To What Extent Can Czech Exporters Cushion Exchange Rate Shocks through Imported Inputs?

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This paper examines the role of imported inputs in cushioning exchange rate shocks by using a partial equilibrium model of heterogeneous firms. Producers in the model can serve the domestic market, export final goods, import inputs or engage in both exporting and importing. In the model, an exogenous exchange rate shock simultaneously affects the variable costs and revenues associated with exports and imports. The impact of a hypothetical 1% appreciation of the domestic currency on sales is estimated using a panel of 7,356 Czech manufacturing firms observed from 2003 to 2006. We focus on the above period to exploit the rich within-firm variation in trade strategies. This variation is likely to be associated with the lifting of trade barriers following the Czech Republic's EU accession in 2004. For firms that both export and import, the model predicts a drop in export sales of 0.8% as opposed to a 1% drop for price-taker exporters who do not use imported inputs.

JEL classification: C23, C26, D22, D24, F12
Keywords: Exchange rate pass-through, international trade, heterogeneous firms, monopolistic competition, total factor productivity, production function

Over recent years, there has been anecdotal evidence in the Czech Republic of domestic currency appreciation shocks causing alarm among the senior managers of large export-oriented industrial companies and industrial associations. These managers argued that a strong domestic currency negatively impacted the profit margins of Czech exporters, as export prices are usually contracted in foreign currency. At the same time, it is a well-known fact that the import intensity of Czech manufacturing exports has been high, especially since the Czech Republic joined the EU. This paper investigates the extent to which cheaper imported intermediate products compensate for a drop in export sales as a result of an appreciation of the local currency. Our answer to this question will be based on a model-backed estimate using firm-level panel data.

We apply a partial equilibrium model with monopolistically competing firms which are heterogeneous in their productivities. In the model setup, firms will serve the domestic market, export final goods or import inputs, depending on their productivity. Next we introduce an exogenous exchange rate shock, which simultaneously affects variable costs and the revenues associated with exports and imports. This allows us to estimate the impact of a hypothetical 1% appreciation of the domestic currency on sales according to different trade strategies. The predictions above will follow from the equilibrium sales equation implied by the model. The equation relates the log of total sales to exports, imports and productivity, and their coefficients are combinations of the model's structural parameters.

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In our effort to identify the coefficients in the sales equation, we face two main econometric problems. The first concerns the fact that firms tend to self-select into exporting and importing. According to our model, their selection is based mainly on firms' productivity and other industry-specific parameters. To correct the potential selection bias in the exporting and importing coefficients, we instrument them by the fitted probabilities of firms engaging in those activities. These probabilities are estimated from a year-by-year multinomial probit model. The model considers the choice between serving the domestic market only, exporting in addition, importing in addition or engaging in all these activities. The second problem is the productivity variable, which needs to be estimated. We fit total factor productivity from a standard firm-level production function extended by the possibility of using imported intermediate goods. Following recent studies in the literature, we use generalized method of moments (GMM) and instrumental variable estimation to correct for the measurement error in the capital stock variable.

To estimate exchange rate elasticities we use an unbalanced panel of 7,356 Czech manufacturing firms observed from 2003 to 2006. The studied interval is crucial for the identification of our estimates, as it can be characterized by high within-firm variation in exporting and importing strategies. The variation can probably be associated with the exogenous lifting of trade barriers following Czech EU accession in 2004. This lifting of trade barriers motivated an increasing share of firms to engage in importing intermediate goods and exporting final products.

The present paper extends the literature on heterogeneous firms and trade by offering a static alternative to the dynamic model proposed by Kasahara and Lapham (2013). Compared to their approach, our model is much simpler and leads to testable implications that are less computationally intensive to estimate. Further, in contrast to Bas and Strauss-Kahn (2011), who derive a variety of testable predictions on the effects of importing on a firm's export performance that are subsequently studied in a regression framework, we test the implications of the model through the equilibrium sales equation obtained directly from the model. The main novelty of this paper lies in studying exchange rate shocks in the context of heterogeneous firms and international trade whereas, in the related literature, it is common to estimate the impact of hypothetical changes in import tariffs.

The remaining part of this paper is organized as follows. Section 1 sets up the model and outlines its testable implications, section 2 describes the dataset, section 3 explains the estimation procedure, section 4 summarizes the results and the last section concludes.

1 The Model and Its Testable Implications

We consider N sectors in the economy, each of which produces differentiated products. Consumer expenditures on each sector's total output are exogenously fixed. At the beginning of a period, each firm i in a given sector experiences a productivity shock e_i. After e_i is revealed, firms decide whether to do business in their sector or not. If production will take place, firms can choose whether to serve the domestic market only *(X=0)* or, in addition to that, to export *(X=1)*. Furthermore, firms can decide to use domestic intermediate goods only *(M=0)* or to employ a mix of domestic and imported intermediates *(M=1)*. Firms' decisions to export or import will influence their fixed and variable costs associated with trade. Moreover, if production includes imported intermediates, firms' productivity will increase to $e_i\,(M{=}1) = ne_i > e_i\,(M{=}0) = e_i$. As in Kasahara and Rodrigue (2008), we attribute this productivity increase to the higher quality of foreign intermediates or to the variety effect stemming from a more differentiated final good.[2]

Trading decisions are subject to the following fixed and variable costs. Running a production plant necessitates spending a fixed cost f. Serving foreign markets bears additional fixed costs f_X associated with expenditures on marketing and maintaining logistic networks abroad. Similarly, importing intermediates also involves extra fixed costs f_M. Participation in trade is additionally associated with variable costs of transportation. As is common in the literature, we assume melting-iceberg transport costs for exports $\tau_X > 1$ and imports $\tau_M > 1$, which require τ units to be shipped for one unit to arrive. The full structure of variable costs $c(X,M)$ and fixed costs $f(X,M)$ looks as follows:

$$c(X{=}0, M{=}0) = c, \qquad f(X{=}0, M{=}0) = f,$$

$$c(X{=}0, M{=}1) = c\tau_M, \qquad f(X{=}0, M{=}1) = f + f_M,$$

$$c(X{=}1, M{=}0) = c\tau_X, \qquad f(X{=}1, M{=}0) = f + f_X,$$

$$c(X{=}1, M{=}1) = c\tau_M\tau_X, \qquad f(X{=}1, M{=}1) = f + f_M + f_X$$

Firms compete in monopolistic competition[3] and preferences across varieties within a sector are modeled by a constant elasticity of substitution (CES) utility function[4,5]. The elasticity of substitution between varieties within a sector is a constant $\varepsilon = 1/(1-\alpha) > 1$, where $1/\alpha$ is the monopolistic price mark-up. Monopolistic competition and CES preferences imply the following demand function for the product of firm i in market j:

$$q_{ij} = A_j p_{ij}^{-\varepsilon} \qquad (1)$$

where A_j is the constant sectoral demand level in market j, with values $A_{j=0} = A$ for the domestic market and $A_{j=x} = A_x$ for the foreign market. The values of A_j are assumed to be exogenous to the firm.

