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Trade, skills and productivity

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Abstract
We examine how firms adjust their production and technology in response to exogenous trade shocks. We develop a model in which revenue TFP can be distinguished from quantity TFP, and where skill upgrading is explicitly embedded into the firm's technology choice. Within our framework, firms respond to export and import shocks by adjusting their trade-off between quantity and quality, as well as the skill composition of their workforce. Ultimately, these decisions impact firms' quantity and revenue TFP, marginal costs, prices, and markups. We quantify the model using detailed firm and product data from Brazil and show how export and import shocks, instrumented using exogenous changes in exchange rates, GDP, and tariffs, affect a wide array of firm margins. Our results indicate both skill and quality upgrading in response to export shocks, while import shocks foster technology upgrading and productivity improvements.

Keywords: exports, imports, shocks, skill upgrading, quality, technology, quantity TFP, revenue TFP, markups
JEL codes: F61; F14; D24; L11; L25

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1 Introduction

The increasing involvement of firms in international activities characterising recent decades has spurred a large number of contributions devoted to understanding firm behaviour in a globalised world and the margins available to firms to respond to an increasingly connected environment. The literature has identified several features associated with the internationalization process of firms, including skill upgrading of the workforce, product quality upgrading, technological innovation, and productivity improvements. Despite abundant evidence, the literature has thus far produced frameworks focusing on a subset of these channels at a time while largely neglecting the key distinction between revenue productivity (i.e., the capacity of firms to generate revenue with a given amount of inputs) and quantity productivity (i.e., the capacity of firms to generate physical output with a given amount of inputs).

In this paper, we fill this gap by developing a productivity model in which revenue TFP can be distinguished from quantity TFP, and skill upgrading is explicitly embedded into firm's technology choice. Within our framework, firms respond to export and import shocks by adjusting their quantity-quality trade-off and the skill composition of their workforce. Ultimately, these choices impact firms' quantity and revenue TFP, marginal costs, prices, and markups. In order to identify the parameters of the model and firms' response to international shocks, we rely on the structure of the model and instruments constructed from exogenous changes in exchange rates, GDP, and tariffs, weighted using the pre-sample network of firms' origin and destination countries.

Our analysis provides a comprehensive view of firm responses to international trade shocks, highlighting both the similarities and differences between shocks affecting export and import involvement. In this respect, our analysis indicates both skill and quality upgrading in response to export shocks, while import shocks promote technology upgrading and productivity improvements. The findings better qualify results from the previous literature, while offering deeper and sharper insights into the margins of adjustment, which are relevant for both theory development and policy design.

In our analysis, we use detailed balance sheet, production, skills, and trade data at the firm-level for Brazil over the period 2005-2014. Our data allow us to measure physical output and prices of the different products produced by a firm. Focusing on Brazil enables us, among others, to obtain instruments constructed from exchange rates, GDP, and tariff changes that have enough variation to generate instruments powerful enough to identify the impact of both export and import shocks on firm behavior. We use the data to estimate the parameters of our productivity model and to measure the impact of export and import shocks on a broad range of firm margins: revenue, quantity, prices, inputs consumption, share of skilled workers, revenue TFP, quantity TFP, marginal costs, and markups. In this regard, we provide evidence that our findings on the firm response to trade shocks are robust to different ways of distinguishing between skilled and unskilled workers, alternative strategies for apportioning inputs, different instruments, and weighting observations.

Our findings can be summarised as follows. First, we find robust evidence that increased involvement in export and/or import activities decreases the output elasticity of unskilled workers while increasing the output elasticity of skilled workers. In other words, as the firm becomes more involved in international trade, skilled workers become relatively more productive than unskilled workers. Such behavior represents a clear channel through which skill upgrading occurs with the internationalization of a firm, a factor either absent in the previous literature or not directly identified.

Second, while both export and import positive shocks increase firm revenue, quantity, and inputs consumption, positive export shocks increase the average firm price, while the opposite occurs with import shocks. Indeed, positive shocks affecting exports should act as a demand increase, possibly of higher-quality products, leading firms to charge higher prices. Conversely, positive shocks affecting imports should act as a reduction in the cost of foreign inputs, prompting firms to adopt better technologies and pass some cost savings onto consumers by charging lower prices. This interpretation is confirmed by a reduction in quantity TFP in the case of increased exports and an improvement in quantity TFP in the case of imports, as well as by an increase in marginal costs and the share of skilled workers in the case of positive export shocks.

Third, we find an overall weak reaction in terms of revenue TFP, while markups actually decrease in response to both export and import positive shocks. We rationalise this latter finding in light of the fact that exporting and importing firms operate in an environment of costly international trade in which they absorb (through markups) part of the additional costs to reach international customers and suppliers. Regarding the heterogeneity of the impacts, we find that revenue TFP is a useful dimension for distinguishing firms. In particular, we find heterogeneity in response along the productivity distribution, strongly characterizing the response to imports shocks. Less productive firms increase both revenue TFP and quantity TFP, while charging lower prices and higher markups and sustaining lower marginal costs. This suggests that import shocks have a more profound and cleaner impact on low productivity firms, reacting along all margins as if a substantial decrease in the cost of their inputs has occurred, thus spurring productivity gains only partially passed onto consumers.

Our paper is related to several literatures. First, it is related to the literature on the consequences of globalization on the market returns to different skills/occupations and changes in the composition of employment.[1] While these papers study the effects of trade on skill

[1]See Wood (1998), Goldberg and Pavcnik (2007), Harrison et al. (2011), Pavcnik (2011), Goldberg (2015), Goldberg and Pavcnik (2016), and Pavcnik (2017) for recent surveys of the literature.

utilization within firms, we analyse how they are related and interact with the effect of trade on firm technology and productivity.

Second, it is related to contributions linking export activity and skill upgrading (Yeaple, 2005; Bustos, 2011; Brambilla et al., 2012), as well as to papers exploring the nexus between exporting and product quality (Hallak, 2006; Verhoogen, 2008; Bastos and Silva, 2010; Kugler and Verhoogen, 2011; Manova and Zhang, 2012; Feenstra and Romalis, 2014; Bastos et al., 2018; Demir et al., 2024). While such investigations find that exporting increases skill utilization within firms, our paper also demonstrates that increased imports enhance productivity while increased exports have important effects on prices and the quality-quantity tradeoff. In this respect, while there are several hypotheses to explain the effects of exporting and/or importing on productivity (e.g. learning by exporting, quality choice, scale effects), the exact channel through which productivity gains are realized varies across these hypotheses. Gains could be driven by the reallocation of market shares towards more productive firms and/or an increase in within-firm revenue productivity, which could result from improvements on productive efficiency (i.e., physical productivity) or higher markups. While in both cases firms benefit as a result of trade, our paper quantifies the different margins of adjustment and shows that they have different implications for the composition of employment within firms.

Third, our paper connects to the literature identifying direct positive effects of exporting on firm revenue productivity (Bernard and Jensen, 1999; Pavcnik, 2002; Amiti and Konings, 2007; De Loecker, 2007), as well as to papers focusing on importing and firm performance (Blom et al., 2003; Fernandes, 2007; Topalova and Khandelwal, 2011; De Loecker et al., 2016). While these studies focus on effects on firm sales, productivity, employment growth and volatility, we focus on a wider range of firm-level adjustments while endogenizing the skill composition of the workforce and simultaneously looking at both import and export shocks. Last but not least, our framework belongs to the recent contributions that separate quantity from revenue TFP, thanks to both improved data availability and enhanced modeling (De Loecker et al., 2016; Forlani et al., 2023). We extend these methods to accommodate for the choice of skills and apply them to understand the effect of both exports and imports shocks.

The rest of the paper is organised as follows. Section 2 presents our productivity model, while Section 3 is devoted to the estimation strategy. Section 4 provides information on the data sources and instruments, as well as some key features of the firms in our sample. Section 5 contains results from the estimation of the model, the analysis of firm response to trade shocks, and a number of robustness checks. Finally, Section 6 concludes and draws directions for further research. Appendices A to C provide details about the multi-product firms extension of our model, further details about the instruments, as well as additional Tables.

2 The model

Firms involved in international trade sell their output both domestically and abroad and source materials from both the domestic and foreign markets. Trade shocks, and in particular exchange rates, tariffs and GDP shocks, modify the relative profitability of domestic and foreign operations. In this respect, the literature (Yeaple, 2005; Bustos, 2011; Brambilla et al., 2012) has so far provided ample evidence that this re-shifting of firms' operations has substantial implications for both the level and the ratio of unskilled and skilled workers employed by firms. Therefore, in the model we focus our attention to the relationship between trade and the labor input and in particular between trade and skills. In doing so, we construct a simple production function model consistent with the evidence so far provided about trade and the skill composition of the workforce while at the same time capable of taking the analysis forward with respect to the implications for technology, TFP, revenue TFP, prices and markups. In our framework, we do not fully distinguish between materials sourced domestically or imported as well as between production for the domestic market and exports. The key reason for this simplification is the absence of information in the data allowing us to associate specific inputs, and in particular materials and their domestic or foreign origin, to domestic or export output. Therefore, when thinking about materials in our framework, one has to think about the average bundle of domestic and foreign materials sourced by a firm in a particular year. In the same vein, when thinking about production in our framework one has to think about the average bundle of products for the domestic and foreign markets produced by a firm in a particular year.

2.1 Production technology

We index firms by i and time by t. We consider a production technology with 4 inputs: unskilled labour (L), skilled labour (H), materials (M) and capital (K). More specifically we consider:[2]

$$Q_{it} = L_{it}^{\alpha_{Lit}} H_{it}^{\alpha_{Hit}} M_{it}^{\alpha_M} K_{it}^{\alpha_K} A_{it},$$

where A_{it} is TFP while labor coefficients α_{Lit} and α_{Hit} are allowed to be firm-specific and in particular, as described more in detail below, to depend upon the involvement in international trade of firm i. Considering the log production function we thus have:

$$q_{it} = \alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it} + a_{it}, \tag{1}$$

[2]To simplify notation we ignore components that are common across firms in a given time period or for a given product. Those constants will be captured in the estimations by suitable sets of time and product dummies. Furthermore, production function estimations are carried out separately for each product group (essentially two-digit industries) so allowing coefficients to differ across sectors.

where small case letters indicate logs (for example $k_{it} = \log K_{it}$). In line with the productivity literature, we assume that the TFP process is driven by an autoregressive component. However, we enrich the basic framework by allowing exports and imports activities to affect TFP and in particular:

$$a_{it} = \phi_a \; a_{it-1} + b_{Ea} \Delta exp_{it}^{\mathbb{E}} + b_{Ia} \Delta imp_{it}^{\mathbb{E}} + \nu_{ait}, \tag{2}$$

where $\Delta exp_{it}^{\mathbb{E}}$ and $\Delta imp_{it}^{\mathbb{E}}$ represent the (expected) change in the log value of exports and imports of firm i between $t-1$ and t,[3] while ν_{ait} denotes productivity shocks that represent innovations with respect to the information set of the firm in $t-1$ and are iid across firms and time.

In line with the literature, we assume capital k_{it} to be predetermined in the short-run, i.e., the current capital level has been chosen in t-1 and cannot immediately adjust to current period shocks ν_{ait}.[4] We further assume, as standard in the literature, that materials m_{it} are a variable input free of adjustment costs. This means that materials can be optimally chosen in t based on, among others, the particular realization of ν_{ait}. In this respect, we will see later on that materials being fully adjustable in the short-run allows for a simple rule to pin-down the markup of firm i. Concerning unskilled and skilled labor, we assume them to be semi-flexible inputs meaning that they can, to some extent, adjust to current shocks in t but not to the optimal cost-minimizing level determined only by wages and marginal productivities. This is because they are subject to sizeable delays in between hiring/firing targets decisions and actual hires/fires as well as to various adjustment costs (hiring and firing costs, asymmetric information, costly screening, etc.). In sum, l_{it} and h_{it} should be correlated (like materials m_{it}) with shocks ν_{ait} but the amounts of unskilled and skilled labor in t do not simply reflect wages and marginal productivities implying that they cannot be used to recover markups. As far as the timing is concerned, we assume l_{it} and h_{it} are chosen by firm i at time $t-b$ $(0 < b < 1)$, after k_{it} being chosen in $t-1$ but prior to m_{it} being chosen in t.

Going back to the productivity process (2) a few remarks are in order. First, when a firm does not expect to change the volume of her exports and imports activities the process (2)

[3]More specifically, $\Delta imp_{it}^{\mathbb{E}} = \log(IMP_{it}^{\mathbb{E}} + 1) - \log(IMP_{it-1} + 1)$ where $IMP_{it}^{\mathbb{E}}$ are expected imports of firm i at time t and IMP_{it-1} are actual imports of firm i at time $t-1$ while $\Delta exp_{it}^{\mathbb{E}} = \log(EXP_{it}^{\mathbb{E}} + 1) - \log(EXP_{it-1} + 1)$ where $EXP_{it}^{\mathbb{E}}$ are expected exports of firm i at time t and EXP_{it-1} are actual exports of firm i at time $t-1$. As explained in more detail below, expectations of exports and imports in t refer to the information available to the firm when choosing unskilled and skilled labor: $t-b$ $(0 < b < 1)$.

[4]Intuitively, the restriction behind this assumption is that it takes a full period for new capital to be ordered, delivered, and installed. Note this means that k_{it} is uncorrelated with current period shocks ν_{ait}. However, this does not mean that k_{it} is uncorrelated with the current productivity *level* a_{it}. For example, investment decisions in $t-1$ are likely to be determined by both the level of capital in $t-1$ and the level of productivity in $t-1$. In this light, k_{it} should be correlated with a_{it-1} and so with a_{it}. See Ackerberg et al. (2015) for more details.

simplifies to the standard AR(1) process:

$$a_{it} = \phi_a \ a_{it-1} + \nu_{ait}. \tag{3}$$

We interpret this as the firm using the same production technology in years $t-1$ and t with productivity being subject to, as standard, some degree of depreciation captured by the autoregressive coefficient ϕ_a as well as idiosyncratic contemporaneous shocks ν_{ait}. However when a firm, for example, expects to expand her exports and imports activities will likely put in place a number of changes to her production technology in order to best exploit the characteristics of the growing quantity of foreign inputs as well as to best tailor products that are increasingly sold in foreign markets. In particular, a drop in the price of foreign inputs might spur technology upgrading within the firm and an increased volume of activity driving up quantity TFP a_{it} and reducing production costs. On the other hand, the same price drop might also induce firms to invest more in quality at the expenses of a lower quantity TFP a_{it} with further repercussions on production costs and the skill composition of the workforce. This second channel should be particularly relevant for exports given the well documented evidence of quality upgrading for firms turning to international markets (Verhoogen, 2008). More specifically, the evidence provided by the literature points to firms increasing the quality of their products when increasing their export involvement so altering the quantity-quality trade off firms face and leading to higher costs and prices charged.

Second, coming back to equation (2) we allow for changes to the production technology induced by international trade to impact firm productivity in t via the terms $b_{Ea}\Delta exp^{\mathbb{E}}_{it}$ and $b_{Ia}\Delta imp^{\mathbb{E}}_{it}$. We assume these changes to fully materialize in the space of a year so that, if in the following year the firm does not expect any changes in the volume of her exports and imports activities, the productivity process will resume to (3). This means that the productivity *change* occurred in the past and driven by expected *changes* in exports and imports permanently affect the productivity *level*.

