ are the estimated coefficients.

[14] The nonparametric estimate is a locally weighted smooth regression (LOWESS) with a low bandwidth.

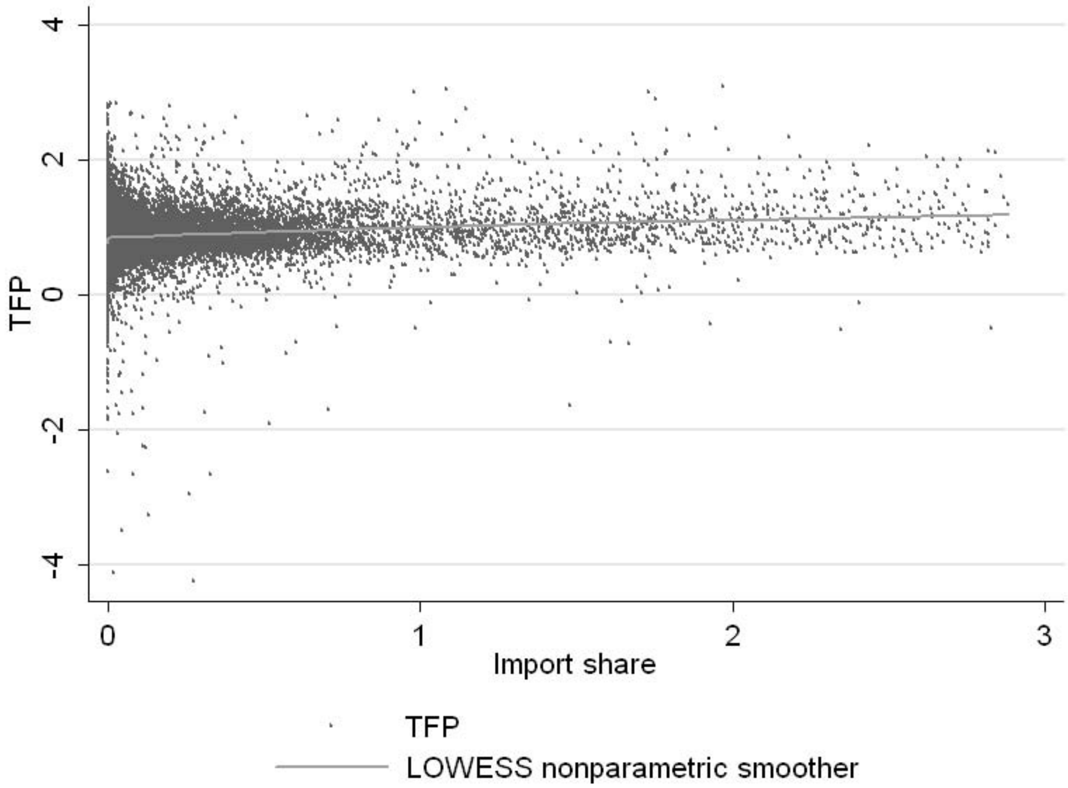

Figure 4: Productivity is linear in imports

linear, showing that there is no evidence of a convex relationship between productivity and imports. This suggests that heterogeneity in A across firms is not a first-order source of variation in import patterns.

Homogeneous and differentiated goods. A second possible source of heterogeneity is that the parameters A and θ may vary across products. For example, homogeneous products are likely to have a high elasticity of substitution, dampening the importance of the variety channel for such goods.

To address this issue, we extend the model by allowing A and θ to assume different values for homogenous and differentiated products. Table 6 reports the estimates of this generalized model, where homogenous and differentiated goods are defined using the classification of Rauch (1999). Not surprisingly, homogeneous products have a higher elasticity of substitution (9.6) than differentiated products (5.9), although the difference is not statistically significant because the parameter θ is estimated somewhat imprecisely. The quality differential is also smaller for homogeneous products (1.5 percent) than for differentiated products (2.9 percent), but again, the difference is insignificant. We conclude that there appears to be some product level heterogeneity in the key parameters, but the differences are not big enough to be precisely identified.