[2] *In the absence of product-level information on imported intermediates matched to firm-level data we are unable to differentiate the two effects empirically. Halpern et al. (2011) study such disaggregated data and conclude that two-thirds of the increase in firm productivity when imported intermediates are used is attributable to the variety effect.*

[3] *As monopolistic competition assumes an infinite number of atomistic firms producing different varieties of a good, we checked the degree of market share concentration within each manufacturing sector by two-digit NACE codes. NACE is a European standard for classifying the economic activity of firms. Using the standard Herfindahl index of sales, all sectors were found to be highly unconcentrated, with index values below 0.01. Note that the Herfindahl index ranges from 0 to 1 and is computed as:*

$H = \sum_{i=1}^{N} (s_i^2)$, *where* s_i *is the market share of firm i and N is the number of firms.*

[4] *The CES utility function over h varieties of goods x within a sector takes the standard form:*
$u(x) = (x_1^\alpha + x_2^\alpha + \ldots + x_h^\alpha)^{1/\alpha}$, *where* $\alpha = (\varepsilon-1)/\varepsilon$.

[5] *The assumption of CES utility can be relaxed while maintaining the main results of the model. Mrázová and Neary (2011) show that if the operating profits function satisfies supermodularity conditions, the equilibria of the model and the productivity cutoffs presented in chart 1 can be maintained. Supermodularity would be satisfied, for example, by quadratic preferences, other things being equal. We leave extensions of the model into this direction for future research.*

The production function is a simplified version of Kasahara and Rodrigue (2008) and extends Helpman et al. (2004) by introducing productivity-increasing imported intermediates. We define production as:

$$q_i = e_i(M)I_i \tag{2}$$

where *e(M)* is the productivity coefficient as a function of the binary import indicator M, and I_i is the amount of intermediate goods used in production.

Using demand (1), production (2) and cost functions *c(X,M)* and *f(X,M),* we can write firm i's profit from serving market j as:

$$\begin{aligned} \Pi_{ij}(M) &= A_j p_{ij}^{1-\varepsilon} - c(X,M)I_{ij} - f(X,M) = \\ &= A_j p_{ij}^{1-\varepsilon} - c(X,M)q_{ij} / e_i(M) - f(X,M) = \\ &= A_j p_{ij}^{1-\varepsilon} - c(X,M)A(X)p_{ij}^{-\varepsilon} / e_i(M) - f(X,M) \end{aligned} \tag{3}$$

The profit-maximizing unit price then becomes:

$$p_{ij}{}^* = p_i{}^* = \varepsilon c(X,M) / \left[e_i(M)(\varepsilon - 1)\right] \tag{4}$$

Plugging the above equilibrium prices (4) into the profit function (3), we get the following equilibrium profits for various trade strategies:[6]

$$\begin{aligned} \Pi_i{}^*(X,M) &= \Pi_{i0}{}^*(M) + \Pi_{ix}{}^*(M) \\ \Pi_i{}^*(0,0) &= EA\left[e_i(0) / c\right]^{\varepsilon-1} - f \\ \Pi_i{}^*(0,1) &= EA\left[e_i(1) / c\tau_M\right]^{\varepsilon-1} - f - f_M \\ \Pi_i{}^*(1,0) &= E\left(A + A_x\tau_X^{1-\varepsilon}\right)\left[e_i(0) / c\right]^{\varepsilon-1} - f - f_X \\ \Pi_i{}^*(1,1) &= E\left(A + A_x\tau_X^{1-\varepsilon}\right)\left[e_i(1) / c\tau_M\right]^{\varepsilon-1} - f - f_M - f_X \end{aligned} \tag{5}$$

where $E = \varepsilon^{-\varepsilon} (\varepsilon-1)^{\varepsilon+1}$ is a positive constant. In equilibrium, each firm i will select the trade strategy *(X,M)* with the highest profit for firm i or will exit if none of $\Pi_i{}^*(X,M) > 0$.

Note that all parameters of $\Pi_i{}^*(X,M)$ are constant for a given sector, except the firm-specific productivities e_i. Therefore, the equilibrium trade strategies *(X,M)* within a sector will differ only by e_i. Plotting all $\Pi_i{}^*(X,M)$ against $[e_i(0)]^{\varepsilon-1}$ results in a linear graph which offers helpful insights into the model's equilibrium trade strategies (chart 1). Notably, we find firms in our dataset self-selecting into all four *(X,M)* strategies within each manufacturing subsector.[7] We therefore focus on a set of parameters that implies the existence of all trade strategies in sectoral equilibrium.

[6] *Note that equilibrium requires* $\Pi_{ij}{}^* > 0$.

[7] *In our empirical analysis we use the first two digits of firms' NACE codes.*

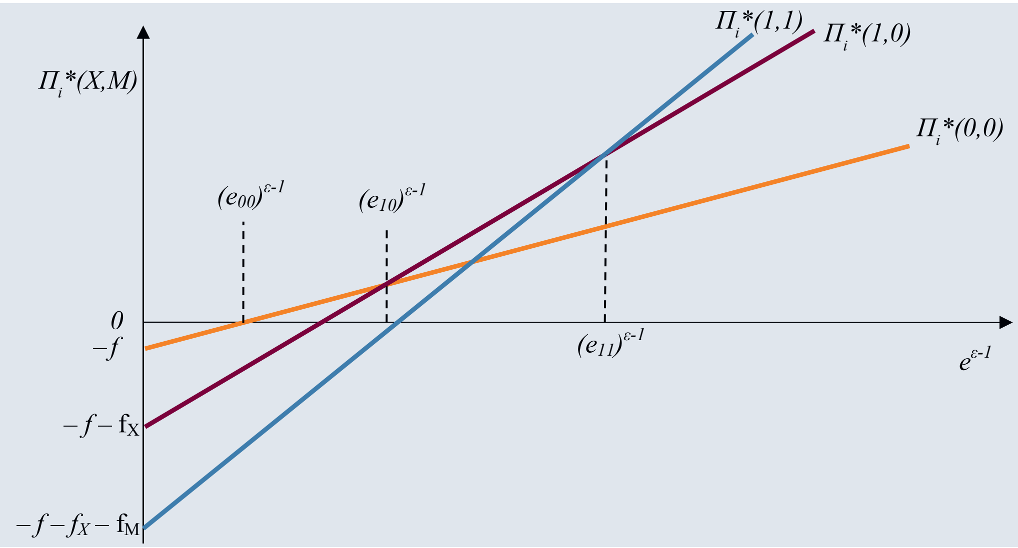
Furthermore, we assume the following ranking of cutoff productivities that imply equilibrium trade strategies for firms in terms of e_i: $0 < e_{00} < e_{10} < e_{01} < e_{11}$. This means that the least productive firms, with $e_i < e_{00}$, will not do business. Next, firms with e_i falling into any of the latter four intervals will optimally choose the *(X,M)* strategy as indicated by the subscript of each interval's lower bound e_{XM}. The ranking of productivity cutoffs above is justified by our data. As we will show in section 2 below,[8] the average firm size in the subsamples broken down by trade strategies follows the same order as our assumption about firm's productivity ranking. In the model, a higher productivity coefficient e_i implies higher profits and revenues and therefore a larger firm size.

We can argue that if all *(X,M)* strategies are to be observed in sectoral equilibrium, e_{00} must come first and e_{11} last. This is because the slope of $\Pi_i^*(1,1)$ with respect to $[e_i(0)]^{\varepsilon-1}$ is the highest and the intercept the smallest among $\Pi_i^*(X,M)$. The other extreme is $\Pi_i^*(0,0)$, with the smallest slope and the largest intercept. Although both alternative positions of e_{10} and e_{01} can exist in different sectoral equilibria, we will discuss only the $e_{10} < e_{01}$ case as suggested by our data. In the following, we outline the assumptions about the parameters of $\Pi_i^*(X,M)$ other than e_i that are necessary to arrive at the productivity ranking mentioned above.