Third, given that contemporaneous productivity shocks ν_{ait} represent innovations with respect to the information set of the firm in $t-1$, they are uncorrelated with all past levels of productivity, and in particular with a_{it-1}, as well as with imports and exports in $t-1$. At the same time, we assume expectations about exports and imports in t are formed after $t-1$ and more specifically when the firm makes decisions about unskilled and skilled labour: $t-b$ $(0 < b < 1)$. This is to reflect the key technology relationship between trade activities and the skill composition of the labour force. When forming expectations about exports and imports at time $t-b$ the firm has a better knowledge of ν_{ait} than it had in $t-1$; where the expected value of ν_{ait} was actually zero. At the same time the value, and so the expectation, of exports and imports in t depend upon the realization of ν_{ait}. For example, an expected positive productivity shock will, ceteris paribus, increase the expected level of exports and imports leading the firm to reconsider her production technology and ultimately affecting productivity a_{it}. Therefore, the expected (log) levels of exports and imports in t, and so $\Delta exp_{it}^{\mathbb{E}}$ and $\Delta imp_{it}^{\mathbb{E}}$, should be correlated with ν_{ait}. This ultimately implies that $\Delta exp_{it}^{\mathbb{E}}$ and $\Delta imp_{it}^{\mathbb{E}}$ are endogenous variables in the process (2) which needs to be taken into account in the estimation.

Finally, based on arguments similar to those provided above for the TFP process, we allow labour coefficients α_{Lit} and α_{Hit} in the production function (1) to be firm-specific and in particular to depend upon the involvement of firm i in international trade. More specifically, we assume firms use different technologies in order to best exploit the characteristics of their specific combination of domestic and foreign inputs as well as to best tailor products that are sold in both the domestic and foreign markets. To model this in a parsimonious way we assume that:

$$\begin{aligned} \alpha_{Lit} &= \alpha_L + b_{EL} exp_{it}^{\mathbb{E}} + b_{IL} imp_{it}^{\mathbb{E}}, \\ \alpha_{Hit} &= \alpha_H + b_{EH} exp_{it}^{\mathbb{E}} + b_{IH} imp_{it}^{\mathbb{E}}, \end{aligned} \tag{4}$$

i.e., the that the elasticities of output with respect to unskilled and skilled labour are a function of the expected level of exports and imports of firm i at time t. Depending on her expected involvement in exports and imports activities at time $t-b$, the firm will adopt a particular production technology and will therefore choose a particular skill composition and overall employment.

2.2 Markups, marginal costs and revenue TFP

At time t firms have already chosen capital, unskilled labor and skilled labor and so these inputs are considered as given in their decision process along with the cost of materials W_{Mit}. At the same time, productivity a_{it} and the demand firms are facing become known at time t. We assume firms in t use the above information and constraints to choose materials in order to minimize production costs and choose quantity or price (depending upon the features of competition) in order to maximize profits. In this respect, as first highlighted in Hall (1986) and further implemented in De Loecker and Warzynski (2012), De Loecker et al. (2016) and Forlani et al. (2023) among others, cost-minimization of a variable input free of adjustment costs provides a simple rule to pin down markups. The marginal cost is:

$$\frac{\partial C_{it}}{\partial Q_{it}} = \frac{\partial C_{it}}{\partial M_{it}} \frac{\partial M_{it}}{\partial Q_{it}} = W_{Mit} \frac{\partial M_{it}}{\partial Q_{it}}.$$

Now define the markup as:

$$\mu_{it} \equiv \frac{P_{it}}{\frac{\partial C_{it}}{\partial Q_{it}}}.$$

We thus have:

$$\frac{P_{it}}{\mu_{it}} = W_{Mit} \frac{\partial M_{it}}{\partial Q_{it}}.$$

Multiplying by Q_{it} and dividing by M_{it} on both sides implies that:

$$\frac{P_{it} Q_{it}}{M_{it} \mu_{it}} = \frac{R_{it}}{M_{it} \mu_{it}} = W_{Mit} \frac{\partial M_{it}}{\partial Q_{it}} \frac{Q_{it}}{M_{it}} = W_{Mit} \frac{\partial m_{it}}{\partial q_{it}}.$$

Re-arranging we finally have:

$$\mu_{it} = \frac{\frac{\partial q_{it}}{\partial m_{it}}}{\frac{W_{Mit} M_{it}}{R_{it}}} = \frac{\frac{\partial q_{it}}{\partial m_{it}}}{s_{Mit}}.$$

This simple rule to pin-down markups is consistent with many hypotheses on product market structure (monopolistic competition, monopoly and standard forms of oligopoly) and consists in taking the ratio of the output elasticity of materials ($\frac{\partial q_{it}}{\partial m_{it}}$) to the share of materials in revenue ($s_{Mit} \equiv \frac{W_{Mit} M_{it}}{R_{it}}$). Considering our production function (1) we simply have:

$$\mu_{it} = \frac{\alpha_M}{s_{Mit}}. \tag{5}$$

Therefore, provided estimates of the parameters of the production function (1), and in particular of α_M, as well as data on materials expenditure and revenue, one can simply compute the firm-specific markup μ_{it} using (5). Using information on prices P_{it}, one can subsequently compute marginal costs as:

$$MC_{it} = \frac{P_{it}}{\mu_{it}}. \tag{6}$$

Finally, considering that log revenue is $r_{it} = p_{it} + q_{it}$ and defining (log) revenue TFP as $TFP_{it}^R \equiv r_{it} - \bar{q}_{it}$, where $\bar{q}_{it} = \alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$, we have:

$$TFP_{it}^R \equiv r_{it} - \bar{q}_{it} = p_{it} + q_{it} - \bar{q}_{it} = p_{it} + a_{it} = mc_{it} + \log \mu_{it} + a_{it}, \tag{7}$$

where the last equality comes from (6) and in particular from $p_{it} = mc_{it} + \log \mu_{it}$. Therefore, TFP_{it}^R can be decomposed into the sum of log price and log productivity as well as into the sum of log marginal cost, log markup and log productivity.

3 Estimation Procedure

The set of assumptions laid down above allows, along with information on inputs, revenue, quantity, prices, exports and imports, to recover the parameters of the production function, and so productivity a_{it} as well as markups, marginal costs and revenue TFP, for single-product firms. In this Section, we show how to achieve this. In order to ease the exposition, we refer to Appendix A for the more involved case of multi-product firms.

3.1 Measurement error in output

One issue we need to first account for is the presence of measurement error in quantity and/or revenue. In the case of quantity, instead of q_{it}, the econometrician might be observing q'_{it}=$q_{it} + e_{it}$ where e_{it} is measurement error. Another interpretation of the same equation is that e_{it} represents productivity shocks unanticipated by the firm. (1) thus becomes:

$$q'_{it} = q_{it} + e_{it} = \alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it} + a_{it} + e_{it}. \tag{8}$$

The standard approach suggested by the literature (Ackerberg et al., 2015; De Loecker et al., 2016) to deal with measurement error in output and/or unanticipated shocks e_{it} is based on monotonicity and the use a semi-parametric approach to purge q'_{it} from e_{it}. More specifically, in our framework firms choose materials optimally in t based on a_{it}, the demand they face, k_{it}, l_{it} h_{it} as well as exp_{it} and imp_{it}. First, in order to proxy for variables determining the demand a firm faces we use information on the (log) firm price p_{it}. Second, denoting by $h(.)$ the function relating optimal material expenditure to the other variables we have m_{it}=$h(a_{it}, p_{it}, k_{it}, l_{it}, h_{it}, exp_{it}, imp_{it})$. Now assume $\partial h(.)/\partial a_{it}$ is globally monotonous. We can thus invert h(.) and obtain a well-defined function $a_{it} = g(m_{it}, p_{it}, k_{it}, l_{it}, h_{it}, exp_{it}, imp_{it})$. At this stage we do not know the shape of $g(.)$. To solve this issue we use a third order polynomial in m_{it}, p_{it}, k_{it}, l_{it}, h_{it}, exp_{it} and imp_{it} to approximate $g(.)$. Let's denote this polynomial as $poly_{it}$. We can thus substitute for a_{it} with $poly_{it}$ in (8) to get:

$$q'_{it} = poly'_{it} + e_{it}, \tag{9}$$

where $poly'_{it} = \alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it} + poly_{it}$ is again a third order polynomial in m_{it}, p_{it}, k_{it}, l_{it}, h_{it}, exp_{it} and imp_{it}. We run (9) separately for each product group (essentially two-digit industries), while including a full set of 8-digit product dummies and year dummies, and use the OLS prediction of q'_{it}, that we label $\hat{q}^{OLS}_{it}$, as (log) quantity in the rest of the analysis.

We also use a similar approach for revenue and consider

$$r'_{it} = poly'_{it} + \bar{e}_{it}, \tag{10}$$

where $\bar{e}_{it}$ now contains measurement error in both quantity and prices, as well as unobserved productivity shocks. We run (10) separately for each product group, while including a full set of 8-digit product dummies and year dummies, and use the OLS prediction of r'_{it}, that we label $\hat{r}^{OLS}_{it}$, as (log) revenue in the rest of the analysis.

3.2 Estimating the production function

In what follows we build upon Wooldridge (2009), Ackerberg et al. (2015) and De Loecker et al. (2016) while allowing for technology and TFP to depend upon the trade involvement of a firm. First, from the previous Section we have that, by using the assumption of monotonicity and a semi-parametric approximation, $a_{it} = poly_{it}$. Using $a_{it-1} = poly_{it-1}$ in (2) we have:

$$a_{it} = \phi_a poly_{it-1} + b_{Ea}\Delta exp^{\mathbb{E}}_{it} + b_{Ia}\Delta imp^{\mathbb{E}}_{it} + \nu_{ait},$$

while substituting this into the production function (1) one gets:

$$q_{it} = \alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \phi_a poly_{it-1} + b_{Ea}\Delta exp^{\mathbb{E}}_{it} + b_{Ia}\Delta imp^{\mathbb{E}}_{it} + \nu_{ait}.$$

Finally, making use of (4) one obtains:

$$\begin{aligned} q_{it} &= \alpha_L l_{it} + b_{EL} exp^{\mathbb{E}}_{it} l_{it} + b_{IL} imp^{\mathbb{E}}_{it} l_{it} + \alpha_H h_{it} + b_{EH} exp^{\mathbb{E}}_{it} h_{it} + b_{IH} imp^{\mathbb{E}}_{it} h_{it} \\ &+ \alpha_M m_{it} + \alpha_K k_{it} + \phi_a poly_{it-1} + b_{Ea}\Delta exp^{\mathbb{E}}_{it} + b_{Ia}\Delta imp^{\mathbb{E}}_{it} + \nu_{ait}. \end{aligned} \tag{11}$$

Note that in (11) one does not need to identify the parameter ϕ_a and so $\phi_a poly_{it-1}$ is simply a polynomial we label $poly'_{it-1}$:

$$\begin{aligned} q_{it} &= \alpha_L l_{it} + b_{EL} exp^{\mathbb{E}}_{it} l_{it} + b_{IL} imp^{\mathbb{E}}_{it} l_{it} + \alpha_H h_{it} + b_{EH} exp^{\mathbb{E}}_{it} h_{it} + b_{IH} imp^{\mathbb{E}}_{it} h_{it} \\ &+ \alpha_M m_{it} + \alpha_K k_{it} + poly'_{it-1} + b_{Ea}\Delta exp^{\mathbb{E}}_{it} + b_{Ia}\Delta imp^{\mathbb{E}}_{it} + \nu_{ait}. \end{aligned} \tag{12}$$

Given the assumption that productivity shocks ν_{ait} are innovations with respect to the information set of the firm in $t-1$, ν_{ait} is uncorrelated with $poly'_{it-1}$ in (12). Furthermore, capital is predetermined and so uncorrelated with ν_{ait} too. Therefore, the endogenous variables in (12) are materials m_{it}, unskilled labour l_{it}, skilled labour h_{it}, the interactions of skilled and unskilled labour with expected exports and imports ($exp^{\mathbb{E}}_{it} l_{it}$, $imp^{\mathbb{E}}_{it} l_{it}$, $exp^{\mathbb{E}}_{it} h_{it}$, $imp^{\mathbb{E}}_{it} h_{it}$) as well as changes in expected exports and imports $\Delta exp^{\mathbb{E}}_{it}$ and $\Delta imp^{\mathbb{E}}_{it}$. Note that all these variables/expectations are chosen/formed at time $t - b$.

We replace expected values in (12) with actual exports and imports levels and changes in t[5] and, in order to identify the parameters of the endogenous variables, we exploit additional moments conditions. More specifically, we use as instruments: i) materials, unskilled labour, skilled labour and capital at time $t-2$; ii) the interactions of skilled and unskilled labour with exports and imports, as well as changes in exports and imports, at time $t-1$. Indeed, given that shocks ν_{ait} are innovations with respect to the information set of the firm in $t-1$, they are uncorrelated with the above instruments. We estimate (12) by IVs separately for each product group while including a full set of 8-digit product dummies and year dummies. This ultimately allows us to get estimates of the production function parameters for each product group and so recover an estimate of TFP:

$$\hat{a}_{it} = q_{it} - \hat{\alpha}_L l_{it} - \hat{b}_{EL} exp_{it} l_{it} - \hat{b}_{IL} imp_{it} l_{it} - \hat{\alpha}_H h_{it} - \hat{b}_{EH} exp_{it} h_{it} - \hat{b}_{IH} imp_{it} h_{it} - \hat{\alpha}_M m_{it} - \hat{\alpha}_K k_{it},$$

as well as of markups, marginal costs and revenue TFP by means of (5) to (7).

4 Data and instruments

4.1 Production and inputs data

The first dataset we use is the *Pesquisa Industrial Anual - Empresa* (PIA-Empresa), which contains detailed information on revenues and costs of firms in Brazil's manufacturing and mining sectors. The dataset is constructed by the Brazilian National Statistical Institute (*Instituto Brasileiro de Geografia e Estatística*, or IBGE) based on annual firm surveys in the manufacturing and mining sector. This survey is filled by all firms with either more than 30 employees or above a revenue threshold as well as by an annual random sample of smaller firms. The survey is mandatory and non-compliance is subject to a fine by national authorities. Each firm has a unique anonymized identifier which we use, for example, to link firm characteristics data from PIA empresa to worker-level variables on skills as explained below. From this dataset we focus on manufacturing firms and borrow information over the period 2005-2014 on firm revenue, capital stock, cost of goods and services purchased (that from now onwards we refer to as the cost of materials), total wage bill and industry affiliation.

[5] The difference between, for example, expected exports $exp^{\mathbb{E}}_{it}$ at time in $t-b$ and actual exports exp_{it} is given by shocks between $t-b$ and t that are innovations with respect to the information set of the firm in $t-b$ and so are also innovations with respect to the information set of the firm in $t-1$ and $t-2$. Such shocks have zero mean and are uncorrelated with $poly'_{it-1}$ and capital in t as well as with the set of instruments we use, which is based on lags. For example, we have $\mathbb{E}[(exp^{\mathbb{E}}_{it} - exp_{it})m_{it-2}] = 0$ as well as $\mathbb{E}[(exp^{\mathbb{E}}_{it} - exp_{it})l_{it}] = 0$. Therefore, the same IV approach applies when using either $exp^{\mathbb{E}}_{it}$ or exp_{it}. A similar reasoning applies to expected and actual imports as well as to expected and actual changes in exports and imports.