Sample selection. As we discussed in Section 2, our sample is not randomly selected. Hence, sample selection may bias our estimates. To understand the likely direction of any such bias, note that the sample only includes firms with exports above a certain threshold. As a result, a firm with low imports and low productivity is unlikely to be in the sample, since the exports of such firms probably do not meet the threshold. In contrast, firms that export a large amount relative to their productivity, and firms that are highly productive and hence large relative to their export intensity, are more likely to be in the sample. This argument suggests that sample selection is likely to introduce a negative correlation between imports and productivity. Any such correlation would bias our estimated coefficient downward. Hence, if sample selection is an important consideration for our data, the true effect of imports on productivity is likely to be higher than our estimates.

5 Counterfactual Experiments

To analyze how the different channels through which imports affect productivity operate for different firms, in this section we conduct two simple policy experiments.

5.1 Tariff reduction

We begin with analyzing the effects of a hypothetical tariff cut. Suppose that all imported products are subject to a uniform tariff reduction of size τ. What is the effect of this change on firm productivity? We address this question in a partial equilibrium setup, where the tariff change reduces the price of all foreign inputs by a factor τ, but does not affect the prices of other inputs and the final good. These assumptions can be justified if the country under consideration is a small open economy, and the industry affected by the tariff change is a small segment of this country. In this case, the prices of foreign inputs and output are determined on international markets, and due to the small size of the industry domestic general equilibrium effects can be safely ignored.

The mechanism through which the policy change affects firm productivity is summarized in the following points.

1. *Intensive margin.* The per-dollar quality index of foreign inputs increases in proportion to the tariff reduction:

   $$A' = (1+\tau)A.$$

   As a result, firms buy more of each product they are already importing:

   $$s' = (1+\tau)^{\theta-1}A^{\theta-1}/(1+(1+\tau)^{\theta-1}A^{\theta-1}) > s.$$

   Combining the improvement in A with the increased import of variety i implies that the contribution to productivity of each good increases to

   $$a' = \frac{1}{\theta-1}\ln\left[1+(1+\tau)^{\theta-1}A^{\theta-1}\right] > a.$$

Note that if τ is small, the increase in contribution to productivity can be linearly approximated as $a' - a \approx s\tau$.

2. *Extensive margin.* As importing each variety now brings higher benefits, firms choose to enter more import markets. A firm with fixed cost f will optimally increase n to n' such that

$$\gamma_{n'} a' Y' = f = \gamma_n a Y.$$

To express n' from this equation, we need a measure of the new firm size (Y'); this will be determined in a later step. For now, we compute the partial effect of the tariff change assuming that firm size does not adjust.

Since γ_n follows a Zipf distribution, we can loglinearize the expression for n' to obtain

$$\ln n' - \ln n = \frac{1}{\xi}\left(\ln a' - \ln a + y' - y\right).$$

Given the assumption that $y' = y$, the right hand side can be written, for a small tariff change τ, as

$$\ln n' - \ln n \approx \frac{1}{\xi}\frac{s}{a}\tau.$$

The corresponding increase in G_n, the Cobb-Douglas share of imported goods is

$$G_{n'} - G_n \approx \frac{\gamma_n n}{\xi}\frac{s}{a}\tau.$$

3. *Decomposition.* The overall productivity gain of the firm is

$$a' G_{n'} - a G_n = \underbrace{(a' - a) G_n}_{\text{intensive}} + \underbrace{a'(G_{n'} - G_n)}_{\text{extensive}}.$$

Here the intensive margin captures the effect of the firm importing more of each existing input, while the extensive margin is the productivity gain from entering new import markets. The relative importance of these two margins is of central interest in our policy experiment.

Based on the above approximations, for small τ the intensive margin can be written as

$$(a' - a) G_n \approx \tau s G_n = \tau S$$

which implies that a 1% reduction in tariffs leads to an S% increase in measured productivity through the intensive margin. This is simply the direct effect of purchasing the imported inputs at a lower price. Hence, this effect should not be interpreted as a "true" increase in productivity, because, once we deflate inputs with the appropriate after-tariff price, the increase in measured productivity disappears.

In contrast, the effect on the tariff change on the extensive margin leads to an increase in the set of imported products used in production and hence results in increased productivity even after correctly controlling for all input prices.