If $\Pi_i^*(0,0)$ is to earn positive profits, productivity e_i must exceed the cutoff point $(e_{00})^{\varepsilon-1} = (fc^{\varepsilon-1})/EA$. Given that $\Pi_i^*(0,1)$ and $\Pi_i^*(1,0)$ have a lower intercept than $\Pi_i^*(0,0)$, strategies *(0,1)* and *(1,0)* will exist in equilibrium only if the slopes of $\Pi_i^*(0,1)$ and $\Pi_i^*(1,0)$ with respect to $[e_i(0)]^{\varepsilon-1}$ are greater than the slope of $\Pi_i^*(0,0)$.

Chart 1

The Most Productive Firms Both Import and Export



Source: Author's calculations.

Note: For better tractability, let us assume that $\Pi_i^*(1,0) = \Pi_i^*(0,1)$ and $f_X = f_M$.

[8] *See sales, real value added, real capital, labor, energy and material inputs in table 4 in section 2 and table A1 in appendix 1 of the working paper version of this article (Tóth, 2013).*

This requires $[n / \tau_M]^{\varepsilon-1} > 1$ in the case of $\Pi_i^*(0,1)$ and $A_x\tau_X^{1-\varepsilon} > 0$ for $\Pi_i^*(1,0)$. From inequalities $e_{10} < e_{01}$, $e_{00} < e_{01}$ and $e_{00} < e_{10}$ we get further conditions. We further assume that $f_M > f_X$ and $A(n/\tau_M)^{\varepsilon-1} > (A+A_x\tau_X^{1-\varepsilon})$. This will ensure that the equilibrium is located within the relevant positive range of $[e_i(0)]^{\varepsilon-1}$, where the latter inequality is the relationship between the slopes of $\Pi_i^*(1,0)$ and $\Pi_i^*(1,0)$ with respect to $[e_i(0)]^{\varepsilon-1}$. The condition $e_{10} < e_{01}$ further requires $f_M(A^{-1}A_x\tau_X^{1-\varepsilon}) > f_X[(n/\tau_M)^{\varepsilon-1} - 1]$.

The remaining equilibrium profit function, $\Pi_i^*(1,1)$, has the lowest intercept of all the trade strategies employed, amounting to $-f-f_M-f_X$. The profit of the strategy of simultaneously exporting and importing will thus exceed that of other strategies if, and only if, the slope of $\Pi_i^*(1,1)$ with respect to $[e_i(0)]^{\varepsilon-1}$ is larger than the slopes of the other three $\Pi_i^*(.,.)$. This requires $[n / \tau_M]^{\varepsilon-1} > 1$ and $A_x\tau_X^{1-\varepsilon} > 0$, which is in accordance with all the assumptions above. Chart 1 depicts the sectoral equilibrium with profit lines for different trade strategies.

In the remaining part of section 1, we derive the estimating equation for the equilibrium sales[9] equations of our model. The estimates from the sales equations enable us to quantify the impact of a hypothetical exchange rate shock on firm sales depending on different trade strategies. At the end of the section, we derive the exchange rate elasticity estimates obtained from the sales equations.

Using (1) and (4), the equilibrium sales equation of firm *i* serving market *j* can be written as:

$$S_{ij}\left(X,M\right) = A_j\left(p_{ij}*\right)^{1-\varepsilon} = A_jE'c\left(X,M\right)^{1-\varepsilon}e_i\left(M\right)^{\varepsilon-1} \tag{6}$$

where $E' = [\varepsilon/(\varepsilon-1)]^{1-\varepsilon}$ is a positive constant. Using (6) we can also write total sales in all markets served as a function of trade strategies:

$$\begin{aligned}
S_i\left(X,M\right) &= S_{i0}\left(X,M\right) + S_{ix}\left(X,M\right)\\
S_i\left(0,0\right) &= AE'c^{1-\varepsilon}e_i\left(0\right)^{\varepsilon-1}\\
S_i\left(0,1\right) &= AE'\left(c\tau_M\right)^{1-\varepsilon}e_i\left(1\right)^{\varepsilon-1}\\
S_i\left(1,0\right) &= (A+A_x\tau_X^{1-\varepsilon})E'c^{1-\varepsilon}e_i\left(0\right)^{\varepsilon-1}\\
S_i\left(1,1\right) &= (A+A_x\tau_X^{1-\varepsilon})E'(c\tau_M)^{1-\varepsilon}e_i\left(1\right)^{\varepsilon-1}
\end{aligned} \tag{7}$$

Now let us introduce the exchange rate into the above sales equations with the aim of estimating the impact of a hypothetical exchange rate shock. We assume that the exchange rate $r > 1$ expresses the value of the foreign currency in terms of the domestic currency.[10] Furthermore, connecting to our anecdotal evidence from the Czech Republic mentioned in the introduction, we study the shock of an appreciating domestic currency reducing r and find that an appreciation results in decreased variable costs of acquiring imported intermediates τ_M and thus higher equilibrium profits and sales. At the same time a stronger domestic currency

[9] *We estimate sales equations rather than equilibrium profits, as in the former case we do not need to identify the fixed cost parameters f(X,M) for the exchange rate elasticity estimates. Note that in order to estimate fixed costs we would need further identifying assumptions.*

[10] *This is CZK/EUR in the Czech case.*

implies a decreased demand level in export markets A_x measured in the domestic currency. We examine the instant impact of the exchange rate shock on profit and sales assuming that the prices of imported intermediates and exported final goods are contracted in the foreign currency and that the firm is unhedged against currency movements. The next paragraph lends some support to our assumptions above.

Recent survey evidence by Čadek et al. (2011) on the hedging behavior of 184 Czech exporting firms in the period from 2005 to 2009 relates to our assumptions regarding the exchange rate shock. Specifically, more than 75% of exports of the firms surveyed are contracted in euro and about 90% go to the euro area and the rest of Europe. Next, about 30% of respondents are fully unhedged against currency movements. Furthermore, about 50% of those who at least partially hedge their foreign currency exposure use so-called natural hedging. This involves the temporal alignment of cash inflows and outflows denominated in foreign currencies. As is known, natural hedging does not perfectly eliminate foreign currency risk. Finally, the typical hedging horizon among respondents was also in line with our assumption of a short-run effect. Specifically, about 80% of hedgers typically considered a horizon of less than one year.

Now we implement the exchange rate shock in equations (6) and (7). According to our model, firms with different trade strategies are affected differently by the exchange rate shock.[11] Those which neither export nor import will not be impacted. Next, firms using imported inputs will be able to offer their product at a lower price and their equilibrium sales will increase, ceteris paribus. Furthermore, firms serving export markets will experience a decrease in their equilibrium export sales as the demand level goes down. Finally, the net effect of the exchange rate shock on the total sales of firms that both export and import can be either positive or negative. This is because their sales on domestic markets will increase as imported inputs become cheaper. At the same time, the negative effect of lower export demand may or may not fully outweigh the positive effect of cheaper imported inputs on export sales.