The second dataset we use is the *Pesquisa Industrial Anual - Produto* (PIA-Produto), which contains detailed information on both the value and the quantity of the different products produced by manufacturing and mining firms in Brazil. Since 2005 the coverage of PIA produto basically coincides with the one of PIA empresa. Each product is identified by a unique 8-digit code whose first 4-digits come from the Brazilian CNAE classification (*Classificação Nacional de Atividades Econômicas*). There are about 3,400 different products in the database and each product has an associated unit of measurement for quantities. Again, the survey is mandatory and non-compliance is subject to a fine by national authorities. Each firm has the same unique identifier of PIA empresa that we use to link the two datasets. From this dataset we focus on manufacturing firms and borrow information on the value and the quantity of the different products produced by firms over the period 2005-2014.

For the estimation of the production function parameters using quantity as a measure of output we perform, as in De Loecker et al. (2016) and Forlani et al. (2023), a similar industry grouping in order to have sufficient data and in particular, starting from 2-digit CNAE industries, we : i) combine sectors 10 and 11; ii) discard sector 12 'Manufacture of tobacco products'; iii) combine sectors 13, 14 and 15; iv) discard sector 19 'Manufacture of coke and refined petroleum products'; v) combine sectors 20 and 21; vi) combine sectors 26, 27 and 28; vii) combine sectors 29 and 30; viii) combine sectors 32 and 33. Finally, in those instances in which total sales from PIA produto are 10% or more smaller than sales in PIA empresa (likely because the firm performs activities other than manufacturing) we use the former measure for sales and assign to the firm a portion of the original inputs (costs of materials, capital and wage bill) reported in PIA empresa based on the ratio of PIA produto sales to PIA empresa sales.

4.2 Skills data

In order to differentiated between skilled and unskilled workers within a firm we use the *Relação Anual de Informações Sociais* (RAIS) containing earnings, education, occupation and demographic characteristics of workers as reported by employers. The RAIS data contains linked employer-employee records that are constructed from a mandatory survey filled annually by all registered firms in Brazil and administered by the Brazilian Ministry of Labor and Employment (*Ministerio do Trabalho e Emprego*, or MTE). Fines are levied on late, incomplete, or inaccurate reports, and as a result many businesses hire a specialized accountant to help with the completion of the survey. In addition, MTE conducts frequent checks on establishments across the country to verify the accuracy of information reported in RAIS.

The RAIS contains an anonymized person identifier for each worker, as well as the same anonymized firm identifiers used in PIA empresa and PIA produto. We select those firms in

RAIS that are present in the matched PIA empresa PIA produto sample and, for each firm-year, we compute the share of workers that are skilled and unskilled. More specifically, using information on educational attaintment in RAIS we classify in our benchmark analysis workers as skilled if they have at least completed high school education and unskilled otherwise. With information on the share of skilled and unskilled workers we then use the total wage bill from PIA empresa to split it between the two groups of workers.

We also provide below a number of results based on two alternative ways of drawing the line between skilled and unskilled workers: 1) classifying workers as skilled if they have a level of education above high school and unskilled otherwise; 2) classifying workers as skilled based on their occupation within the firm and in particular defining as skilled those workers occupying professional & managerial jobs, technical and supervisory jobs, as well as other white collar occupations (ISCO one-digit categories 1 to 5).

4.3 Trade data and instruments

In our analyses we make use of firm-level exports and imports data disaggregated by country of destination and origin in order to construct instruments for the change in the observed export and imports of the firm.[6] More specifically, we start from data on real exchange rates, real GDP and Brazilian applied import tariffs and use changes in those variables as instruments for changes in actual exports and imports at the firm-level. In constructing changes in real exchange rates, real GDP and import tariffs we use the past portfolio of firm export destinations and import origins to weigh changes across countries. In our benchmark analysis we use the export and import network of the firm in the pre-sample period 2002-2005 to compute weights. In order to better capture the contributions of those firms starting exporting and/or importing post-2005 we then consider as a robustness an alternative set of weights based on the export and import network of the firm for years $t-1$ and $t-2$. More details about the construction of the instruments are provided in Appendix B.

The idea behind our instrumentation strategy is that changes in real exchange rates, real GDP and import tariffs affect the change of exports and imports of a firm but should be uncorrelated with other shocks affecting firm operations and impacting upon the outcome variables we are interested in (revenue TFP, TFP, markups, marginal costs, skill upgrading, etc.). A similar instrumentation strategy has been used in Revenga (1992), Park et al. (2010), Brambilla et al. (2012), Mion and Zhu (2013), among other.

[6]The trade data has the same anonymized firm identifiers used in PIA empresa, PIA produto and the RAIS which we use to match with the rest of the data.

4.4 Final sample and summary statistics

We match the information coming from the different datasets using the common anonymized firm identifiers. In order to deal with multi-product firms we follow the procedure described in Appendix A and in particular we split multi-product firms into single-product units while using the techniques described in Appendix A to apportion inputs across single-product units.[7] As a robustness check, we provide below key results obtained using a simple rule to apportion inputs across the products of a multi-product firms and in particular using the revenue shares of the different products.

Table 1: Descriptive Statistics

	Mean	Std. Dev.	p5	p50	p95	Observations
Sales	14.7728	121.2853	0.0352	1.5457	47.5922	338,160
Capital	11.1258	83.0502	0.0016	0.7267	37.6072	338,160
Materials	8.0237	67.0012	0.0124	0.6954	25.7824	338,160
Unskilled labour	0.6897	18.6549	0.0014	0.1237	1.9636	338,160
Skilled labour	1.3062	10.2531	0.0023	0.1347	4.2589	338,160
Export intensity	0.0473	0.1395	0.0000	0.0000	0.2700	338,160
Import intensity	0.0698	0.1688	0.0000	0.0000	0.4600	338,160

Notes: Descriptive statistics are reported at the firm-product level across all years (2005-2014). The unit of measurement of sales, capital, materials, unskilled labour and skilled labour is million of current Brazilian reals. Unskilled and skilled labour represent unskilled and skilled labour total cost. Export (Import) intensity represents the share of sales (materials) that is exported (imported). p5, p50 and p95 represent the 5th percentile, the median and the 95th percentile, respectively.

Table 1 provides key summary statistics for the main variables. Our analysis encompasses over 338,000 observations over the period 2005-2014, representing approximately half of the manufacturing production value in Brazil for 2014.[8] An observation in the data is a firm-product-year tuple. As can be seen from Table 1, the average (median) annual sales being around 15 (1.5) million Brazilian Reals (BRL). The average (median) firm-product unit spends

[7] From now onwards, and with the exception of imports and exports value and intensity which are at the firm-level, all of the variables in our analysis refer to the firm-product-level. For revenue, quantity and prices information at the firm-product level is directly provided by PIA produto. For inputs we instead start from firms and use the apportion procedure described in Appendix A.

[8] We apply various trimmings to the data to deal with extreme observations. For example, we discard observations with missing or negative values of sales, intermediates, capital, quantity produced and wages and trim the top and bottom 5% of observations with respect to the distributions of the following 3 ratios: 1) Capital over sales; 2) Intermediates over sales; 3) Wage bill over sales. We also discard observations corresponding to little production as reported in PIA produto with respect to sales in PIA empresa and trim the top and bottom 2% of observations with respect to the price distribution within each 8-digit product. Finally, we also discard observations corresponding to markups above 5 or markups below of output elasticity of materials and trim the top and bottom 1.5% of the distributions of change in exports and change in imports as well as the top and bottom 1% of the distributions of instruments.

about 8 (0.7) million reals in intermediate goods and services and around 2 (0.25) million reals in wages between skilled and unskilled workers. Furthermore, the average (median) capital stock is in the range of 11 (0.7) million reals with an average ratio of exports (imports) to sales (materials) of about 5% (7%). The 5th and 95th percentiles of each distribution are, along with the standard deviation, also reported in Table 1 and they overall suggest that we have a broad coverage of both small and large enterprises.

Table 2: Characteristics of Exporters and Importers

	Share skilled baseline	Share skilled alt. educ.	Share skilled alt. occup.	Revenue	Quantity	Price
Panel A. Exporters						
Exporter	0.0898***	0.0512***	0.1028***	1.0416***	0.9558***	0.0858***
	(0.0014)	(0.0011)	(0.0012)	(0.0144)	(0.0164)	(0.0092)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	338,160	338,160	338,160	338,160	338,160	338,160
Number of firm-product couples	134,348	134,348	134,348	134,348	134,348	134,348
R-squared	0.4017	0.4187	0.4380	0.2673	0.5738	0.8059
Panel B. Importers						
Importer	0.1160***	0.0926***	0.1302***	1.1178***	0.9544***	0.1634***
	(0.0015)	(0.0013)	(0.0013)	(0.0153)	(0.0175)	(0.0100)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	338,160	338,160	338,160	338,160	338,160	338,160
Number of firm-product couples	134,348	134,348	134,348	134,348	134,348	134,348
R-squared	0.4122	0.4391	0.4550	0.2692	0.5724	0.8062

Notes: The Table provides estimates of simple OLS regressions where each dependent variable is regressed on 8-digit product dummies and year dummies as well as on a dummy variable indicating whether the firm is an exporter (top panel) or an importer (bottom panel) and zero otherwise. In the first 3 columns the depend variable is the share of skilled workers and in particular column 1 refers to our baseline definition of skilled and unskilled workers while columns 2 and 3 refer to the two alternative ways of drawing the line between skilled and unskilled workers (see Section 4.2). In columns 4, 5 and 6 the dependent variable is log revenue, log quantity and log price, respectively. Standard errors (in parenthesis) are clustered at the firm-product level. ∗ ∗ ∗ p<0.01, ∗∗ p<0.05, ∗ p<0.1.

Before turning to the estimations of the production function and our analysis on the impacts of export and import shocks on various margins, we present in Table 2 some key features of exporting and importing firms. These features will be useful in interpreting some of the results to follow. More specifically, we consider the share of skilled workers, revenue, quantity, and price of firm-product units in our sample. We systematically assess whether and how exporters and importers differ from other firms with respect to these characteristics. In the top panel of Table 2 we focus on the comparison between exporting and non-exporting firms and run a simple regression where the outcome variable is one of the above characteristics and, while controlling for 8-digit product dummies and year dummies, the key regressor is a dummy variable taking value of if a firm is an exporter and zero otherwise. The bottom panel of Table 2 is constructed in a similar way while focusing on the distinction between importers and non-importers.

Table 2 indicates that the share of skilled workers is significantly higher in both exporting and importing firms compared to non-trading firms. This is the case irrespective of whether we consider our baseline definition of skilled workers (column 1) or use two alternative ways of distinguishing between skilled and unskilled workers (columns 2 and 3). At the same time, exporting and importing firms are characterised by higher (log) revenues and sell higher (log) quantities despite charging higher (log) prices. For example, importers sell three times as much than non-importers ($e^{1.1178}$=3.0581) and in particular, sell 2.6 times as much quantity ($e^{0.9544}$) despite charging 18% higher prices ($e^{0.1634} - 1$). All of the above is consistent with extensive evidence in the literature (Verhoogen, 2008; Bernard et al., 2012) indicating that exporting and importing firms are larger, employ a more skilled labor force, and produce higher quality products that they sell in abundance despite their higher prices.

5 Results

5.1 Technology and Skills

Table 3 provides estimates of the parameters of the production function (1) obtained from IVs estimations of equation (12). Estimations are carried on the sub-sample of single-product firms for each of the 13 industry groups we consider.[9] All regressions include a full set of 8-digit product dummies and year dummies while standard errors are clustered at the firm-product level. The measure of skills we use in those regressions is our baseline one. Tables C-1 and C-2 in Appendix C provide complementary estimates based on the two alternative definitions of skilled and unskilled workers we consider, with results being qualitatively identical to those reported here.

Coefficients estimates for materials and capital are consistent with previous findings in the literature, particularly in line with De Loecker et al. (2016) and Forlani et al. (2023). These studies also estimate productivity using quantity as a measure of output while dealing with multi-product firms. In particular, the output elasticity of materials ranges from 0.58 to 0.72, while the output elasticity of capital falls in the 2% to 3% range, sometimes not significant. Regarding the elasticities of output with respect to skilled and unskilled workers, they are firm-product-specific in our framework, as they are related to the degree of involvement in international trade and do not have direct counterparts in the previous literature. The coefficients of skilled and unskilled labor expenditure correspond to the output elastic-

[9] See Appendix A for details on the need to focus on single-product firms for the estimation of production function parameters and the assumptions needed to extend those parameters to multi-product firms. Also see Section 4.1 for details on the 13 industry groups we consider.

Table 3: Production Function Estimations: Baseline Measure of Skilled and Unskilled Workers

Industry	10-11	13-15	16	17-18	20-21	22	23
Materials	0.6476***	0.5867***	0.6124***	0.6824***	0.7229***	0.6162***	0.6146***
	(0.0329)	(0.0324)	(0.0312)	(0.0849)	(0.0884)	(0.0279)	(0.0223)
Unskilled labor	0.1157***	0.1546***	0.1529***	0.1094***	0.0872***	0.1196***	0.1612***
	(0.0060)	(0.0086)	(0.0175)	(0.0152)	(0.0138)	(0.0089)	(0.0093)
Skilled labor	0.1742***	0.1405***	0.1078***	0.1613***	0.2118***	0.1895***	0.1322***
	(0.0068)	(0.0059)	(0.0075)	(0.0141)	(0.0157)	(0.0087)	(0.0040)
Unskilled labor × Exports	-0.0018**	0.0003	0.0034**	0.0109	-0.0017	-0.0006	-0.0045**
	(0.0008)	(0.0011)	(0.0014)	(0.0089)	(0.0013)	(0.0009)	(0.0023)
Unskilled labor × Imports	-0.0029***	-0.0022**	-0.0063**	-0.0123*	-0.0027**	-0.0035***	-0.0018
	(0.0008)	(0.0010)	(0.0030)	(0.0067)	(0.0014)	(0.0009)	(0.0021)
Skilled labor × Exports	0.0014*	-0.0008	-0.0018**	0.0071	0.0006	0.0007	0.0009
	(0.0008)	(0.0008)	(0.0009)	(0.0068)	(0.0032)	(0.0008)	(0.0010)
Skilled labor × Imports	0.0017	0.0019**	0.0063**	-0.0043	0.0036	0.0025***	0.0044***
	(0.0012)	(0.0009)	(0.0026)	(0.0077)	(0.0041)	(0.0009)	(0.0014)
Capital	0.0311***	0.0343***	0.0143	-0.0253	0.0218***	0.0338***	0.0072*
	(0.0074)	(0.0070)	(0.0116)	(0.0577)	(0.0070)	(0.0088)	(0.0037)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,783	5,674	1,561	1,653	1,100	3,163	4,969
Number of firm-product couples	1,512	1,924	585	526	357	1,013	1,495
R-squared	0.9982	0.9950	0.9955	0.9906	0.9986	0.9989	0.9973