4. *Reallocation of variable inputs.* Increased productivity due to the tariff change will increase the firm's demand for variable inputs L and M. The Cobb-Douglas production function implies that use of these variable inputs increases in proportion with sales,

$$l' - l = m' - m = y' - y.$$

Substituting the changes in inputs and productivity into the production function (7) yields

$$y' - y = \frac{1}{1 - \beta - \gamma} \left(a' G_{n'} - a G_n \right). \tag{21}$$

Because $1 - \beta - \gamma < 1$, the on impact effect of the tariff change on productivity is magnified due to the reallocation of variable inputs. In our specification, for a firm with $\beta = 0.18$ and $\gamma = 0.70$, a 1 percent increase in productivity results in a 12 percent increase in sales. This number appears to be high, and there are several reasons to believe that the actual magnification is smaller in the data. First, the above derivation took output prices as given, whereas in an imperfectly competitive market a downward sloping demand curve can limit the growth of the firm. Second, adjustment costs may slow down the response of L and M.

From the entry condition on import markets derived above we obtain

$$y' - y = \ln \gamma_n - \ln \gamma_{n'} + \ln a - \ln a'. \tag{22}$$

Combining equations (21) and (22) allows us to solve for y' and n' simultaneously.

Table 7 reports the results of this policy experiment for two firms, one at the 25th percentile of the number of imported products ($n = 4$), the other at the 75th percentile ($n = 26$). The small firm spends 8 percent of its output on imports, whereas the large firm spend 37 percent. Given the relatively small tariff change of 10 percent, the above derivations will be approximately valid, and allow us to compute the effect of the tariff cut on productivity.

As noted, the productivity gain from the intensive margin is proportional to the import share, and is hence much larger for the large firm. The increase in the benefit of imports induces firms to enter more product markets. Even keeping the overall size of the firm fixed, the small firm enters 2 additional import markets, while the large firm enters 7 more. This results in additional increases in productivity. The gain from this extensive margin is substantially larger for the small firm, as the two new products represent a large share of production. The seven new products of the large firm are relatively unimportant, as the returns to variety diminish sharply.

Given the increase in productivity, both firms hire more variable inputs and increase in size. This brings about further entry into import markets and additional productivity gains. These gains are due to the increasing returns nature of access to import markets: bigger firms can recover the fixed cost more easily. The additional gains are small for the small firm but relatively large for the large firm.

Overall, productivity increases by 1.9 percent for the small firm, most of which (58 percent) is due to entry into new import markets. The large firm gains 4.2 percent, almost entirely due to the more intensive use of existing imported products.

5.2 Fixed cost reduction

In our second policy experiment, we consider the effects of a reduction in the fixed cost of entering import markets. As is evident from Table 5, fixed costs have fallen dramatically over the sample period. To measure how much this has contributed to growth in imports and productivity, we conduct a counterfactual experiment where we keep fixed costs at their initial values for each firm.

We conduct this experiment on the subsample of 447 firms for which data are available in all years. We calculate the fixed cost for each firm and each year with the procedure outlined in Section 4. Then, for years 1993 through 2002, we replace the fixed cost with what it was in 1992 for each firm. Using our estimated values for A and the elasticity θ, holding fixed the size of firms at their actual values, we can use the model to calculate the hypothetical number of imported products. This will typically be lower than the actual number, because the counterfactual fixed cost is higher. Using the counterfactual number of products estimated this way, we can calculate the counterfactual productivity using equations (10) and (11).

Table 8 presents the results of this exercise. The decline of fixed costs over time has contributed to between 0.2 and 3.7 percent increase in productivity. Most of the benefits accrue at the beginning of the sample period, because fixed costs have fallen most in the first 2-3 years. Because of the diminishing returns to imports, foreign firms, who already have access to a large number of products, benefit the least ($0.2 - 0.5$ percent), while state-owned firms, who use few imported inputs, benefit the most ($0.4 - 3.7$ percent).

6 Conclusion

This paper explores the effect of imports on productivity in a panel of Hungarian firms. Using a model of heterogenous importers, we identify two mechanisms through which imports can affect productivity, a quality and a variety channel. We structurally estimate this model and find that entering all import markets increases total factor productivity of a firm by 14%, of which about two thirds is due to the variety channel, and the remaining one third is due to the higher quality of foreign inputs. We then use out estimates to conduct counterfactual experiments. Overall, we find that imports have a substantial effect on productivity, but magnitude of the effect depends on the size of the firm. It would be interesting to incorporate these findings to models of economic growth and international trade.