We can incorporate the exchange rate r into the equilibrium sales equations (7) as follows:

$$S_i(0,1) = S_{i0}(0,1) = AE'\left[c\tau_M r\right]^{1-\varepsilon} e_i(1)^{\varepsilon-1} \tag{8}$$

$$S_i(1,0) = S_{i0}(1,0) + S_{ix}(1,0) = \left(A + rA_x\tau_X^{1-\varepsilon}\right)E'c^{1-\varepsilon}e_i(0)^{\varepsilon-1} \tag{9}$$

$$S_i(1,1) = S_{i0}(1,1) + S_{ix}(1,1) = \left(A + rA_x\tau_X^{1-\varepsilon}\right)E'\left[c\tau_M r\right]^{1-\varepsilon} e_i(1)^{\varepsilon-1} \tag{10}$$

The equations above imply the following exchange rate elasticities of sales for the trade strategy *(X,M)* and the market served j, where $j=0$ denotes the domestic market and $j=x$ denotes export markets:

[11] *Here we focus on the intensive margin only, which means discussing the partial effects on firms in a given equilibrium trade strategy. At the same time we ignore the extensive margin, i.e. the effect of the exchange rate shock on some firms changing their trade strategies.*

$$
\begin{aligned}
&\rho_j(X,M) = (r \ / \ S_{ij}) \ \partial S_{ij} / \ \partial r \ \ and \\
&\rho(X,M) = (r \ / \ (S_{i0} + S_{ix}) \ \partial(S_{i0} + S_{ix}) \ / \ \partial r \\
&\rho_0(0,1) = \rho(0,1) = \rho_0(1,1) = (1-\varepsilon) \\
&\rho_x(1,0) = 1
\end{aligned}
\tag{11}
$$

$$
\rho_x(1,1) = (2 - \varepsilon) \tag{12}
$$

$$
\begin{aligned}
\rho(1,1) &= \left[(1 - \varepsilon)A + (2 - \varepsilon)rA_x\tau_X^{1-\varepsilon}\right] / \left(A + rA_x\tau_X^{1-\varepsilon}\right) = \\
&= \left[1 - \varepsilon + rA_x\tau_X^{1-\varepsilon} / \left(A + rA_x\tau_X^{1-\varepsilon}\right)\right] = \\
&= 1 - \varepsilon + R
\end{aligned}
\tag{13}
$$

where ratio $0 < R < 1$ on the right-hand side of the above equation is the share of the freight cost-discounted foreign demand level $rA_x\tau_X^{1-\varepsilon}$ in the total demand level exporters face.

Given that the elasticity of substitution between varieties in a given sector, ε, is assumed to be greater than one,[12] we expect a negative exchange rate elasticity of domestic sales $\rho_0(.,1)$. This means that the shock of an appreciating domestic currency implies positive sales growth on domestic markets for firms that import some of their intermediates. Furthermore, according to the equations above, export sales are unit elastic to the exchange rate when no intermediates are imported and therefore will decrease if the domestic currency appreciates. Next, the elasticity of export sales in case some intermediates are imported, $\rho_x(1,1)$, is negative if $\varepsilon > 2$ and nonnegative if $1 < \varepsilon < 2$. Hence it follows that firms with trade strategy *(1,1)* can still experience increased export sales despite the exchange rate shock, i.e. $\rho_x(1,1) < 0$, if ε is large enough. In the above case, the positive effect of cheaper imported intermediates outweighs the effect of the virtual drop in foreign demand. Finally, the condition for a negative exchange rate elasticity of total sales for firms with trade strategy *(1,1)* can be expressed as:

$$
\varepsilon^* > 1 + R \tag{14}
$$

As will be shown, the above condition (14), parameter ε and the listed partial effects (11)–(13) can be estimated from our data on Czech manufacturing firms. So, finally, we will test the hypothesis that the terms (11)–(13) are significantly different from zero.

To proceed, we take natural logarithms from the equilibrium sales equations (7)–(10) and combine them into one equation using mutually nonexclusive dummy

[12] *Please note that a constant ε across all sectors follows from the CES utility function. As we will see in section 4 below, the assumption of $\varepsilon > 1$ is consistent with our empirical estimates.*

variables[13] *d(1,.) = d(1,0) + d(1,1)* and *d(.,1) = d(0,1) + d(1,1)*. As a result, we get the following relationship:

$$\begin{aligned} log\left[S_i\left(X,M\right)\right] &= log\left(AE'\right) + \left(1-\varepsilon\right)log\left(c\right) + d\left(1,.\right)log\left(1+rA_x A^{-1}\tau_X^{1-\varepsilon}\right) + \\ &+ d\left(.,1\right)\left(1-\varepsilon\right)log\left(r\tau_M\right) + \left(\varepsilon-1\right)log\left(e_i\left(M\right)\right) \end{aligned} \tag{15}$$

In order to convert (15) into an estimable format, let us assume that all the addends in (15) are constants[14] except the trade dummies *d(.,.)* and the productivity term $log(e_i\,(M))$. Furthermore, as the productivity term *log(ei(M))* is not directly observed, let us approximate it using an estimate of total factor productivity (TFP). Given all the above, and after adding a normal i.i.d., zero-mean error term θ_{it}, equation (15) can be rewritten as follows:

$$s_{it} = \alpha_0 + \alpha_1 d\left(1,.\right)_{it} + \alpha_2 d\left(.,1\right)_{it} + \alpha_3 TFP_{it} + \theta_{it} \tag{16}$$

where s_{it} is the log of total sales of firm *i* in time period *t*, $d(.,.)_{it}$ are dummy variables indicating trade strategies as in equation (15), and TFP_{it} is equal to $log(e_i\,(M))$, i.e. the firm's total factor productivity as a function of its importing strategy. The rest of the parameters of (15) are stacked into constants α_0 to α_3 of (16) as shown by the following expressions:

$$\begin{aligned} \alpha_0 &= log\left(AE'\right) + (1-\varepsilon)log\left(c\right) \\ \alpha_1 &= log(1+rA_x A^{-1}\tau_X^{\varepsilon-1}) \\ \alpha_2 &= (1-\varepsilon)log(r\tau_M) \\ \alpha_3 &= \varepsilon - 1 \end{aligned}$$

which leads to:

$$\begin{aligned} \varepsilon &= \alpha_3 + 1 \\ E' &= \left[\left(\alpha_3+1\right)/\alpha_3\right]^{-\alpha 3} \\ r\tau_M &= exp\left(\alpha_2/-\alpha_3\right) \\ rA_x\tau_X^{1-\varepsilon} &= A\left[exp\left(\alpha_1\right) - 1\right] \\ R &= A\left[exp\left(\alpha_1\right)-1\right]/\left[A + A\left(exp\left(\alpha_1\right)-1\right)\right] = 1 - exp\left(-\alpha_1\right) \end{aligned}$$

[13] *Note that using mutually exclusive trade strategy dummies would lead to the overidentification of structural parameters.*

[14] *Note that some of the assumptions about these constants could be relaxed and made firm-specific or time-variant. For example, the term* $rA_x A^{-1}\tau_X^{1-\varepsilon}$, *i.e. the trade cost-weighted ratio of the foreign demand level to the domestic demand level, could be firm-specific based on the firm's exposure to foreign markets and the mix of foreign countries in its portfolio. Similarly, the productivity mark-up dummy for using imported intermediates,* $e_i(M)$, *could be continuous based on the share of imported goods in total intermediate products used. This would allow us to derive firm-specific exchange rate elasticities. This interesting extension is beyond the scope of the present paper and is left for future research.*