Industry	24	25	26-28	29-30	31	32-33
Materials	0.6397***	0.5813***	0.5823***	0.7193***	0.6780***	0.6042***
	(0.0950)	(0.0219)	(0.0193)	(0.0382)	(0.0411)	(0.0323)
Unskilled labor	0.1236***	0.1198***	0.1029***	0.0863***	0.1229***	0.0942***
	(0.0145)	(0.0064)	(0.0057)	(0.0074)	(0.0123)	(0.0099)
Skilled labor	0.1477***	0.1967***	0.2123***	0.1835***	0.1502***	0.2307***
	(0.0199)	(0.0063)	(0.0091)	(0.0086)	(0.0096)	(0.0153)
Unskilled labor × exports	0.0005	-0.0007	-0.0006	-0.0004	-0.0011	-0.0010
	(0.0046)	(0.0008)	(0.0007)	(0.0006)	(0.0022)	(0.0016)
Unskilled labor × imports	-0.0051	-0.0028***	-0.0022***	-0.0024***	-0.0031	-0.0012
	(0.0036)	(0.0008)	(0.0007)	(0.0006)	(0.0022)	(0.0016)
Skilled labor × exports	-0.0005	0.0007	0.0007	0.0005	0.0004	0.0049***
	(0.0044)	(0.0010)	(0.0013)	(0.0006)	(0.0014)	(0.0015)
Skilled labor × imports	0.0044	0.0011	0.0022*	0.0016***	0.0039**	-0.0041*
	(0.0040)	(0.0012)	(0.0013)	(0.0005)	(0.0020)	(0.0021)
Capital	0.0081	0.0159***	0.0154**	0.0248	0.0156	0.0015
	(0.0079)	(0.0032)	(0.0070)	(0.0163)	(0.0103)	(0.0151)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,176	2,814	3,661	2,287	1,656	1,593
Number firm-product couples	343	937	1,245	660	582	506
R-squared	0.9967	0.9988	0.9993	0.9992	0.9943	0.9983

Notes: The Table provides estimates of the parameters of the production function (1) obtained from IVs estimations of equation (12). Estimations are carried on the sub-sample of single-product firms for each of the 13 industry groups we consider. For skilled and unskilled workers we use here our benchmark definition: we classify workers as skilled if they have at least completed high school education and unskilled otherwise (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

ities of firms not involved in exporting and/or importing and are typically in the 0.10-0.20 range. The coefficients corresponding to the interactions of skilled and unskilled labor expenditure with exports and imports indicate how output elasticities are shaped by involvement in international trade, and are mostly significant, especially for imports.

To better interpret the implications of the interaction coefficients, we report in Table 4 the results of a simple exercise. In this exercise, we compute the skilled and unskilled labor output elasticities for all firm-product observations in our sample, including multi-product firms. Subsequently, we regress those elasticities on firm log exports and log imports. The top panel of Table 4 refers to our baseline definition of skilled and unskilled workers, while the middle and bottom panels deliver results for the two alternative definitions we consider. Estimates in Table 4 indicate, across all of the three sets of results, that a stronger involvement in export and/or import activities decreases the output elasticity of unskilled workers while increasing the output elasticity of skilled workers. In other words, skilled workers become relatively more productive than unskilled workers as the firm becomes more involved in international trade. Such behavior represents a clear channel through which skill upgrading takes place with the internationalisation of a firm, which is either absent in the previous literature or presumed to be at work but not directly identified.

In terms of magnitude, the effects are also substantial. The difference between the 95th and 5th percentiles in the distributions of log exports and log imports is about 17 in both cases. This means that, for example, comparing the 5th to the 95th percentiles, imports (exports) reduce the output elasticity of unskilled labour by about $-0.0029 * 17 = -0.0493$ ($-0.0004 * 17 = -0.0068$), which compares to an output elasticity in the range of 0.09-0.16 for firms with no involvement in international trade from Table 3. At the same time, comparing the 5th to the 95th percentiles, imports (exports) increase the output elasticity of skilled labor by about $0.0019 * 17 = 0.0323$ ($0.0007 * 17 = 0.0119$), which compares to an output elasticity of about of 0.11-0.23 for firms with no involvement in international trade from Table 3.

Table 4: Relationship between Unskilled and Skilled Labor Production Function Coefficients and Trade

	Elasticity Unskilled Labor	Elasticity Skilled Labor
Panel A. Baseline		
Exports	-0.0004***	0.0007***
	(0.0000)	(0.0000)
Imports	-0.0029***	0.0019***
	(0.0000)	(0.0000)
Industry group dummies	Yes	Yes
Observations	338,160	338,160
Number of firm-product couples	134,348	134,348
R-squared	0.8513	0.9187
Panel B. Alternative education		
Exports	-0.0024***	0.0014***
	(0.0000)	(0.0000)
Imports	-0.0038***	0.0023***
	(0.0000)	(0.0000)
Industry group dummies	Yes	Yes
Observations	338,160	338,160
Number of firm-product couples	134,348	134,348
R-squared	0.8924	0.8837
Panel C. Alternative occupation		
Exports	-0.0009***	0.0006***
	(0.0001)	(0.0000)
Imports	-0.0040***	0.0026***
	(0.0001)	(0.0000)
Industry group dummies	Yes	Yes
Observations	338,160	338,160
Number of firm-product couples	134,348	134,348
R-squared	0.7273	0.8676

Notes: The dependent variables in the regressions are the skilled and unskilled labor output elasticities computed for all firm-product observations in our sample, including multi-product firms. These elasticities are regressed on firm log exports and log imports, and coefficients are estimated via OLS. The top panel refers to our baseline definition of skilled and unskilled workers, while the middle and bottom panels refer to the two alternative definitions considered. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

5.2 Some intermediate steps

Before delving into the analysis of the array of response margins of firms to trade shocks, it is important to first establish two important things. The first one is that the measures we obtain from our model correlate well with firm expected behaviour (see Table 5). For example, one would expect a productivity increase to translate into lower prices, as well as an increase in the capital stock to also correspond to lower prices. This is confirmed by the panel regression estimates provided in column 1 of Table 5, where we regress log price on quantity TFP and log capital stock, while allowing for time dummies and firm-product fixed effects, and employing the within estimator. Identification of regression coefficients in Table 5 thus come from within firm-product variables changes over time.

Table 5: Relationship of Total Factor Productivity (TFP) and Capital with Prices and Markups

	Price	Markup
TFP	-0.8793***	0.0874***
	(0.0070)	(0.0028)
Capital	-0.1248***	0.0023***
	(0.0042)	(0.0019)
Firm-product FE	Yes	Yes
Year dummies	Yes	Yes
Observations	338,160	338,160
Number of firm-product couples	134,348	134,348
R-squared	0.9708	0.4898

Notes: The table provides results of two estimations in which we regress log price and the markup on quantity TFP and log capital stock, while allowing for time dummies and firm-product fixed effects, and employing the within estimator. Identification of regression coefficients thus comes from within firm-product variable changes over time. For skilled and unskilled workers, we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

The -0.88 coefficient of quantity TFP in column 1 of Table 5 is in line with the 0.83, 0.80 and 0.89 average cost pass-through elasticities found in Berman et al. (2012), Amiti et al. (2014) and Forlani et al. (2023), respectively. In terms of markups, column 2 of Table 5 further indicates that a productivity increase corresponds to a higher markup, i.e, firms do not fully transfer cost reductions due to increased productivity to consumers, which is in line with the incomplete pass-through elasticity of column 1. Regarding capital, a higher capital stock implies, everything else equal, a lower short-term marginal cost, and indeed a positive increases in the capital stock corresponds in Table 5 to both lower prices and higher markups.

Table 6: Additional Features of Exporters and Importers

	Rev. TFP	TFP	Price	Marg. Cost	Markup
Panel A. Exporters					
Exporter	0.0661***	-0.0197***	0.0858***	0.1065***	-0.0207***
	(0.0031)	(0.0071)	(0.0092)	(0.0095)	(0.0022)
Product and year dummies	Yes	Yes	Yes	Yes	Yes
Observations	338,160	338,160	338,160	338,160	338,160
Number of firm-product couples	134,348	134,348	134,348	134,348	134,348
R-squared	0.7069	0.7734	0.8059	0.7967	0.1490
Panel B. Importers					
Importer	0.1901***	0.0267***	0.1634***	0.1779***	-0.0145***
	(0.0030)	(0.0085)	(0.0100)	(0.0103)	(0.0023)
Product and year dummies	Yes	Yes	Yes	Yes	Yes
Observations	338,160	338,160	338,160	338,160	338,160
Number of firm-product couples	134,348	134,348	134,348	134,348	134,348
R-squared	0.7177	0.7576	0.8062	0.7970	0.1487

Notes: The Table provides estimates of simple OLS regressions where each dependent variable is regressed on 8-digit product dummies and year dummies, as well as on a dummy variable indicating whether the firm is an exporter (top panel) or an importer (bottom panel) and zero otherwise. The dependent variables used are revenue TFP, quantity TFP, log price, log marginal cost and log markups. For skilled and unskilled workers, we use our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ $p<0.01$, $**$ $p<0.05$, $*$ $p<0.1$.

The second point we want to highlight is how the measures obtained from our model compare with the findings on the differences between exporting and importing firms coming from the raw data, and presented in Table 2 of Section 4.4. Table 2 indicates that the share of skilled workers is significantly higher in both exporting and importing firms compared to non-trading firms. Additionally, exporting and importing firms are characterised by higher (log) revenues and sell higher (log) quantities despite charging higher (log) prices, which is consistent with ample evidence in the literature that exporting and importing firms are larger firms employing a more skilled labor force and producing higher-quality products (Verhoogen, 2008; Bernard et al., 2012).

Table 6 confirms and expands these findings by using some of the measures generated within our model. Specifically, we consider revenue TFP, quantity TFP, log price (again), log marginal cost, and log markups. We regress each of these measures in turn on a dummy indicating whether the firm is an exporter (top panel) or an importer (bottom panel), along with a battery of 8-digit product dummies and year dummies and estimate via OLS. Column 1 of Table 6 first indicates that exporting and importing firms are characterised by higher revenue TFP, which is in line with abundant evidence in the literature (Bernard et al., 2012). However, while for importers, the higher revenue TFP comes from both a higher technical efficiency (quantity TFP) and a higher prices,[10] the same is not true for exporters. Instead, exporters are characterised by higher prices but lower quantity TFP than non-exporting firms (columns 2 and 3).

We interpret this as a sign of the quantity/quality tradeoff in technology, which seems to be particularly binding for exporting firms. On the other hand, both exporting and importing firms feature higher marginal costs than non-trading firms (column 4), confirming the idea that they both produce higher-quality varieties. Despite this, they charge, on average, lower (log) markups (column 5).[11] This likely comes from the fact that these firms operate in an environment of costly international trade in which they absorb (through markups) part of the additional costs to reach international customers and suppliers. [12]

5.3 Response to trade shocks

In this Section, we analyze the response of firms to trade shocks along several margins. We start by introducing the specification we employ to this purpose:

$$\Delta y_{it} = c_E \Delta exp_{it} + c_I \Delta imp_{it} + \mathbf{CTR}'_{\mathbf{it}}\mathbf{d} + \epsilon_{it}, \tag{13}$$

where Δy_{it} is the change of margin y_{it} in between $t-1$ and t (for example $\Delta TFP_{it} = TFP_{it} - TFP_{it-1}$), Δexp_{it} and Δimp_{it} are changes in observed (log) exports and imports,[13] the vector $\mathbf{CTR_{it}}$ indicates a battery of control variables,[14] and ϵ_{it} are shocks that are likely to be correlated with changes in exports and imports. We think of ϵ_{it} as idiosyncratic shocks of non-trade nature affecting firms' broad operations that are innovations with respect to

[10]By construction the coefficient of revenue TFP is the sum of the coefficients of quantity TFP and log price. See equation (7).

[11]By construction the coefficient of log price is the sum of the coefficients of log marginal cost and log markup. See equation (7).

[12]For example, the relationship between the average (across destination countries) firm markup and export activity is indeed ambiguous. On the one hand, internationally active firms are more productive, which should correspond to a higher average markup, as also indicated by the findings of Table 5. On the other hand, more international activity means the firm is tapping into more costly destinations on which she optimally charges lower markups. See Figure 4 and related material in Behrens et al. (2014) for an analysis of this issue.

[13]The fact that we regress changes on changes allows us to account for unobserved time-invariant heterogeneity potentially correlated with regressors (firm fixed effects). Firm fixed effects would indeed drop out when considering time differencing.

[14]We use log exports, log imports, and log sales, all in $t-1$, as well as the interaction between log exports (log imports) and log sales in $t-1$.

the information set of the firm at time $t-1$.[15] Firms react to these shocks at time t by adjusting their technology (as seen above), skill up/downgradig, setting profit maximizing prices and markups, and adjusting their sales and inputs consumption. These shocks also affect firms' exports and imports strategies and so Δexp_{it} and Δimp_{it} in equation (13) are likely to be correlated with shocks ϵ_{it}. At the same time, trade-specific shocks υ_{it} affecting the profitability of international activity (exchange rates, GDP, and tariff changes) also impact firm imports and exports, contributing to the overall firm response with respect to margin y_{it}. This is modelled by the presence of Δexp_{it} and Δimp_{it} on the right hand side of equation (13). Under the assumptions that trade shocks υ_{it} are uncorrelated with non-trade shocks ϵ_{it}, as well as that trade shocks υ_{it} affect firm behavior only to the extent that they affect exports and imports in t, the impact of trade shocks υ_{it} on firms' operational margins (parameters c_E and c_I) can be identified by using these shocks as instrumental variables for Δexp_{it} and Δimp_{it} in equation (13). In what follows, we build upon these assumptions and use the exchange rates, GDP, and tariff changes described in Section 4.3 as instruments to estimate c_E and c_I.

In order to best describe our results, we split the set of firm response margins into two groups. The first group includes impacts on log revenue, log quantity, log price, inputs demand, and the share of skilled workers, with key results being reported in Table 7, while Tables C-5 and C-6 in Appendix C provide information on control variables and first stages, respectively. An observation in the regressions is a firm-product-year tuple and the number of observations is 106,751, which is smaller than the 338,160 figure in the previous Tables because now we are time-differencing. We have 10 instruments for 2 variables to be instrumented and so are left with 8 degrees of freedom. Last but not least, in terms of instruments' power both the Kleibergen-Paap LM under-identification test and the Kleibergen-Paap Wald F weak identification statistic (above the critical value of 10) indicate that our instruments are strong.

The first column of Table 7 indicates that positive trade shocks increase the value of log sales, particularly for exports. In terms of magnitude, a positive trade shock increasing firm exports (imports) by 10% increases firm revenue by 1.34% (0.76%). A the same time, column 2 of Table 7 shows that the bulk of the increase in revenue is due to higher quantities for both exports and imports. Column 3 instead reveals differences between shocks affecting exports and imports. While positive shocks increasing the viability of exports increase the average firm price, the reverse applies to shocks positively affecting imports. Indeed, positive shocks affecting exports should act as a demand increase, possibly of higher-quality products. Therefore, it is reasonable to expect that firms charge a higher price. On the other hand,

[15] For example, productivity shocks ν_{ait} are part of the broader shocks ϵ_{it}.