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TABLE 1

Descriptive Statistics

	Our sample			Representative sample		
Variable	**Obs**	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
Employment	16918	327	744	259432	77	630
Sales (million HUF)	16918	1,761	13,951	259432	293	3,879
Fixed assets (million/worker)	16918	2.150	13.016	259432	1.381	16.092
Sales per worker	16918	5.552	17.098	259432	5.132	39.886
Share of intermediates	16916	0.656	0.194	258344	0.650	0.238
Export share	16873	0.495	0.347	254201	0.103	0.253
Import share	16913	0.204	0.245			
Number of imported products	16918	18.4	18.8			
Foreign owned	16918	0.514	0.500	259432	0.141	0.348
State owned	16918	0.063	0.242	259432	0.081	0.274

Notes: Table reports the average and standard deviation of key variables in our sample and in a representative sample of Hungarian manufacturing firms. *Employment* is average annual employment. *Sales* are reported in millions of 1995 forints (HUF). Book value of *fixed assets,* which we use to measure capital, and *sales per worker* are reported in million forints per worker. *Share of intermediates* is the ratio of intermediate input expenditure to sales. *Export share* is the fraction of sales revenue that comes from exports. *Import share* is the share of imported inputs in total expenditure on intermediate goods. The *number of imported products* is the number of HS4 categories the firm is importing. The latter two measures are only available in our sample, not in the representative sample. F*oreign owned is an indicator variable* that equals one if the firms is more than 30% foreign owned. The *state owned* indicator equals one if the firm is more than 50% state owned.

TABLE 2

Trends in International Participation

Year	# of firms	Share of foreign firms		Share of state firms			Number of
			Sales		Sales	Imports/	imported
		Unweighted	weighted	Unweighted	weighted	intermediates	products
1992	890	42%	22%	28%	60%	21%	15.4
1993	1,114	47%	35%	19%	44%	22%	15.0
1994	1,262	48%	42%	13%	36%	27%	16.1
1995	1,335	50%	48%	8%	27%	31%	16.8
1996	1,465	51%	57%	6%	19%	40%	17.7
1997	1,576	52%	75%	3%	3%	46%	18.7
1998	1,623	54%	80%	2%	1%	52%	20.1
1999	1,559	53%	84%	2%	1%	52%	20.5
2000	1,630	53%	82%	2%	1%	59%	20.8
2001	1,580	54%	86%	2%	1%	60%	20.4
2002	1,487	53%	85%	2%	0%	57%	20.5
2003	1,397	53%	88%	2%	0%	53%	20.5

Notes: Table reports key trends in international participation for our sample of firms. See the notes to Table 1 for variable definitions.

TABLE 3

Production Function Estimates

	(1) Ordinary Least Squares	(2) Olley-Pakes
Capital	0.059 (0.008)	0.080 (0.009)
Labor	0.179 (0.010)	0.176 (0.010)
Materials	0.721 (0.010)	0.702 (0.011)
Imported inputs	0.119 (0.039)	0.136 (0.039)
Productivity persistence (rho)		0.19 (0.12)
TFP gain (*a*)		0.194 (0.056)
Optimal share (*s*)		0.571 (0.029)
Relative quality (*A*)		1.068 (0.032)
Elasticity (theta)		5.4 (1.8)
Number of observations	10941	10941
Number of firms	1838	1838

Notes: Table reports estimated parameters of the import-augmented production function. Column 1 contains ordinary least squares estimates while column 2 contains estimates obtained using the Olley and Pakes (1996) procedure. See the text for the estimation details. Bootstrapped standard errors, given in parantheses, are clustered by firm. In the Olley-Pakes procedure in column 2 we proxy productivity by investment, controlling for export share, industry, year, and ownership category. Instruments include capital, lagged capital, and lagged imported capital. See Section 4.2 for details.

TABLE 4

Regression Results by Year

Year	TFP gain (a)	Relative quality (A)	Optimal share (s)
1992	0.206 (0.051)	1.088 (0.101)	0.586 (0.097)
1993	0.197 (0.046)	1.073 (0.086)	0.571 (0.085)
1994	0.105 (0.030)	0.881 (0.073)	0.365 (0.082)
1995	0.123 (0.049)	0.917 (0.114)	0.406 (0.122)
1996	0.184 (0.034)	1.050 (0.064)	0.551 (0.066)
1997	0.167 (0.033)	1.016 (0.065)	0.515 (0.070)
1998	0.165 (0.035)	1.013 (0.069)	0.511 (0.073)
1999	0.223 (0.046)	1.121 (0.083)	0.617 (0.076)
2000	0.073 (0.036)	0.790 (0.106)	0.265 (0.113)
2001	0.104 (0.030)	0.878 (0.076)	0.362 (0.084)
2002	0.065 (0.030)	0.767 (0.098)	0.242 (0.098)