Furthermore, based on (11), (12) and (13), we can express the elasticities of a hypothetical 1% change in the value of the foreign currency vis-à-vis sales on market *j*, $\rho_j(X,M)$, in terms of the estimates of (16):

$$\rho_0(0,1) = \rho(0,1) = \rho_0(1,1) = -\alpha_3 \tag{17}$$

$$\begin{aligned} \rho_x(1,0) &= 1 \\ \rho_x(1,1) &= 1 - \alpha_3 \end{aligned} \tag{18}$$

$$\rho(1,1) = 1 - \alpha_3 - exp(-\alpha_1) \tag{19}$$

Following our assumptions in the model, we expect α_0, α_1 and α_3 to be positive and α_2 to be negative. Regarding the estimable structural parameters of interest, we expect $\varepsilon > 1$, $r\tau_M > 1$ and $0 < R < 1$. Furthermore, based on the model's predictions for $\rho_j(X,M)$, we anticipate a negative $\rho_0(1,1)$ and a positive $\rho_x(1,1)$. Finally, we are not able to predict the sign of $\rho(1,1)$ without making further assumptions about the model's parameters.

2 Data Base Used for Estimation

Our data sample consists of an unbalanced panel of 7,356 Czech manufacturing firms. The motivation to focus on the time period from 2003 to 2006 will be explained in more detail in the next paragraphs. The dataset was obtained from the Albertina database, which is collected by the private company Creditinfo Czech Republic, s.r.o. and available at Česká národní banka. Although several commercial firm databases exist in the Czech Republic, to our knowledge only Albertina contains information on exports and imports.

One of the key advantages of analyzing the exports and imports of Czech firms during the defined period arises from the Czech Republic's accession to the EU in 2004. EU entry represents an exogenous event for firms and is associated with the lifting of trade barriers within the European Union. This implies that several nontrading Czech firms were able to participate in international trade after 2004 as both fixed and variable costs of accessing foreign markets went down. Table 1 shows the tendency of several firms shifting toward exporting and importing strategies in our sample after 2004. In particular, the share of firms that both export and import, denoted by the dummy variable *d(1,1)*, increases from about 25% in 2003 and 2004 to around 40% in 2005 and 2006.[15]

Table 1

Czech Firms Engaged in Trade Strategies d(export, import)

Strategy	2003	2004	2005	2006
	%			
d(0,0)	58	63	42	44
d(1,0)	12	10	8	7
d(0,1)	5	4	8	10
d(1,1)	26	22	42	39
Total	100	100	100	100

Source: Author's calculations.

[15] *For additional firm-level and macro evidence on high trade intensity in the Czech Republic, see tables A1 and A9 in the appendix of the working paper version of this article (Tóth, 2013).*

Table 2

Trade Strategy Switches from 2003 to 2006

	To strategy				Total
	d(0,0)	d(1,0)	d(0,1)	d(1,1)	
From strategy	%				
d(0,0)		12.1	13.8	22.2	48.1
d(1,0)	5.7		0.3	17.2	23.1
d(0,1)	4.6	0.3		7.1	12.0
d(1,1)	5.3	4.9	6.7		16.8
Total	15.6	17.2	20.7	46.6	100.0

Source: Author's calculations.

Note: The total number of switches during the period from 2003 to 2006 equals 2,630. Sums of all rows and sums of all columns add up to 100.

Table 3

Transitions between Trade Strategies from 2003 to 2006

	To strategy				Total
	d(0,0)	d(1,0)	d(0,1)	d(1,1)	
From strategy	%				
d(0,0)	38.8	2.9	3.3	5.4	50.4
d(1,0)	1.4	4.6	0.1	4.2	10.2
d(0,1)	1.1	0.1	3.3	1.7	6.2
d(1,1)	1.3	1.2	1.6	29.1	33.2
Total	42.6	8.7	8.3	40.4	100.0

Source: Author's calculations.

Note: The total number of switches during the period from 2003 to 2006 equals 2,630. Sums of all rows and sums of all columns add up to 100.

As our panel is unbalanced, we also checked whether the higher share of exporters and importers stems from trade strategy switchers or new entrants to the dataset. We are mostly interested in switchers, since our main results – the model-implied exchange rate elasticities – are functions of export and import dummy coefficient estimates[16] and switchers allow us to identify these dummy coefficients from within-firm variation in trade strategies after controlling for firm-specific fixed effects. Given the time period analyzed, within-firm variation in trade strategies is likely to be associated with exogenous EU accession. It turned out that more than 14% of the observations in the pooled sample are firms that switched their trade strategy since the preceding year.

Further stylized facts are consistent with the hypothesis of the lifting of trade barriers implied by the Czech Republic's EU accession. According to the last column of the first row in table 2, more than 48% of trade strategy shifts depart from a no-trade status quo. Next, according to the last row of column *d(1,1)* in table 2, up to 47% of trade strategy shifts lead to strategy *d(1,1)* of both exporting and importing. At the same time, table 3 shows that roughly 70% of the observations in the pooled sample consist of firms that do not switch their trade strategy of no-trade *d(0,0)* or full trade *d(1,1)* compared to that of the preceding year. This suggests that many firms cannot access foreign markets, but once a firm manages to export and import, it will tend to stay with that strategy. In other words, we observe substantial persistence in trade strategies on the micro level, which may imply the existence of sunk costs associated with those strategies.[17]

3 Details of the Estimation Procedure

In this section we describe the estimation of equation (16), which involves three main issues. First, the variable TFP_{it}, firm *i*'s total factor productivity as a function of its importing strategy, is fitted from a production function in subsection 3.1. Second, as firms select into trade strategies $d(X,M)_{it}$ endogenously, we have to correct the estimates of α_1, α_2 and α_3 for the probability of having chosen in the respective

[16] *See sales equation (16).*

[17] *Roberts and Tybout (1997) find similar persistence patterns in the exporting activities of Colombian firms.*

strategies. The endogeneity of trade strategy selection follows from our model, where firms choose a trade strategy depending on their current TFP and sector-specific fixed and variable costs associated with trade. Therefore, current period realizations of the sector- and firm-specific cost parameters left in the error term θ_{it} may be correlated with dummies $d(0,1)_{it}$, $d(1,0)_{it}$ and $d(1,1)_{it}$. The probabilities of choosing different trade strategies are estimated from a multinomial probit model in subsection 3.2. The third estimation issue relates to the potential correlation of TFP_{it} with the error term θ_{it}, which is the current period realization of the sales shock. This can lead to a biased estimate of α_3. The solution to this issue is briefly described in subsection 3.3.

3.1 Estimation of the Production Function

Regarding the estimation of TFP as a function of the importing strategy, we consider a standard Cobb-Douglas production function extended to include imported inputs as an additional factor of production:

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 d(.,1)_{it} + \omega_{it} + \eta_{it} \tag{20}$$

where y_{it} is the log of real value added, k_{it} is the log of the real capital stock, l_{it} is the log of the number of employees,[18] $d(.,1)_{it} = d(0,1)_{it} + d(1,1)_{it}$ is a dummy variable indicating the use of imported intermediates, ω_{it} is an unobserved firm-specific productivity shock and η_{it} is an i.i.d. error term from the normal distribution. As the unobserved productivity shock ω_{it} is correlated with the factor inputs and the import dummy, the OLS estimates of β_0 to β_3 are, in general, biased. To solve this endogeneity issue, we combine several approaches available in the literature and mainly follow Wooldridge (2009) and Galuščák and Lízal (2011).[19]

After fitting the production function (20), we save the estimate of total factor productivity in natural logarithm *(tfp)* as a function of the import strategy. We obtain *tfp* from the following expression:

$$tfp_{it} = y_{it} - \beta_1 k_{it} - \beta_2 l_{it} \tag{21}$$

This expression is used in the remaining stages of our estimation, i.e. the multinomial probit models of trade strategy choice and the equilibrium sales equation.