Table 7: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: First Group of Outcome Variables and Key Covariates

	Change revenue	Change quantity	Change price	Change inputs bundle	Change share skilled
Change exports	0.1340***	0.1011***	0.0329*	0.1452***	0.0057***
	(0.0270)	(0.0299)	(0.0181)	(0.0270)	(0.0018)
Change imports	0.0760***	0.0985***	-0.0225*	0.0810***	0.0004
	(0.0200)	(0.0221)	(0.0126)	(0.0200)	(0.0012)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0666	0.0460	0.0133	0.0506	0.0304
K-P LM underidentif. stat.	109.96	109.96	109.96	109.96	109.96
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.640	11.640	11.640	11.640	11.640

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). See Tables C-5 and C-6 in Appendix C for information on control variables and first stages, respectively. See Section 4.3 for details on the instruments. The 5 outcomes measures considered here are changes in log revenue, log quantity, log price, log inputs bundle ($\alpha_{Lit}l_{it} + \alpha_{Hit}h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$.) and the share of skilled workers in the overall wage expenditure. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers, we use our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

positive shocks affecting imports should act as a reduction in the cost of foreign inputs. Therefore, it is likely that firms pass some of the cost savings onto consumers by charging lower prices. Column 4 confirms that firms expand their operations when facing positive exports and imports shocks by increasing overall inputs consumption, as measure by the (log) inputs bundle $\alpha_{Lit}l_{it} + \alpha_{Hit}h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$. Finally, column 5 shows that trade shocks increasing firm exports lead to a significant increase in the share of skilled workers within the firm (skill upgrading). The same does not apply to shocks increasing imports, suggesting that the higher skill intensity of importers reported in Table 2 above is likely to be driven by technological complementarities between the quality of products produced and the skills of the labor force rather than by complementarities between foreign inputs and the demand for skills.[16]

Table 8 contains results on the second group of response margins and includes revenue

[16] In our analysis we isolate the causal effects of export and import shocks. However, in the data import shocks are positively correlated with export shocks and so higher imports are correlated with increased exports and skill upgrading.

TFP, TFP, log price (again), log marginal costs and log markups.[17] Column 1 indicates that the response in terms of revenue TFP is either absent (imports) or slightly negative (for exports). Though, this masks a considerable reduction of quantity TFP for exporters, which is partly offset by the increase in prices (column 3) and with (as discussed above) the sum of the coefficients of quantity TFP and prices adding up to the coefficient of revenue TFP. For importers there is instead an increase in quantity TFP, which is muted by the decrease in prices (column 3) leading to a not significant impact on revenue TFP. Moving to marginal costs one can notice in column 4 that shocks increasing exports lead to a very strong increase in overall marginal costs, which is consistent with quality upgrading taking place. On the contrary, shocks positively affecting imports do not lead to an increase in marginal costs suggesting that quality upgrading is not much driven by shocks making foreign inputs cheaper. Last but least, column 5 indicates that for both exports and imports shocks the firms react to the increased volume of operations by slightly decreasing the average firm markup, which is (as indicated above) not inconsistent with larger and more productive firms having a higher level of markups.

In order to further qualify the results of Table 8 we present in Table 9 an enriched version of our analysis in which we augment equation (13) with two interaction terms, and in particular an interaction between the change in exports and the level of revenue TFP in $t-1$ ($\Delta exp_{it} TFP^R_{it-1}$), as well an interaction between the change in imports and the level of revenue TFP in $t-1$ ($\Delta imp_{it} TFP^R_{it-1}$).[18] In order to best instrument these interactions, we add interactions terms with the level of revenue TFP in $t-1$ to all our 10 instruments ending up with 20 such instruments in total for 4 variables to be instrumented so leading to 16 degrees of freedom. This enriched specification has the advantage of allowing identifying heterogeneity in response margins across the productivity distribution. However, the drawback is that instruments are, particularly as indicated by the Kleibergen-Paap Wald F weak identification statistic which is below the critical value of 10, not particularly strong so suggesting results of Table 9 should be taken with some caution.

Having said that, the big picture emerging from Table 9 is that heterogeneity in response along the productivity distribution is, with the exception of the markups response, not much of a feature for shocks affecting exports as indicated by interaction coefficients lacking in both size and significance. Quite on the contrary, heterogeneity in response along the productivity distribution does characterise shocks affecting imports and in particular is such that less productive firms increase both revenue TFP and quantity TFP while charging lower prices and

[17] Table C-7 in Appendix C provides information on control variables.

[18] Tables C-8 and C-9 in Appendix C provide information on control variables and first stages, respectively. We end up with a slightly smaller number of observations for these specifications (103,065) due to some additional trimming on the distribution of TFP^R_{it-1}.

Table 8: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Second Group of Outcome Variables and Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	-0.0112*	-0.0441**	0.0329*	0.0733***	-0.0404***
	(0.0057)	(0.0191)	(0.0181)	(0.0207)	(0.0089)
Change imports	-0.0051	0.0175*	-0.0225*	-0.0034	-0.0191***
	(0.0045)	(0.0110)	(0.0126)	(0.0147)	(0.0067)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0294	0.0205	0.0133	0.0352	0.0880
K-P LM underidentif. stat.	109.96	109.96	109.96	109.96	109.96
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.640	11.640	11.640	11.640	11.640

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). See Tables C-7 and C-6 in Appendix C for information on control variables and first stages, respectively. See Section 4.3 for details on the instruments. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal cost and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our benchmark definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

higher markups and sustaining lower marginal costs. This indicates that the cost reduction in foreign inputs, to which import shocks can be assimilated, has a more profound and cleaner impact on low productivity firms reacting along all margins as if a substantial decrease in the cost of their inputs has occurred so spurring productivity gains only partially pass onto consumers.

5.4 Robustness

In this Section we provide evidence that our findings on the firm response to trade shocks are robust to different ways of distinguishing between skilled and unskilled workers, alternative inputs apportionment strategies, different instruments as well as weighting observations.

Alternative distinction between skilled and unskilled workers based on occupations. In our baseline analysis we use educational attainment to draw the line between

Table 9: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Second Group of Outcome Variables, Heterogeneous Effects, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	-0.0956**	-0.1385**	0.0429	0.1462***	-0.1033***
	(0.0419)	(0.0637)	(0.0387)	(0.0533)	(0.0271)
Change exports × lag rev. TFP	0.0286	0.0204	0.0083	-0.0205	0.0288**
	(0.0185)	(0.0275)	(0.0162)	(0.0224)	(0.0116)
Change imports	0.2953***	0.3790***	-0.0837**	-0.2207***	0.1370***
	(0.0495)	(0.0714)	(0.0370)	(0.0552)	(0.0293)
Change imports × lag rev. TFP	-0.1042***	-0.1431***	0.0389**	0.0896***	-0.0507***
	(0.0212)	(0.0307)	(0.0164)	(0.0237)	(0.0124)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	103,065	103,065	103,065	103,065	103,065
Number of firm-product couples	36,162	36,162	36,162	36,162	36,162
R-squared	0.1181	0.0920	0.0698	0.1243	0.0566
K-P LM underidentif. stat.	71.567	71.567	71.567	71.567	71.567
K-P LM underidentif. Df	16	16	16	16	16
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	3.5746	3.5746	3.5746	3.5746	3.5746

Notes: The Table provides IV estimates of an enriched version of equation (13) to which we add two interaction terms, and in particular an interaction between the change in exports and the level of revenue TFP in $t-1$ ($\Delta exp_{it}TFP^R_{it-1}$), as well an interaction between the change in imports and the level of revenue TFP in $t-1$ ($\Delta imp_{it}TFP^R_{it-1}$). See Tables C-8 and C-9 in Appendix C for information on control variables and first stages, respectively. See Section 4.3 for details on the main instruments. In order to best instrument the two interaction terms we add interactions terms with the level of revenue TFP in $t-1$ to all our main 10 instruments ending up with 20 such instruments in total for 4 variables to be instrumented so leading to 16 degrees of freedom. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal cost and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our benchmark definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

skilled and unskilled workers. Yet, occupations represent a complementary way of distinguishing workers in terms of their relationship to technology and/or quality upgrading. In this light, we present in Tables C-10 to C-12 in Appendix C complementary results on the firm response to trade shocks obtained using our alternative distinction between skilled and unskilled workers based on occupations. As one can notice results are qualitatively, and to a large extent also quantitatively, identical to those presented in Tables 7 to 9.

Alternative way of assigning inputs across products for multi-product firms. In our analyses so far we build upon the inputs assignment procedure developed in Appendix A to apportion inputs to the different products of multi-product firms. The procedure we propose has the advantage of being internally consistent with the way we model firm behaviour and has been used already in Forlani et al. (2023). In order to allay concerns that this particular aspect of our analysis is driving results we propose in Tables C-13 and C-14 in Appendix C some additional results obtained using products revenue shares to apportion inputs. Such results are in line with those of our baseline analysis, which is not surprising given the strong correlation (typically in the range of 0.90-0.95) between inputs as assigned by our benchmark procedure and inputs assigned based on revenue shares.

Alternative way of constructing instruments. The instruments we use employ the pre-sample network of firms' exports and imports destinations/origins to weigh country-level changes in exchanges rates, GDP and tariffs. Although sound from an exogeneity point of view, this solution has the drawback of not accounting for entry and exit of firms across destination/origin countries over the sample period so reducing the scope of the analysis. In order to account for this we present in Tables C-15 to C-17 in Appendix C complementary findings obtained using the network of firms' exports and imports destinations/origins in the two years prior to t to weigh country-level changes in exchanges rates, GDP and tariffs (see Appendix B). Again, these additional findings confirm the robustness of our baseline results.

Weighting observations. Our findings in Section 5.3 are revealing of the response of the average firm to trade shocks. However, to draw conclusions about the aggregate one has to consider the fact that firms have different sizes and that there might be some heterogeneity in the response based on firm size with large firms driving aggregate trends. In this respect, Table 9 does indicate the presence of heterogeneity in behaviour for import shocks with respect to revenue TFP. In order to further investigate this aspect we provide in Tables C-18 and C-19 in Appendix C results obtained weighting observations by log sales in $t-1$. Overall, results look very similar to our benchmark findings so suggesting that response heterogeneity in terms of firm size is not a big issue in the data and that our results are also representative of the aggregate of firms.

6 Conclusions

In this paper, we examine how firms adjust their production and technology in response to exogenous trade shocks. In the literature, the effects of demand shocks on the relative demand for skills within each firm are often argued based on changes in technology, but these effects are not explicitly modeled nor linked to productivity. This paper fills this gap. We develop a structural model and estimate it using detailed longitudinal firm-product data from Brazil. In our framework, revenue TFP can be distinguished from quantity TFP, and skill upgrading is explicitly embedded into the firm's technology choice. Firm technology, including skilled and unskilled labor, is endogenous to changes in export and import intensity.

Quantifying the model, we show how export and import shocks, instrumented using exogenous changes in exchange rates, GDP, and tariffs, weighted using the pre-sample network of firms' origin and destination countries, affect firms' quantity and revenue TFP, marginal costs, prices, and markups. Our results indicate both skill and quality upgrading in response to export shocks, while import shocks foster technology upgrading and productivity improvements.

Our contribution lies in identifying, both empirically and theoretically, the mechanisms that explain how trade shocks affect the behavior of firms. Our results clarify the nature of this behavior, which may prove useful in current research efforts to understand the factors driving firm choices of engaging in international markets via not only exports but also imports, and their effects on firms' performance and the quantity-quality tradeoff.

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Appendix

A Multi-product firms

In the production data we use (PIA Produto) information on quantities, prices and revenues is available for all the manufacturing products produced by each firm in the survey. However, information on inputs used for a specific product is not available; which is typically the case for this type of data. We report here an extension of our model, based on Forlani et al. (2023), to solve the problem of assigning inputs to outputs for multi-product firms. In doing so we assume, as in De Loecker et al. (2016), there is a limited role for economies (or diseconomies) of scope on the cost side. However, contrary to De Loecker et al. (2016), we do not impose multi-product firms to be characterized by a common productivity across the different products they produce. We also allow for firm-product-time specific markups but impose that the product appeal/quality of a firm's product portfolio is common across products within a firm. This corresponds to a setting where firms can be distinguished into those consistently selling high quality products and those consistently selling low quality products. Yet firms are allowed to be more or less efficient in the production of a specific product and charge different markups. We use the model below in the analysis to recover TFP, revenue TFP, markups and marginal costs for the different products of multi-product firms.

As usual we denote a firm by i and time by t. A firm i produces in t one or more products indexed by p and the number of products produced by the firm is denoted by I_{it}. In our data p is an 8-digit PIA produto product code. Following Forlani et al. (2023), we assume firms maximize profits for each of their products. This implies that the elasticity of revenue R_{ipt} with respect to quantity Q_{ipt} is one over the profit maximizing markup:

$$\frac{\partial r_{ipt}}{\partial q_{ipt}} = \underbrace{\frac{\partial R_{ipt}}{\partial Q_{ipt}}}_{\text{marginal revenue}} \frac{Q_{ipt}}{R_{ipt}} = \underbrace{\frac{\partial C_{ipt}}{\partial Q_{ipt}}}_{\text{marginal cost}} \frac{Q_{ipt}}{P_{ipt}Q_{ipt}} = \frac{\frac{\partial C_{ipt}}{\partial Q_{ipt}}}{P_{ipt}} = \frac{1}{\mu_{ipt}}, \tag{A-1}$$

where μ_{ipt} is the profit maximizing markup. This result comes from static profit maximization and holds under different assumptions about demand (representative consumer and discrete choice models) and product market structure (monopolistic competition, monopoly and standard forms of oligopoly). In particular, (A-1) holds in the case where firms are characterized by heterogeneous demands, because they sell products of different appeal/quality, which seems like a natural setting when considering multi-product firms. In this respect Forlani et al. (2023) show that, under some general conditions, one can model differences in demand across products via a parameter Λ_{ipt} entering as a multiplier of quantity Q_{ipt} in the underlying utility function. Such parameter Λ_{ipt} is a measure of the quality/appeal of a particular variety and is such that the elasticity of revenue R_{ipt} with respect to product appeal Λ_{ipt} is, again, one over the profit maximizing markup. Therefore, the (unknown) log revenue function corresponding to a particular product of firm i $r(q_{ipt}, \lambda_{ipt})$ can be approximated, around the observed profit-maximizing solution, by the linear function:[19]

$$r_{ipt} \simeq \frac{1}{\mu_{ipt}}(q_{ipt} + \lambda_{ipt}). \tag{A-2}$$

In what follows we assume product appeal is firm-time specific (λ_{it}) while we allow markups (μ_{ipt}) and productivity (a_{ipt}) to be firm-product-time specific. The production function for product p produced by firm i is given by:[20]

$$Q_{ipt} = A_{ipt} L_{ipt}^{\alpha_{Lit}^g} H_{ipt}^{\alpha_{Hit}^g} M_{ipt}^{\alpha_M^g} K_{ipt}^{\alpha_K^g}, \tag{A-3}$$

where g identifies a product group/industry. Production function coefficients are the same for products within a product group because a certain level of data aggregation is needed to deliver enough observations to estimate parameters. (A-3) means we allow for technology (α_{Lit}^g, α_{Hit}^g, α_M^g, α_K^g) to differ across the different products p produced by a multi-product firm. At the same time productivity is allowed to vary across products within a firm and information coming from single-product firms need to be used to infer the technology of multi-product firms, i.e., we rule out physical synergies in production but allow for some of the economies (diseconomies) of scope discussed in De Loecker et al. (2016). Furthermore, we assume firm i to maximize profits and choose at time t (for each product p) the amount of materials M_{ipt} in order to minimize short-term costs while taking capital K_{ipt}, unskilled labour L_{ipt}, skilled labour H_{ipt}, as well as productivity a_{ipt} and product appeal λ_{it}, as given.[21] The TFP process is:

$$a_{ipt} = \phi_a^g \; a_{ipt-1} + b_{Ea}^g \Delta exp_{it}^{\mathbb{E}} + b_{Ia}^g \Delta imp_{it}^{\mathbb{E}} + \nu_{aipt}, \tag{A-4}$$

where $\Delta exp_{it}^{\mathbb{E}}$ and $\Delta imp_{it}^{\mathbb{E}}$ represent the expected change in the log value of exports and imports of firm i between $t-1$ and t,[22] while ν_{aipt} denotes productivity shocks that represent

[19] To simplify notation we ignore components that are common across firms in a given time period or for a given product. Those constants will be captured in our estimations suitable sets of time and product dummies.