Notes: Table reports the import parameters estimated separately by year by using the Olley and Pakes (1996) procedure. Other production function parameters (not reported) are held constant across years. Bootstrapped standard errors, in parantheses, are clustered by firm. We proxy productivity by investment, controlling for export share, industry, year, and ownership category. Instruments include capital, lagged capital, and lagged imported capital. See Section 4.2 for details.

TABLE 5

Fixed Costs of Importing

	Ownership Category		
Year	**Domestic**	**Foreign**	**State**
1992	11,508	2,108	10,747
1993	6,073	2,213	7,543
1994	2,943	1,236	3,701
1995	3,317	1,569	5,238
1996	4,957	1,972	18,317
1997	4,061	1,770	3,880
1998	3,362	1,753	31,133
1999	4,844	2,301	6,113
2000	1,426	798	4,727
2001	2,442	1,270	15,822
2002	1,261	905	32,169

Notes: Table shows the median fixed cost of importing a product in 1995 dollars, estimated as described in Section 4.5.

TABLE 6

Estimates for Homogenous and Differentiated Products

	Homogeneous	Differentiated
Capital	0.070 (0.009)	
Labor	0.172 (0.010)	
Materials	0.727 (0.011)	
Imported inputs	0.18 (0.083)	
Productivity persistence (rho)	0.083 (0.041)	0.123 (0.037)
TFP gain (*a*)	0.117 (0.056)	0.166 (0.051)
Optimal share (*s*)	0.525 (0.024)	0.534 (0.028)
Relative quality (*A*)	1.015 (0.018)	1.029 (0.025)
Elasticity (theta)	9.6 (16.0)	5.9 (3.6)
Number of observations	10941	
Number of firms	1838	

Notes: Table reports the import parameters estimated separately for homogeneous and differentiated products. Product are split according to the classification by Rauch (1999). Other production function parameters are kept fixed. Bootstrapped standard errors (in parantheses) are clustered by firm. We proxy productivity by investment, controlling for export share, industry, year, and ownership category. Instruments include capital, lagged capital, and lagged imported capital. See Section 4.2 for details.

TABLE 7

The Impact of a 10% Tariff Reduction

	Small firm	Large firm
Initial *n*	4	26
Initial import share	8%	37%
TFP gain (intensive margin)	0.8%	3.7%
New *n* (conditional on size)	6	33
Additional TFP gain (extensive margin)	0.8%	0.2%
New *n* (after size increase)	7	40
Additional TFP gain (IRS)	0.3%	0.3%
Total TFP gain	1.9%	4.2%
of which		
…intensive	42%	88%
…extensive	42%	5%
…increasing return to scale	16%	7%

Notes: Table reports the results of a counterfactual experiment described in Section 5.1. The first column shows the results for a small firm at the 25th percentile of the number of imported inputs, the second column for a large firm at the 75th percentile. The top panel reports the firms initial number of imported inputs and the productivity increase due to the 10% reduction in the cost of existing imports (intensive margin). The second panel shows the new number of products after optimal entry, and the corresponding TFP gains. The third panel shows the new number of products after the productivity-induced growth of the firm, and the corresponding TFP gains. The last panel shows the total TFP gain and its decomposition into the three effects.

TABLE 8

The Contribution of Lower Fixed Costs to TFP

	Ownership Category		
Year	**Domestic**	**Foreign**	**State**
1992	0.0%	0.0%	0.0%
1993	1.1%	0.2%	0.4%
1994	1.5%	0.5%	1.3%
1995	1.6%	0.5%	1.3%
1996	1.1%	0.3%	0.5%
1997	1.5%	0.5%	2.9%
1998	1.5%	0.5%	3.7%
1999	1.4%	0.4%	2.9%
2000	1.7%	0.5%	2.2%
2001	1.5%	0.5%	2.7%
2002	1.5%	0.5%	1.9%

Notes: Table shows the percentage improvement in TFP associated with the observed reduction fixed costs relative to their 1992 levels, as calculated from a counterfactual experiment described in Section 5.2.