3.2 Estimation of the Probabilities of Choosing Trade Strategies

To address the problem of nonrandom samples of firms self-selecting into different trade strategies in equation (16), we estimate the probabilities of choosing each of the four trade strategies using a year-by-year multinomial probit model. The firm- and year-specific probabilities will then be used as instruments for dummy variables $d(1,.)_{it}$, $d(.,1)_{it}$ in equation (16). The multinomial probit approach is motivated by the unobserved ordering of trade strategies. As noted in section 1, trade strategy choice is determined by firm *i*'s productivity parameter e_i and the

[18] *A more commonly used measure of labor input, namely hours worked, is not available in our dataset.*

[19] *For more details on the assumptions and the approach to estimate equation (20), please refer to the working paper version of this article (Tóth, 2013).*

cutoff productivities for each strategy depending on the relative slopes of trade strategy-specific equilibrium profit functions $\Pi_i*(X,M)$. Using the multinomial probit, we do not have to make further assumptions about the parameters of $\Pi_i*(X,M)$.

Trade strategy choice in the multinomial probit framework is modeled as follows. We introduce latent variables γ_{ij} indexed for each firm i and trade strategy choices j from the set $(X,M) = \{(0,0), (0,1), (1,0), (1,1)\}$ and consider a 1 x q row vector of exogenous firm-specific variables w_i:

$$\gamma_{ij} = \mathbf{w_i}\delta_j + \xi_{ij}$$

where ξ_{iX}, ξ_{iM}, and ξ_{iXM} are distributed independently and identically following a standard normal distribution. The firm chooses trade strategy k such that $\gamma_{ik} \geq \gamma_{im}$ for $m \neq k$. Taking the difference between γ_{ik} and γ_{im} we get:

$$\Gamma_{i,k,m} = \gamma_{ik} - \gamma_{im} = \mathbf{w_i}\left(\delta_k - \delta_m\right) + \left(\xi_{ik} - \xi_{im}\right) = \mathbf{w_i}\varphi_{k'} + \omega_{ik'}$$

where $Var(\omega_{ik'}) = Var(\xi_{ik} - \xi_{im}) = 2$ and $Cov(\omega_{ik'}, \omega_{il'}) = 1$ for $k' \neq l$. Using the above expressions, we can write the probabilities of choosing each of the four trade strategies as follows:

$$\begin{aligned}
Prob\left(i \ chooses \ (0,0)\right) &= Prob\left(\Gamma_{i,00,01} \geq 0,\ \Gamma_{i,00,10} \geq 0,\ \Gamma_{i,00,11} \geq 0\right)\\
Prob\left(i \ chooses \ (1,0)\right) &= Prob\ \left(\Gamma_{i,10,00} \geq 0,\ \Gamma_{i,10,01} \geq 0,\ \Gamma_{i,10,11} \geq 0\right)\\
Prob\left(i \ chooses \ (0,1)\right) &= Prob\left(\Gamma_{i,01,00} \geq 0,\ \Gamma_{i,01,10} \geq 0,\ \Gamma_{i,01,11} \geq 0\right)\\
Prob\left(i \ chooses \ (1,1)\right) &= Prob\left(\Gamma_{i,11,00} \geq 0,\ \Gamma_{i,11,01} \geq 0,\ \Gamma_{i,11,10} \geq 0\right)
\end{aligned}$$

The above probabilities indicate that choice in the multinomial probit model is based on the multivariate normal distribution $MVN(0,\Sigma)$, where Σ is a 3 x 3 variance-covariance matrix with 2-s on the diagonal and 1-s off the diagonal.

We estimate the year-by-year multinomial probits as defined above with exogenous firm-specific variables w_i including the log of capital approximating firm size, *tfp* as a function of importing from (21), a dummy for foreign ownership, a lagged trading dummy indicating engagement in any of the trade strategies except (0,0) in the preceding period[20] and a set of industry dummies. As a concluding step, the fitted probabilities for each firm and time period are recorded.

3.3 Estimation of the Equilibrium Sales Equation

Once tfp_{it} in (21) and the trade strategy probabilities have been fitted, all that remains is to estimate the equilibrium sales equation (16). We use an instrumental variables approach. More specifically, we apply a two-stage least squares (2SLS) estimator and use the firm- and year-specific fitted probabilities associated with

[20] *The indicator of prior trade experience is important given the observed persistence in trade strategies in our dataset. Past exporting activities were found to be a good predictor of future engagement in exports also by Roberts and Tybout (1997) based on a sample of Colombian firms.*

the export and import dummies $d(1,.)_{it}$ and $d(.,1)_{it}$ as instruments. We also consider firm-specific fixed effects in sales. Finally, we perform linear and nonlinear tests of combinations of the sales equation's coefficient estimates. This allows us to test some of the model's structural parameters and the implied exchange rate elasticities in (17)–(19), as presented in table 8 in the next section.

4 Results

Table 4 presents estimates of the production function based on several approaches. Columns (1) to (4) follow and extend the frameworks of Wooldridge (2009) and Galuščák and Lízal (2011) and deal with endogenous variables via GMM. Column (1) is the replication of Wooldridge (2009) on our Czech sample. This involves estimating the extended version of the production function by GMM and treating labor as endogenous. The estimates in column (2) result from the extension of Wooldridge (2009) as suggested by Galuščák and Lízal (2011). The latter authors suggested a measurement error correction in capital using e.g. depreciation and energy inputs as instruments apart from the treatment of endogenous labor. The models in columns (3) and (4) extend the specifications used in (1) and (2) to include an import dummy, which is assumed to be exogenous given the proxy for the productivity shock in the same period.

Comparing our estimates in columns (1) and (2) with those of Galuščák and Lízal (2011) we find similar results. Specifically, correcting for the measurement error in the capital stock variable is important, as the log capital coefficient increases sharply after the correction. At the same time, the elasticity of labor remains roughly the same. However, the sizes of the estimated coefficients are different in the two studies. This may be largely attributable to the fact that we use the number of employees instead of hours worked as the proxy for labor. Our choice of the number of employees was predetermined by data limitations.

The last four columns of table 4 present results from the models including firm-specific fixed effects; endogenous variables are treated by two-stage least squares. The specifications and the pattern of treating endogenous variables are the same as in the first half of table 4. Specifically, in the column (5) model, we use instruments for the labor stock variable but the measurement error in the capital stock variable is not corrected. In the column (6) estimates, we additionally use depreciation and energy and material costs as instruments for the capital stock. Columns (7) and (8) replicate the latter two columns while also including the import dummy.

Comparing the results in the two halves of the table, all the coefficient estimates are roughly halved but remain statistically significant after considering firm-specific fixed effects. This implies that fixed effects should not be disregarded in similar studies.