[20] As already indicated above, we omit in the presentation any product C_p and time C_t constants. Those constants are controlled for by suitable dummies in the estimations.

[21] As discussed in more detail in the main text, we assume capital to be predetermined in the short-run, i.e., the current capital level has been chosen in t-1 and cannot immediately adjust to current period shocks. Concerning unskilled and skilled labor, we assume them to be semi-flexible inputs. More specifically, we assume they are chosen by the firm at time $t-b$ $(0 < b < 1)$ when expectations about exports and imports in t are formed.

[22] Expectations refer to the information set of the firm at time $t-b$ $(0 < b < 1)$.

innovations with respect to the information set of the firm in $t-1$ and are iid across firms, products and time. Finally, we allow labour coefficients α^g_{Lit} and α^g_{Hit} in the production function (A-3) to be firm-specific and in particular to depend upon the expected involvement of firm i in international trade. To model this in a parsimonious way we assume that:

$$\begin{aligned} \alpha^g_{Lit} &= \alpha^g_L + b^g_{EL} exp^{\mathbb{E}}_{it} + b^g_{IL} imp^{\mathbb{E}}_{it}, \\ \alpha^g_{Hit} &= \alpha^g_H + b^g_{EH} exp^{\mathbb{E}}_{it} + b^g_{IH} imp^{\mathbb{E}}_{it}, \end{aligned} \tag{A-5}$$

i.e., the that the elasticities of output with respect to unskilled and skilled labour are a function of the expected level of exports and imports of firm i at time t.

Profit maximization implies:

$$P_{ipt} = \mu_{ipt} \frac{\partial C_{ipt}}{\partial Q_{ipt}}, \tag{A-6}$$

so that we can, starting from data on prices and markups, recover marginal costs. At the same time firms minimize costs and so markups are such that:

$$\mu_{ipt} = \frac{\alpha^g_M}{s_{Mipt}}, \tag{A-7}$$

where s_{Mipt} is the expenditure share of materials for product p at time t in firm revenue for product p at time t. Also note that the marginal cost is equal to:

$$\frac{\partial C_{ipt}}{\partial Q_{ipt}} = A_{ipt}^{-\frac{1}{\alpha^g_{Lit}+\alpha^g_{Hit}+\alpha^g_M}} Q_{ipt}^{\frac{1-\alpha^g_{Lit}-\alpha^g_{Hit}-\alpha^g_M}{\alpha^g_{Lit}+\alpha^g_{Hit}+\alpha^g_M}} K_{ipt}^{\frac{\alpha^g_K}{\alpha^g_{Lit}+\alpha^g_{Hit}+\alpha^g_M}}. \tag{A-8}$$

As far as single-product firms are concerned, the procedure described in the main body of the paper can be used to recover TFP, revenue TFP, markups and marginal costs. Turning to multi-product firms we impose, as in De Loecker et al. (2016), that the same technology parameters coming from single-product producers extend to the products of the former. Yet, in order to quantify multi-product firms TFP, revenue TFP, markups and marginal costs we still need to solve the issue of how to assign inputs to outputs and we do so by building on the above assumptions and the parameters estimated for single-product firms. As far as materials are concerned, we need to assign the observable total firm material expenditure M_{it} across the I_{it} products produced by firm i at time t, i.e., we need to assign values to M_{ipt} such that $\sum_{p=1}^{I_{it}} M_{ipt} = M_{it}$. We can use this condition along with (A-7) and (A-2) to operate this assignment. Substituting (A-7) into (A-2) and adding $\sum_{p=1}^{I_{it}} M_{ipt} = M_{it}$ provides a system of $I_{it}+1$ equations in $I_{it}+1$ unknowns; the I_{it} inputs expenditures M_{ipt} plus λ_{it}. Indeed, at this stage we have data on r_{ipt}, q_{ipt}, α^g_M and M_{it}. Operationally, one can actually proceed in two stages. Combining the above equations one has $\sum_{p=1}^{I_{it}} \frac{\alpha^g_M r_{ipt} R_{ipt}}{q_{ipt}+\lambda_{it}} = M_{it}$. This equation is solved for each firm and delivers λ_{it}. With this at hand one can then obtain materials expenditure from $M_{ipt} = \frac{\alpha_M^g r_{ipt} R_{ipt}}{q_{ipt}+\lambda_{it}}$. By recovering inputs expenditures M_{ipt} we subsequently compute materials expenditure shares in revenues s_{Mipt} and so use (A-7) to recover a firm-product-time specific markup μ_{ipt} as well as the marginal cost from (A-6).

Unskilled and skilled labour are semi-flexible inputs and, given they are chosen at time $t-b$ $(0 < b < 1)$, such choice reflects the information available between $t-1$ and t. In this light we use (A-7) to derive unskilled and skilled labour expenditures, while considering the average markup between $t-1$ and t instead of the markup in t, as well as estimates of α_{Lit}^g and α_{Hit}^g.[23] For example, in the case of unskilled labour $L_{ipt} = \frac{\alpha_{Lit}^g R_{ipt}}{\bar{\mu}_{ipt}}$ where $\bar{\mu}_{ipt}$ is the average markup of firm i for product p between $t-1$ and t. Operationally, this is not guaranteed to satisfy the constraint $\sum_{p=1}^{I_{it}} L_{ipt} = L_{it}$ for each firm and so the L_{ipt} are re-scaled for each firm. The same principles apply to skilled labour.

The above procedure allows so far to obtain markups and marginal costs, as well as information on unskilled and skilled labour and materials use, for each of the products of a multi-product firm. However, in order to recover TFP a_{ipt}, as well as revenue TFP, we still need values for capital K_{ipt}. To do this one can proceed as follows. Combining the marginal cost, profit maximization and quantity equations one gets:

$$K_{ipt} = \left(\frac{P_{ipt}}{\mu_{ipt} Q_{ipt}^{a+b} L_{ipt}^{-a\alpha_{Lit}^g} H_{ipt}^{-a\alpha_{Hit}^g} M_{ipt}^{-a\alpha_M^g}} \right)^{\left(\frac{1}{c-a\alpha_K^g}\right)} \tag{A-9}$$

where $a = -\frac{1}{\alpha_{Lit}^g+\alpha_{Hit}^g+\alpha_M^g}$, $b = \frac{1-\alpha_{Lit}^g-\alpha_{Hit}^g-\alpha_M^g}{\alpha_{Lit}^g+\alpha_{Hit}^g+\alpha_M^g}$, $c = \frac{\alpha_K^g}{\alpha_{Lit}^g+\alpha_{Hit}^g+\alpha_M^g}$. We further refine those values by running an estimation where the computed K_{ipt} from (A-9) is regressed on R_{ipt}, M_{ipt}, L_{ipt} and H_{ipt} as well as total firm expenditure on materials, unskilled and skilled labour plus the capital stock and a full battery of year and product dummies. The predicted values of such regression are then re-scaled for each firm to meet the constraint $\sum_{p=1}^{I_{it}} K_{ipt} = K_{it}$.

[23]Estimations on single-product firms provide coefficients b_{EL}^g, b_{IL}^g, b_{EH}^g and b_{IH}^g needed to compute α_{Lit}^g and α_{Hit}^g from (A-5). Operationally, expected exports and imports in (A-5) are replaced with actual exports and imports in t representing unbiased estimates of $exp_{it}^{\mathbb{E}}$ and $imp_{it}^{\mathbb{E}}$.

B Instruments

In our main analysis we instrument two variables namely the (log) change in exports $\Delta exp_{it} = \log(EXP_{it}+1) - \log(EXP_{it-1}+1)$ and the (log) change in imports $\Delta imp_{it} = \log(IMP_{it} + 1) - \log(IMP_{it-1}+1)$. The instruments we use are based on weighted exchange rates, GDP, and tariff related to the exporting and importing activities of firm i.

B.1 Instruments definition

Real exchange rate indexes

Using bilateral real exchange rates between Brazil and each destination (origin) country c, we compute two measures; one for exports and one for imports. We do these calculations using weights for imports and exports separately. Real exchange rates are nominal exchange rates (expressed in foreign currency per Brazilian Real) multiplied by the Brazil CPI and divided by the foreign country CPI. Nominal exchange rates and foreign CPI's for the period 2005-2014 are borrowed from the International Financial Statistics of the International Monetary Fund.

The weighted changes of the real exchange rates of exporting and importing countries between $t-1$ and t referring to firm i are:

$$\Delta RER^{Exports}_{i,t} = \sum_c \frac{RER_{c,t}}{RER_{c,t-1}} w^{Exports}_{i,c,s} \tag{B-1}$$

$$\Delta RER^{Imports}_{i,t} = \sum_c \frac{RER_{c,t}}{RER_{c,t-1}} w^{Imports}_{i,c,s} \tag{B-2}$$

Where $RER_{c,t}$ is the real exchange rate between Brazil and country c in year t, $RER_{c,t-1}$ is the real exchange rate between Brazil and country c in year $t-1$, $w^{Exports}_{i,c,s}$ is the weight of country c for firm i exports in year s and $w^{Imports}_{i,c,s}$ is the weight of country c for firm i imports in year s. We use two complementary ways of constructing weights as discussed more in detail below: 1) Exports and imports of firm i in the pre-sample period 2002-2005; 2) Export and imports of firm i in $t-1$ and $t-2$.

GDP indexes

Nominal GDP data were downloaded from World Development Indicators [24]. For Argentina, we filled the missing values in the consumer price index with estimations constructed by private consultants. For Chile, the missing values were filled with information from the Ministry of Economy.

[24] Data are available at $https://data.worldbank.org/products/wdi$

The weighted changes of the real GDP of exporting and importing countries between $t-1$ and t referring to firm i are:

$$\Delta GDP_{i,t}^{Exports} = \sum_c \frac{GDP_{c,t}}{GDP_{c,t-1}} w_{i,c,s}^{Exports} \quad \text{(B-3)}$$

$$\Delta GDP_{i,t}^{Imports} = \sum_c \frac{GDP_{c,t}}{GDP_{c,t-1}} w_{i,c,s}^{Imports} \quad \text{(B-4)}$$

Where $GDP_{c,t}$ is the real GDP (nominal GDP over CPI) of the destination (origin) country c in year t, $GDP_{c,t-1}$ is the real GDP (nominal GDP over CPI) of the destination (origin) country c in year $t-1$, while $w_{i,c,s}^{Exports}$ and $w_{i,c,s}^{Imports}$ are the same weights used for the real exchange indexes discussed above.

Tariff index

Using applied import tariffs data for different products p and countries c from COMTRADE - TRAINS [25] we compute the following weighted change of tariffs between $t-1$ and t referring to firm i:

$$\Delta Tariff_{i,t} = \sum_c \sum_p (Tariff_{c,p,t} - Tariff_{c,p,t-1}) w_{i,c,s}^{Imports} \quad \text{(B-5)}$$

Where $Tariff_{c,p,t}$ is the applied tariff of Brazil with respect to the origin country c for product p (6 digit HS code) in year t, $Tariff_{c,p,t-1}$ is the applied tariff of Brazil with respect to the origin country c for product p (6 digit HS code) in year $t-1$, and $w_{i,c,s}^{Imports}$ are the same weights used for the real exchange and GDP indexes discussed above.

B.2 Weights

We compute two complementary sets of weights for exports and imports. In the benchmark case we construct weights using trade data on the period 2002-2005:

$$w_{i,c,02-05}^{Exports} = \frac{Exports_{i,c,02-05}}{\sum_c Exports_{i,c,02-05}} \quad \text{(B-6)}$$

$$w_{i,c,02-05}^{Imports} = \frac{Imports_{i,c,02-05}}{\sum_c Imports_{i,c,02-05}} \quad \text{(B-7)}$$

[25] Data are available at *https://comtrade.un.org/*

where $Exports_{i,c,02-05}$ is the exports of firm i to country c in the period 2002-2005 and $Imports_{i,c,02-05}$ is the imports of firm i from country c in the period 2002-2005. We set to zero the weight when the firm does not export (import) to (from) country c in the base period.

In order to better capture the contributions of those firms starting exporting and/or importing post-2005 we then consider as a robustness an alternative set of weights based on trade data for years $t-1$ and $t-2$:

$$w^{Exports}_{i,c,t-1,t-2} = \frac{Exports_{i,c,t-1,t-2}}{\sum_c Exports_{i,c,t-1,t-2}} \tag{B-8}$$

$$w^{Imports}_{i,c,t-1,t-2} = \frac{Imports_{i,c,t-1,t-2}}{\sum_c Imports_{i,c,t-1,t-2}} \tag{B-9}$$

where $Exports_{i,c,t-1,t-2}$ is the exports of firm i to country c in the years $t-1$ and $t-2$ and $Imports_{i,c,t-1,t-2}$ is the imports of firm i from country c in the years $t-1$ and $t-2$. We set to zero the weight when the firm does not export (import) to (from) country c in $t-1$ and $t-2$.

C Additional Tables and Figures

Table C-1: Production Function Estimations: Distinction between Skilled and Unskilled Workers Based on a Different Educational Level Cutoff

Industry	10-11	13-15	16	17-18	20-21	22	23
Materials	0.6155***	0.5536***	0.5805***	0.6366***	0.5462***	0.5783***	0.5600***
	(0.0237)	(0.0238)	(0.0224)	(0.0585)	(0.0701)	(0.0221)	(0.0163)
Unskilled labor	0.3053***	0.3735***	0.3525***	0.3102***	0.3071***	0.3207***	0.3473***
	(0.0076)	(0.0082)	(0.0161)	(0.0199)	(0.0235)	(0.0100)	(0.0086)
Skilled labor	0.0624***	0.0354***	0.0144**	0.0376***	0.0856***	0.0587***	0.0401***
	(0.0026)	(0.0026)	(0.0056)	(0.0059)	(0.0082)	(0.0035)	(0.0026)
Unskilled labor × Exports	-0.0037***	-0.0006	-0.0022	0.0040	-0.0039*	-0.0016	-0.0055***
	(0.0007)	(0.0007)	(0.0017)	(0.0074)	(0.0020)	(0.0009)	(0.0017)
Unskilled labor × Imports	-0.0039***	-0.0036***	-0.0044	-0.0150*	-0.0016	-0.0041***	-0.0016
	(0.0011)	(0.0007)	(0.0036)	(0.0089)	(0.0019)	(0.0008)	(0.0021)
Skilled labor × Exports	0.0028***	-0.0005	0.0003	0.0056	0.0030**	0.0010*	0.0016**
	(0.0005)	(0.0004)	(0.0011)	(0.0076)	(0.0015)	(0.0006)	(0.0008)
Skilled labor × Imports	0.0021***	0.0023***	0.0046**	0.0026	0.0010	0.0024***	0.0028***
	(0.0006)	(0.0005)	(0.0020)	(0.0038)	(0.0015)	(0.0005)	(0.0010)
capital	0.0248***	0.0245***	0.0133**	-0.0166	0.0175***	0.0247***	0.0103***
	(0.0053)	(0.0052)	(0.0066)	(0.0539)	(0.0053)	(0.0047)	(0.0025)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,783	5,674	1,561	1,653	1,100	3,163	4,969
R-squared	0.9991	0.9974	0.9975	0.9951	0.9993	0.9994	0.9987
Number firm-product couples	1,512	1,924	585	526	357	1,013	1,495

Industry	24	25	26-28	29-30	31	32-33
Materials	0.5258***	0.5516***	0.5554***	0.7141***	0.6144***	0.5142***
	(0.0741)	(0.0162)	(0.0173)	(0.0380)	(0.0349)	(0.0228)
Unskilled labor	0.3445***	0.3222***	0.2997***	0.2472***	0.3551***	0.3823***
	(0.0187)	(0.0083)	(0.0088)	(0.0118)	(0.0221)	(0.0132)
Skilled labor	0.0245***	0.0546***	0.0581***	0.0576***	0.0362***	0.0526***
	(0.0064)	(0.0032)	(0.0038)	(0.0068)	(0.0059)	(0.0048)
Unskilled labor × Exports	-0.0051*	-0.0038***	-0.0015**	-0.0000	-0.0059	-0.0032
	(0.0028)	(0.0010)	(0.0007)	(0.0010)	(0.0044)	(0.0023)
Unskilled labor × Imports	0.0018	-0.0029***	-0.0032***	-0.0042***	-0.0106	-0.0045
	(0.0063)	(0.0011)	(0.0007)	(0.0008)	(0.0070)	(0.0029)
Skilled labor × exports	0.0019	0.0015*	0.0015***	-0.0003	0.0028*	0.0040***
	(0.0015)	(0.0008)	(0.0006)	(0.0006)	(0.0016)	(0.0009)
Skilled labor × imports	-0.0018	0.0020**	0.0030***	0.0033***	0.0041**	-0.0004
	(0.0060)	(0.0008)	(0.0006)	(0.0005)	(0.0019)	(0.0009)
Capital	0.0179***	0.0159***	0.0191***	0.0176	0.0133	0.0108
	(0.0066)	(0.0025)	(0.0058)	(0.0152)	(0.0094)	(0.0128)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,176	2,814	3,661	2,287	1,656	1,593
R-squared	0.9978	0.9993	0.9995	0.9993	0.9956	0.9991
Number firm-product couples	343	937	1,245	660	582	506

Notes: The Table provides estimates of the parameters of the production function (1) obtained from IVs estimations of equation (12). Estimations are carried on the sub-sample of single-product firms for each of the 13 industry groups we consider. For skilled and unskilled workers we use here an alternative definition: we classify workers as skilled if they have a level of education above high school and unskilled otherwise (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-2: Production Function Estimations: Distinction between Skilled and Unskilled Workers Based on Occupations

Industry	10-11	13-15	16	17-18	20-21	22	23
Materials	0.5915***	0.5683***	0.6035***	0.6323***	0.6759***	0.5857***	0.5743***
	(0.0226)	(0.0269)	(0.0260)	(0.0662)	(0.0710)	(0.0246)	(0.0186)
Unskilled labor	0.1993***	0.2766***	0.2474***	0.2279***	0.1794***	0.2037***	0.2679***
	(0.0063)	(0.0106)	(0.0205)	(0.0174)	(0.0129)	(0.0094)	(0.0099)
Skilled labor	0.1533***	0.1087***	0.0751***	0.1096***	0.1712***	0.1550***	0.0988***
	(0.0042)	(0.0046)	(0.0072)	(0.0108)	(0.0139)	(0.0060)	(0.0046)
Unskilled labor × Exports	-0.0021***	0.0009	0.0011	0.0229	-0.0018	-0.0025**	-0.0046**
	(0.0006)	(0.0009)	(0.0018)	(0.0260)	(0.0018)	(0.0012)	(0.0018)
Unskilled labor × Imports	-0.0033***	-0.0039***	-0.0046	-0.0313	-0.0030*	-0.0009	0.0000
	(0.0008)	(0.0008)	(0.0035)	(0.0249)	(0.0016)	(0.0012)	(0.0020)
Skilled labor × Exports	0.0013*	-0.0015**	-0.0014	-0.0054	0.0015	0.0018	0.0012
	(0.0007)	(0.0007)	(0.0013)	(0.0092)	(0.0025)	(0.0012)	(0.0009)
Skilled labor × Imports	0.0029***	0.0024***	0.0059**	0.0145	0.0024	-0.0001	0.0016
	(0.0008)	(0.0007)	(0.0024)	(0.0115)	(0.0029)	(0.0013)	(0.0014)
Capital	0.0315***	0.0250***	0.0062	-0.0235	0.0196***	0.0257***	0.0077**
	(0.0056)	(0.0058)	(0.0108)	(0.0608)	(0.0063)	(0.0060)	(0.0033)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,783	5,674	1,561	1,653	1,100	3,163	4,969
R-squared	0.9989	0.9967	0.9966	0.9923	0.9991	0.9993	0.9984
Number firm-product couples	1,512	1,924	585	526	357	1,013	1,495

Industry	24	25	26-28	29-30	31	32-33
Materials	0.5957***	0.5701***	0.5609***	0.6899***	0.6186***	0.5491***
	(0.0727)	(0.0180)	(0.0181)	(0.0378)	(0.0374)	(0.0311)
Unskilled labor	0.2707***	0.2470***	0.1987***	0.1968***	0.2712***	0.2152***
	(0.0176)	(0.0081)	(0.0085)	(0.0123)	(0.0164)	(0.0126)
Skilled labor	0.0824***	0.1244***	0.1610***	0.1187***	0.1075***	0.1726***
	(0.0138)	(0.0059)	(0.0059)	(0.0122)	(0.0075)	(0.0107)
Unskilled labor × Exports	-0.0062**	-0.0050***	-0.0009	0.0007	-0.0017	-0.0029*
	(0.0025)	(0.0014)	(0.0007)	(0.0011)	(0.0025)	(0.0016)
Unskilled labor × Imports	-0.0003	-0.0024*	-0.0032***	-0.0042***	-0.0071	-0.0050**
	(0.0054)	(0.0014)	(0.0009)	(0.0010)	(0.0050)	(0.0023)
Skilled labor × Exports	0.0031	0.0026**	0.0013*	-0.0007	0.0006	0.0036***
	(0.0020)	(0.0012)	(0.0008)	(0.0008)	(0.0016)	(0.0013)
Skilled labor × imports	0.0013	0.0018	0.0029***	0.0030***	0.0034**	-0.0019
	(0.0049)	(0.0013)	(0.0009)	(0.0007)	(0.0016)	(0.0015)
Capital	0.0087	0.0136***	0.0223***	0.0224	0.0173*	0.0061
	(0.0057)	(0.0026)	(0.0065)	(0.0146)	(0.0092)	(0.0153)
Product and year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,176	2,814	3,661	2,287	1,656	1,593
R-squared	0.9984	0.9992	0.9994	0.9993	0.9960	0.9986
Number firm-product couples	343	937	1,245	660	582	506

Notes: The Table provides estimates of the parameters of the production function (1) obtained from IVs estimations of equation (12). Estimations are carried on the sub-sample of single-product firms for each of the 13 industry groups we consider. For skilled and unskilled workers we use here an alternative definition: we classify workers as skilled based on their occupation within the firm (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-3: Relationship of TFP and Capital with Prices and Markups: Alternative Distinction between Skilled and Unskilled Workers Based on Occupations

	Price	Markup
TFP	-0.8468***	0.0683***
	(0.0060)	(0.0084)
Capital	-0.1126***	0.0071***
	(0.0051)	(0.0091)
Firm-product FE	Yes	Yes
Year Dummies	Yes	Yes
Observations	338,160	338,160
Number of firm-product couples	134,348	134,348
R-squared	0.9905	0.6579

Notes: The Table provides results of two estimations in which we regress log price and the markup on quantity TFP and log capital stock, while allowing for time dummies and firm-product FE, and employing the within estimator. Identification of regression coefficients thus comes from within firm-product variable changes over time. For skilled and unskilled workers we use here our alternative definition based on occupations (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-4: Additional Features of Exporters and Importers: Alternative Distinction between Skilled and Unskilled Workers Based on Occupations

	Rev. TFP	TFP	Price	Marg. cost	Markup
Panel A. Exporters					
Exporter	0.2305***	0.1447***	0.0858***	0.1073***	-0.0215***
	(0.0034)	(0.0093)	(0.0092)	(0.0094)	(0.0022)
Product and year dummies	Yes	Yes	Yes	Yes	Yes
Observations	338,160	338,160	338,160	338,160	338,160
Number of firm-product couples	134,348	134,348	134,348	134,348	134,348
R-squared	0.5687	0.7925	0.8059	0.7975	0.1506
Panel B. Importers					
Importer	0.3901***	0.2267***	0.1634***	0.1789***	-0.0155***
	(0.0033)	(0.0091)	(0.0100)	(0.0102)	(0.0023)
Product and year dummies	Yes	Yes	Yes	Yes	Yes
Observations	338,160	338,160	338,160	338,160	338,160
Number of firm-product couples	134,348	134,348	134,348	134,348	134,348
R-squared	0.6113	0.76633	0.8062	0.7978	0.1503

Notes: The Table provides estimates of simple OLS regressions where each dependent variable is regressed on 8-digit product dummies and year dummies as well as on a dummy variable indicating whether the firm is an exporter (top panel) or an importer (bottom panel) and zero otherwise. The dependent variables used are revenue TFP, quantity TFP, log price, log marginal cost and log markups. For skilled and unskilled workers we use here our alternative definition based on occupations (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-5: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: First Group of Outcome Variables, Key Controls

	Change revenue	Change quantity	Change price	Change inputs bundle	Change share skilled
lag exports	0.0633***	0.0415**	0.0218**	0.0707***	0.0034***
	(0.0155)	(0.0171)	(0.0103)	(0.0155)	(0.0010)
lag imports	0.0267**	0.0442***	-0.0175***	0.0284***	-0.0003
	(0.0108)	(0.0119)	(0.0066)	(0.0108)	(0.0006)
lag sales	-0.0523***	-0.0501***	-0.0022	-0.0542***	-0.0026***
	(0.0116)	(0.0129)	(0.0078)	(0.0116)	(0.0008)
lag exports × lag sales	-0.0192***	-0.0122**	-0.0069**	-0.0212***	-0.0013***
	(0.0047)	(0.0052)	(0.0031)	(0.0047)	(0.0003)
lag imports × lag sales	-0.0000*	-0.0000*	0.0000	-0.0000*	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0666	0.0460	0.0133	0.0506	0.0304
K-P LM underidentif. stat.	109.96	109.96	109.96	109.96	109.96
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.640	11.640	11.640	11.640	11.640

Notes: The Table provides IV estimates of the parameters of the control variables in equation (13): log exports, log imports and log sales all in $t-1$ as well as the interaction between log exports (log imports) and log sales in $t-1$. The 5 outcomes measures considered here are changes in log revenue, log quantity, log price, log inputs bundle ($\alpha_{Lit}l_{it} + \alpha_{Hit}h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$.) and the share of skilled workers in the overall wage expenditure. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-6: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: First Stages

	Change exports	Change imports
Instruments		
Change GDP exp.	1.3652***	-2.4225***
	(0.3956)	(0.4551)
Change RER exp.	-0.3712**	0.4520***
	(0.1444)	(0.1543)
Change GDP exp. × lag exports	9.9674***	-0.0103
	(1.8740)	(2.1196)
Change RER exp. × lag exports	3.3759***	-1.5398***
	(0.4867)	(0.5646)
Change GDP imp.	-1.8812***	-1.4118***
	(0.4181)	(0.3931)
Change RER imp.	-0.0681	-1.4771***
	(0.1522)	(0.1539)
Change GDP imp. × lag imports	-11.8113***	24.9183***
	(1.2749)	(1.3771)
Change RER imp. × lag imports	-0.8647*	1.0858**
	(0.4439)	(0.4257)
Change tariff	-1.0296***	-0.4302**
	(0.2536)	(0.2000)
Change tariff × lag imports	0.7448	0.0807
	(0.5442)	(0.4944)
Other covariates		
lag exports	-0.6047***	0.0803***
	(0.0044)	(0.0026)
lag imports	0.0728***	-0.5930***
	(0.0025)	(0.0042)
lag sales	0.2672***	0.2843***
	(0.0075)	(0.0086)
lag exports × lag sales	0.1778***	-0.0310***
	(0.0039)	(0.0036)
lag imports × lag sales	0.0000*	0.0000**
	(0.0000)	(0.0000)
Year dummies	Yes	Yes
Observations	106,751	106,751
Number of firm-product couples	37,263	37,263
K-P Wald F weak identif. stat.	11.640	11.640

Notes: The Table provides the two first stages related to the IV estimations of equation (13). There are two instrumented variables (change in exports and change in imports) and 10 instrumental variables. See Section 4.3 for details on the instruments. The Table reports the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ $p<0.01$, $**$ $p<0.05$, $*$ $p<0.1$.