Regarding the coefficient on the import dummy – the estimate of key interest to us within the production function – we can say that imported intermediates tend to increase total factor productivity significantly. However, after correcting the potential measurement error in capital stock, the effect of imported intermediates is roughly halved. The same conclusion holds for both the GMM and the 2SLS fixed effects estimates. To sum up, the above results are in line with the assumptions made in our model and similar to other studies that consider import dummies in the production function, such as Kasahara and Rodrigue (2008).

As we have concluded that both firm-specific fixed effects and the measurement error correction with respect to capital stocks are important, we will use estimates of TFP based on column (8) in the remainder of the empirical analysis. Note that, given data limitations, we were forced to estimate the production function based on a reduced sample. This meant considering only 4,815 to 5,180 different firms instead of the full sample of 7,356 firms, depending on the method of estimation and the associated data requirements. However, to recover a TFP estimate for each firm in the full sample, we only need to observe labor and capital and use the associated coefficient estimates from equations (20) and (21). Thanks to this fact we can also estimate TFP out of the production function sample. Therefore, as a sensitivity check, we will replicate the final results of our analysis for both the *full* and the *reduced* sample. By *full sample* we mean the sample also containing TFP estimates outside the sample considered for estimating the production function. Similarly, when referring to the *reduced sample,* we mean keeping only those observations which were used in the production function estimation.

The fitted TFP from above first enters the estimation of the probabilities of being in a particular trade strategy from the year-by-year multinomial probit models. To keep the summary of results to a manageable size, we present estimates only for the pooled sample for 2003 to 2006 in table 5.[21]

The coefficients on log real capital and log TFP in table 5 suggest that an increase in these variables improves the probabilities of being engaged in any form of trade compared to the base outcome of showing neither imports nor exports. The coefficients of these two regressors tend to be the largest for the full trade strategy *d(1,1)*, which implies that any increase in the two regressors increases the probability, for the firm in question, of being both an importer and an exporter by more than that of being an importer or exporter only. These findings, therefore, do not contradict our model in general. Furthermore, foreign ownership tends to increase the probability of a firm being involved in international trade. The size of the coefficient on the foreign ownership dummy, however, does not follow a clear systematic pattern over time and across different trade strategies. The coefficient on the lagged trade dummy is significantly positive, which suggests persistence in trade strategies.[22] We can also assert this because once a firm starts trading, it is likely to stick to its strategy. Finally, we can observe some systematic patterns in the coefficients on the listed industry dummies, though interpreting them is not the main focus of the present study.

After obtaining the fitted firm- and year-specific TFP and the probabilities of having chosen a particular trade strategy, we estimated the sales equation. This allows us to identify selected structural parameters of the model and to estimate the exchange rate elasticities of sales. The estimates of the sales equation itself, for both the full and the reduced samples, can be found in table 6 below. The signs of

[21] *For the year-by-year estimates, please refer to tables A2–A5 in appendix 2 of the working paper version of this article (Tóth, 2013).*

[22] *Persistence in trading activities is consistent with the findings of Roberts and Tybout (1997) on Colombian firm-level data.*

the export and import dummy coefficients and log TFP are as expected and in accordance with our model in both samples. Unfortunately, though, the coefficient estimate of the import dummy is insignificant in both versions of the dataset.[23] Note, however, that the imprecise estimate of α_2 in (16) only affects the estimate of the structural parameter $r\tau_M$ (table 7) discussed below and does not influence our main results regarding exchange rate elasticities (table 8).

By using the estimates of the sales equation in table 6, we can derive estimates of some of the model's structural parameters. These are summarized and tested in table 7. The estimate of the elasticity of substitution ε is greater than one and thus in accordance with our theoretical assumptions. The estimated share of the freight cost-discounted foreign demand level in the total demand level faced by exporter firms, R, lies between zero and one as expected. The product of the unit cost of importing and the nominal exchange rate $r\tau_M$ exceeds one, which is again in line with the model's assumptions. Notably, there are some differences between the three estimates depending on whether the full or the reduced sample is used, especially in the case of parameter $r\tau_M$. Moreover, the standard error of the latter estimate is relatively large, making the point estimate indistinguishable from zero. This is likely to be a result of the imprecise estimate of coefficient α_2 in sales equation (16).

Table 4

Estimates of the Production Function

	Estimator							
	GMM				IV-2SLS with fixed effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	5.644***	3.867***	5.266***	3.655***	7.899***	2.876***	7.858***	2.895***
	(0.474)	(0.871)	(0.48)	(0.858)	(0.43)	(0.578)	(0.429)	(0.576)
Log of number of employees	0.458***	0.426***	0.452***	0.422***	0.213***	0.287***	0.216***	0.287***
	(0.015)	(0.019)	(0.015)	(0.019)	(0.039)	(0.05)	(0.039)	(0.05)
Log of real capital	0.261***	1.528***	0.254***	1.489***	0.185***	0.760***	0.183***	0.756***
	(0.021)	(0.141)	(0.021)	(0.138)	(0.011)	(0.034)	(0.011)	(0.034)
Import dummy d(0,1)+d(1,1)	–	–	0.205***	0.099***	–	–	0.073***	0.039**
			(0.017)	(0.024)			(0.013)	(0.017)
R-squared	0.829	0.635	0.832	0.648	0.809	0.760	0.813	0.762
Number of observations	12,434	11,393	12,434	11,393	12,434	11,393	12,434	11,393
Number of firms	5,180	4,815	5,180	4,815	5,180	4,815	5,180	4,815

Source: Author's calculations.

*Note: The dependent variable is the log of real value added. Estimation period: 2003–06. Standard errors are reported in parentheses. *, **, and *** denote significance at the 90%, 95% and 99% levels. Year dummies were included in all regressions.*

Estimates: (1) follows Wooldridge (2009);
(2) Wooldridge (2009), real capital instrumented by depreciation and energy and material inputs;
(3) Wooldridge (2009), import dummy included;
(4) Wooldridge (2009), import dummy included and real capital instrumented by depreciation and energy and material costs;
(5) IV-2SLS version of Wooldridge (2009), fixed effects included;
(6) IV-2SLS version of Wooldridge (2009), fixed effects included and capital instrumented by depreciation and energy and material costs;
(7) IV-2SLS version of Wooldridge (2009), fixed effects and import dummy included;
(8) IV-2SLS version of Wooldridge (2009), fixed effects and import dummy included and capital instrumented by depreciation and energy and material costs.

[23] *The reason for the above result is probably the fact that the two trade dummies in equation (16) are correlated.*

Table 5

Estimates of the Multinomial Probit Model of Trade Strategy Choice

Choice outcomes	d(1,0)	d(0,1)	d(1,1)
Constant	–3.782***	–5.065***	–7.069***
	(0.227)	(0.323)	(0.257)
Log of real capital	0.211***	0.212***	0.458***
	(0.009)	(0.009)	(0.009)
Log of TFP	0.147***	0.206***	0.228***
	(0.012)	(0.013)	(0.011)
Foreign ownership dummy	0.657***	0.502***	0.497***
	(0.130)	(0.141)	(0.125)
Lagged trade dummy	1.640***	1.487***	2.176***
	(0.042)	(0.044)	(0.037)
Light industry dummy	–0.678***	0.428	0.354
	(0.206)	(0.308)	(0.238)
Raw materials industry dummy	–0.405**	0.482	0.444
	(0.206)	(0.308)	(0.238)
Machinery industry dummy	–0.042	0.458	0.813***
	(0.209)	(0.311)	(0.240)
Electric industry dummy	–0.730***	0.534*	0.697***
	(0.212)	(0.311)	(0.241)
Car manufacturing industry dummy	–0.614***	0.290	0.900***
	(0.232)	(0.328)	(0.252)
Number of observations		20,165	

Source: Author's calculations.

*Note: Estimates by choice outcomes d (export, import) with d(0,0) as the base outcome. Estimation period: 2003–06. Standard errors are reported in parentheses. *, **, and *** denote significance at the 90%, 95% and 99% levels. The above model was estimated on the pooled sample for 2003 to 2006 with the largest number of observations. In a further estimation, we use fitted choice probabilities estimated from year-by-year multinomial probit models. The year-on-year estimates of the model can be found in appendix 2 of Tóth (2013).*

Table 6

Estimates of the Equilibrium Sales Equation

	Coefficients of equation(16)	Full sample	Reduced sample
Constant	α_0	3.666***	3.989***
		(0.000)	(0.000)
Export dummy d(1,0)+d(1,1)	α_1	0.585**	0.907**
		(0.000)	(0.000)
Import dummy d(1,0)+d(1,1)	α_2	–0.008	–0.208
		(0.000)	(0.000)
Log of TFP as a function of import dummy	α_3	0.201***	0.227***
		(0.000)	(0.000)
R-squared		0.077	0.053
Number of observations		18,344	11,217
Number of firms		7,356	4,752

Source: Author's calculations.

*Note: The dependent variable is the log of total sales. The equation was estimated by 2SLS including fixed effects. Log of TFP was fitted from the production function in table 5, column 8. Standard errors are reported in parentheses. *, **, and *** denote significance at the 90%, 95% and 99% levels. The reduced sample corresponds to the observations used in table 5, column 8.*

In addition to the above structural parameters of the model, we can use the estimates of sales equation (16) to express the exchange rate elasticities of sales as predicted by the model. The elasticities tell us the percentage response of sales to a 1% depreciation of the nominal exchange rate. As the elasticities are symmetric with respect to a positive or a negative currency shock, we only need to invert the sign of the coefficient in order to look at the response of sales to an *appreciation* of the domestic currency in table 8 below. This is motivated by the fact that appreciation shocks usually receive more attention in Czech economic news reports than depreciation episodes.

According to our results as presented in table 8, a 1% appreciation of the domestic currency leads to a 0.2% rise in domestic sales for firms which import some of their inputs. For comparison, the same shock causes export sales to drop by 1% if the firm does not import inputs. This latter result follows from our assumption that exporters are price-takers on foreign markets and their contracts are written in the foreign currency. The similarly negative impact on export sales is somewhat reduced to 0.8% if the firm uses imported intermediate goods. Thus the negative effect of an appreciation on exports is somewhat cushioned by imported intermediates, still the negative exchange rate effect on export sales outweighs the positive effect on domestic sales. The appreciation shock leads to a drop of 0.2% or 0.4% in total sales of firms that both export and import, depending on whether the estimate is based on the full or the reduced sample. The above elasticity estimates are roughly comparable to our estimates on macro data.[24]

[24] *For more details on our macro estimates, see appendix 3 in the working paper version of this article (Tóth, 2013).*

Table 7

Estimates of Selected Structural Parameters

	Parameter (theoretical model)	Coefficients of equation (16)	Full sample	Reduced sample
Elasticity of substitution of the CES utility function	ε	$1 + \alpha_3$	1.201***	1.227***
			(0.072)	(0.073)
Share of freight cost-discounted foreign demand level in total demand level faced by exporters	R	$1 - \exp(-\alpha_1)$	0.443***	0.597***
			(0.148)	(0.159)
Variable unit cost of imports (CZK thousand)	$r\tau M$	$\exp(\alpha_2/-\alpha_3)$	1.042	2.501
			(0.929)	(2.505)
Number of observations			18,344	11,217
Number of firms			7,356	4,752

Source: Author's calculations.

*Note: Standard errors are reported in parentheses and are obtained by the delta method for the last two parameters. *, **, and *** denote significance at the 90%, 95% and 99% levels.*

Table 8

Implied Exchange Rate Elasticities of Sales

	Model	Coefficients of equation (16)	Full sample	Reduced sample
	Change in sales in % if domestic currency appreciates by 1%			
Domestic sales under strategies d(1,1) and d(0,1)	$-\rho 0(0,1) = -\rho(0,1) = -\rho 0(1,1)$	α_3	0.201***	0.227***
			(0.072)	(0.073)
Export sales under strategy d(1,1)	$-\rho x(1,1)$	$\alpha_3 - 1$	–0.799***	–0.775***
			(0.072)	(0.075)
Total sales under strategy d(1,1)	$-\rho(1,1)$	$\alpha_3 + \exp(-\alpha_1) - 1$	–0.243*	–0.370**
			(0.127)	(0.161)
Number of observations			18,344	11,217
Number of firms			7,356	4,752

Source: Author's calculations.

*Note: Standard errors are reported in parentheses. The delta method is used to obtain the standard error for the last elasticity. *, **, and *** denote significance at the 90%, 95% and 99% levels.*

5 Conclusion

In this paper, we studied the impact of a hypothetical currency shock on firm sales depending on a mix of firms' exporting and importing strategies. We argue that the exchange rate pass-through to sales is special in the case of firms that both export and import – a class of firms that became more widespread after the Czech Republic entered the European Union. Accordingly, we used within-firm variation in the time period around EU entry to identify our estimates. Our aim was to capture the exogenous effect of the lifting of trade barriers associated with EU entry on the participation of firms in international trade.

We found that importing firms are partially able to cushion the negative impact of an exchange rate shock on their export sales. In particular, export sales were found to drop by 0.8% as a result of a 1% appreciation of the domestic currency if the firm imports some of its intermediate goods, instead of dropping by 1%, as assumed, if a price-taker firm does not import inputs. At the same time, domestic sales are expected to rise by 0.2% and total sales to drop by 0.2% for the same subsample of firms. The above elasticities of export and total sales are roughly in line with our estimates based on macro-level data. While a currency appreciation still hurts firms engaged in international trade (in the sense that their overall sales are reduced), this negative effect is softened as firms integrate into global value chains (i.e. by importing intermediates).

Our research is also interesting from the point of view of estimating production functions. Our findings concur with those of other studies regarding the importance of measurement error correction in capital stock data. In particular, Galuščák and Lízal (2011) came to the same conclusion from a different Czech dataset. Moreover, our estimates imply that firm-specific fixed effects should not be ignored when estimating production functions. Finally, we confirm that imported intermediates increase firms' total factor productivity, as found also by Bas and Strauss-Kahn (2011), Halpern et al. (2011) and Kasahara and Rodrigue (2008) on microdata from France, Hungary and Chile, respectively.

Our analysis contributes to the literature on heterogeneous firms and trade by studying the impact of a hypothetical exchange rate shock to firm sales, a topic which has not been studied before in this context to our knowledge. All the more, this topic has received heightened attention in the policy sphere and media recently, as Česká národní banka decided to weaken the Czech koruna by starting to carry out interventions on the foreign exchange markets for an undefined period last November. Regarding this policy shock to the Czech koruna, our findings suggest that the benefits from the recently improved price competitiveness of Czech exporters will be somewhat dampened if exporters have to rely on more expensive imported inputs.

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