Table C-7: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Second Group of Outcome Variables, Key Controls

	Change Rev. TFP	Change TFP	Change Price	Change Marg. cost	Change Markup
lag exports	-0.0074**	-0.0292***	0.0218**	0.0451***	-0.0233***
	(0.0033)	(0.0108)	(0.0103)	(0.0118)	(0.0050)
lag imports	-0.0017	0.0158**	-0.0175***	-0.0108	-0.0067*
	(0.0024)	(0.0071)	(0.0066)	(0.0078)	(0.0036)
lag sales	0.0018	0.0040	-0.0022	-0.0160*	0.0138***
	(0.0025)	(0.0082)	(0.0078)	(0.0089)	(0.0039)
lag exports × lag sales	0.0020**	0.0089***	-0.0069**	-0.0138***	0.0069***
	(0.0010)	(0.0033)	(0.0031)	(0.0035)	(0.0015)
lag imports × lag sales	0.0000*	0.0000	0.0000	-0.0000	0.0000*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0294	0.0205	0.0133	0.0352	0.088
K-P LM underidentif. stat.	109.96	109.96	109.96	109.96	109.96
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.640	11.640	11.640	11.640	11.640

Notes: The Table provides IV estimates of the parameters of the control variables in equation (13): log exports, log imports and log sales all in $t-1$ as well as the interaction between log exports (log imports) and log sales in $t-1$. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal cost and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-8: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Second Group of Outcome Variables, Heterogeneous Effects, Key Controls

	Change Rev. TFP	Change TFP	Change Price	Change Marg. cost	Change Markup
lag exports	-0.0187***	-0.0554***	0.0367***	0.0627***	-0.0260***
	(0.0068)	(0.0121)	(0.0091)	(0.0112)	(0.0050)
lag imports	0.0350***	0.0355**	-0.0004	-0.0185	0.0181**
	(0.0106)	(0.0169)	(0.0113)	(0.0144)	(0.0071)
lag sales	-0.0146**	0.0119	-0.0265***	-0.0324***	0.0059
	(0.0070)	(0.0120)	(0.0087)	(0.0108)	(0.0051)
lag exports × lag sales	0.0073***	0.0199***	-0.0125***	-0.0218***	0.0092***
	(0.0024)	(0.0042)	(0.0031)	(0.0038)	(0.0017)
lag imports × lag sales	-0.0073**	-0.0049	-0.0024	0.0012	-0.0036*
	(0.0029)	(0.0046)	(0.0032)	(0.0040)	(0.0020)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	103,065	103,065	103,065	103,065	103,065
Number of firm-product couples	36,162	36,162	36,162	36,162	36,162
R-squared	0.1181	0.092	0.0698	0.1243	0.0566
K-P LM underidentif. stat.	71.567	71.567	71.567	71.567	71.567
K-P LM underidentif. Df	16	16	16	16	16
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	3.5746	3.5746	3.5746	3.5746	3.5746

Notes: The Table provides IV estimates of the parameters of the control variables of the enriched version of equation (13) presented in Table 9: log exports, log imports and log sales all in $t-1$ as well as the interaction between log exports (log imports) and log sales in $t-1$. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal cost and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-9: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Heterogeneous Effects, First Stages

	Change exports	Change exports × lag rev. TFP	Change imports	Change imports × lag rev. TFP
Instruments				
Change GDP exp.	2.2664**	-1.0194	-1.0784	5.4109**
	(0.9607)	(2.9357)	(0.8305)	(2.1798)
Change GDP exp. × lag rev. TFP	-2.1594***	-2.0879	0.4134	-1.5440
	(0.4055)	(1.3894)	(0.3568)	(1.0088)
Change GDP exp. × lag exports	7.2597	5.6123	18.9400***	77.6885***
	(5.7806)	(14.1910)	(4.9055)	(10.3269)
Change GDP exp. × lag exports × lag rev. TFP	-1.9781	-0.4246	-3.4378*	-26.0244***
	(2.4195)	(6.3927)	(2.0379)	(4.5103)
Change RER exp.	0.4931	0.2770	1.3704***	0.3872
	(0.4114)	(1.2134)	(0.4042)	(1.1141)
Change RER exp. × lag rev. TFP	-0.0017	0.3513	-0.6028***	-0.3455
	(0.1792)	(0.5825)	(0.1744)	(0.5278)
Change RER exp. × lag exports	-3.6626**	-8.3941*	6.4915***	20.1834***
	(1.8246)	(4.6373)	(1.7653)	(3.6049)
Change RER exp. × lag exports × lag rev. TFP	1.2456	2.8256	-0.6529	-3.9894**
	(0.7721)	(2.1539)	(0.7223)	(1.5847)
Change GDP imp.	0.0646	-2.1028	-3.2906***	-13.0588***
	(0.9444)	(2.9193)	(1.1267)	(2.9811)
Change GDP imp. × lag rev. TFP	0.9446**	3.8192***	0.6933	4.0330***
	(0.4088)	(1.3793)	(0.4936)	(1.3710)
Change GDP imp. × lag imports	-2.1288	19.2178***	1.0646	-6.8478
	(2.4122)	(5.5740)	(2.7691)	(6.8587)
Change GDP imp. × lag imports × lag rev. TFP	-0.8934	-14.7258***	-3.3571***	-4.5110
	(0.9987)	(2.6409)	(1.2030)	(3.2523)
Change RER imp.	-1.7859***	-1.0664	-2.0087***	-4.0664***
	(0.3799)	(1.1931)	(0.4802)	(1.2315)
Change RER imp. × lag rev. TFP	0.2891*	-0.7233	0.7363***	1.5907***
	(0.1607)	(0.5731)	(0.2069)	(0.5678)
Change RER imp. × lag imports	3.5262***	0.2765	1.5840	8.3013***
	(0.8579)	(2.0166)	(1.0587)	(2.8698)
Change RER imp. × lag imports × lag rev. TFP	-1.2026***	0.6046	-1.1354**	-5.1489***
	(0.3744)	(1.0290)	(0.4704)	(1.4601)
Change tariff	-0.1888	0.5750	-3.1893***	-6.8770***
	(0.3313)	(0.6303)	(0.5323)	(2.3919)
Change tariff × lag rev. TFP	-0.2338	-0.9856**	1.0617***	2.6175*
	(0.1589)	(0.3912)	(0.2399)	(1.3423)
Change tariff × lag imports	-1.2421	-5.4692***	4.0495***	7.3719**
	(0.8840)	(1.5814)	(1.3935)	(3.4909)
Change tariff × lag imports × lag rev. TFP	0.9182**	3.2400***	-1.6884***	-3.7166**
	(0.3958)	(0.8659)	(0.6047)	(1.7944)

Table C-9: Continued

	Change exports	Change exports × lag rev. TFP	Change imports	Change imports × lag rev. TFP
Other covariates				
lag exports	0.0140***	0.0308***	-0.5908***	-1.2641***
	(0.0023)	(0.0057)	(0.0048)	(0.0128)
lag imports	-0.6328***	-1.3828***	0.0098***	0.0210***
	(0.0043)	(0.0119)	(0.0023)	(0.0056)
lag sales	0.3900***	0.8466***	0.3593***	0.7757***
	(0.0051)	(0.0123)	(0.0055)	(0.0127)
lag exports × lag sales	-0.0234***	-0.0473***	0.1953***	0.4255***
	(0.0039)	(0.0092)	(0.0036)	(0.0084)
lag imports × lag sales	0.1772***	0.3960***	0.0169***	0.0323***
	(0.0029)	(0.0075)	(0.0032)	(0.0077)
Year dummies	Yes	Yes	Yes	Yes
Observations	103,065	103,065	103,065	103,065
Number of firm-product couples	36,162	36,162	36,162	36,162
K-P Wald F weak identif. stat.	3.5746	3.5746	3.5746	3.5746

Notes: The Table provides the four first stages related to the IV estimations of the enriched version of equation (13) presented in Table 9. There are four instrumented variables (change in exports, change in imports and the interactions of these two with revenue TFP at time $t-1$) and 20 instrumental variables. See Sections 4.3 and 5.3 for details on the instruments. The Table reports the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-10: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Distinction between Skilled and Unskilled Workers Based on Occupations, First Group of Outcome Variables, Key Covariates

	Change revenue	Change quantity	Change price	Change inputs bundle	Change share skilled
Change exports	0.0925***	0.1189***	0.0264	0.1320***	0.0032*
	(0.0298)	(0.0269)	(0.0181)	(0.0273)	(0.0018)
Change imports	0.0885***	0.0606***	-0.0279**	0.0652***	0.0017
	(0.0223)	(0.0201)	(0.0128)	(0.0204)	(0.0013)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0510	0.0755	0.0151	0.0637	0.0304
K-P LM underidentif. stat.	109.56	109.56	109.56	109.56	109.56
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.533	11.533	11.533	11.533	11.533

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). The 5 outcomes measures considered here are changes in log revenue, log quantity, log price, log inputs bundle ($\alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$.) and the share of skilled workers in the overall wage expenditure. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our alternative definition based on occupations (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-11: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Distinction between Skilled and Unskilled Workers Based on Occupations, Second Group of Outcome Variables, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	-0.0131**	-0.0395**	0.0264	0.0656***	-0.0392***
	(0.0056)	(0.0191)	(0.0181)	(0.0207)	(0.0088)
Change imports	-0.0046	0.0233*	-0.0279**	-0.0131	-0.0148**
	(0.0044)	(0.0137)	(0.0128)	(0.0149)	(0.0069)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0321	0.0186	0.0151	0.0281	0.0775
K-P LM underidentif. stat.	109.56	109.56	109.56	109.56	109.56
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.533	11.533	11.533	11.533	11.533

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal costs and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our alternative definition based on occupations (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-12: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Distinction between Skilled and Unskilled Workers Based on Occupations, Second Group of Outcome Variables, Heterogeneous Effects, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	change markup
Change exports	-0.1225***	-0.1081	-0.0144	0.1376**	-0.1520***
	(0.0442)	(0.0716)	(0.0475)	(0.0601)	(0.0312)
Change exports × lag rev. TFP	0.0629***	0.0351	0.0278	-0.0329	0.0607***
	(0.0216)	(0.0343)	(0.0225)	(0.0287)	(0.0153)
Change imports	0.3003***	0.3925***	-0.0921**	-0.1891***	0.0970***
	(0.0527)	(0.0777)	(0.0412)	(0.0566)	(0.0303)
Change imports × lag rev. TFP	-0.1143***	-0.1648***	0.0504**	0.0931***	-0.0426***
	(0.0260)	(0.0379)	(0.0199)	(0.0268)	(0.0143)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	103,065	103,065	103,065	103,065	103,065
Number of firm-product couples	36,162	36,162	36,162	36,162	36,162
R-squared	0.0949	0.0408	0.0638	0.0511	0.0465
K-P LM underidentif. stat.	63.899	63.899	63.899	63.899	63.899
K-P LM underidentif. Df	16	16	16	16	16
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	3.1502	3.1502	3.1502	3.1502	3.1502

Notes: The Table provides IV estimates of an enriched version of equation (13) to which we add two interaction terms, and in particular an interaction between the change in exports and the level of revenue TFP in $t-1$ ($\Delta exp_{it} TFP^R_{it-1}$), as well an interaction between the change in imports and the level of revenue TFP in $t-1$ ($\Delta imp_{it} TFP^R_{it-1}$). See Sections 4.3 and 5.3 for details on the instruments. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal cost and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our alternative definition based on occupations (see Section 4.2). Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-13: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Allocation of Firm Inputs across Products Based on Revenue Shares, First Group of Outcome Variables, Key Covariates

	Change revenue	Change quantity	Change price	Change inputs bundle	Change share skilled
Change exports	0.0992***	0.1357***	0.0365**	0.1352***	0.0061***
	(0.0303)	(0.0274)	(0.0183)	(0.0270)	(0.0018)
Change imports	0.0932***	0.0720***	-0.0212*	0.0634***	0.0003
	(0.0218)	(0.0197)	(0.0124)	(0.0196)	(0.0012)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0499	0.0675	0.0138	0.0518	0.0392
K-P LM underidentif. stat.	110.94	110.94	110.94	110.94	110.94
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.792	11.792	11.792	11.792	11.792

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). For obtaining these results we use products revenue shares to attribute inputs across products within multi-product firms rather than the assignment procedure described in Appendix A. The 5 outcomes measures considered here are changes in log revenue, log quantity, log price, log inputs bundle $(\alpha_{Lit}l_{it} + \alpha_{Hit}h_{it} + \alpha_M m_{it} + \alpha_K k_{it}.)$ and the share of skilled workers in the overall wage expenditure. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-14: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Allocation of Firm Inputs across Products Based on Revenue Shares, Second Group of Outcome Variables, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	0.0005	-0.0360*	0.0365**	0.0747***	-0.0382***
	(0.0081)	(0.0195)	(0.0183)	(0.0204)	(0.0086)
Change imports	0.0086	0.0298**	-0.0212*	-0.0016	-0.0196***
	(0.0062)	(0.0135)	(0.0124)	(0.0139)	(0.0063)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0269	0.0171	0.0138	0.0439	0.1046
K-P LM underidentif. stat.	110.94	110.94	110.94	110.94	110.94
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	11.792	11.792	11.792	11.792	11.792

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). For obtaining these results we use products revenue shares to attribute inputs across products within multi-product firms rather than the assignment procedure described in Appendix A. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal costs and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-15: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Way of Constructing Instruments, First Group of Outcome Variables, Key Covariates

	Change revenue	Change quantity	Change price	Change inputs bundle	Change share skilled
Change exports	0.1186***	0.1387***	0.0202	0.1437***	0.0059***
	(0.0325)	(0.0300)	(0.0181)	(0.0299)	(0.0019)
Change imports	0.1005***	0.0911***	-0.0094	0.0924***	0.0037***
	(0.0226)	(0.0209)	(0.0125)	(0.0209)	(0.0013)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0306	0.0479	0.0036	0.0357	0.0199
K-P LM underidentif. stat.	75.375	75.375	75.375	75.375	75.375
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	7.6154	7.6154	7.6154	7.6154	7.6154

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). For obtaining these results we use an alternative way of weighting exchange rates, GDP and tariffs changes to construct instruments based on firm-level trade data for years $t-1$ and $t-2$ (see Section B). The 5 outcomes measures considered here are changes in log revenue, log quantity, log price, log inputs bundle ($\alpha_{Lit}l_{it} + \alpha_{Hit}h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$.) and the share of skilled workers in the overall wage expenditure. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-16: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Way of Constructing Instruments, Second Group of Outcome Variables, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	-0.0050	-0.0251***	0.0202	0.0626***	-0.0425***
	(0.0065)	(0.0093)	(0.0181)	(0.0213)	(0.0102)
Change imports	-0.0013	0.0081	-0.0094	0.0149	-0.0243***
	(0.0045)	(0.0133)	(0.0125)	(0.0148)	(0.0071)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0071	0.0175	0.0036	0.0325	0.1069
K-P LM underidentif. stat.	75.375	75.375	75.375	75.375	75.375
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	7.6154	7.6154	7.6154	7.6154	7.6154

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). For obtaining these results we use an alternative way of weighting exchange rates, GDP and tariffs changes to construct instruments based on firm-level trade data for years $t-1$ and $t-2$ (see Section B). The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal costs and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-17: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Alternative Way of Constructing Instruments, Second Group of Outcome Variables, Heterogeneous Effects, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	-0.0885*	-0.1360**	0.0475	0.1461***	-0.0986***
	(0.0490)	(0.0661)	(0.0382)	(0.0534)	(0.0305)
Change exports × lag rev. TFP	0.0412*	0.0411	0.0001	-0.0330	0.0331**
	(0.0213)	(0.0285)	(0.0163)	(0.0231)	(0.0133)
Change imports	0.2714***	0.3165***	-0.0451	-0.1774***	0.1323***
	(0.0426)	(0.0560)	(0.0306)	(0.0441)	(0.0262)
Change imports × lag rev. TFP	-0.0928***	-0.1128***	0.0200	0.0592***	-0.0392***
	(0.0174)	(0.0231)	(0.0132)	(0.0182)	(0.0106)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	103,065	103,065	103,065	103,065	103,065
Number of firm-product couples	36,162	36,162	36,162	36,162	36,162
R-squared	0.0655	0.0627	0.0325	0.0612	0.0899
K-P LM underidentif. stat.	62.173	62.173	62.173	62.173	62.173
K-P LM underidentif. Df	16	16	16	16	16
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	3.2062	3.2062	3.2062	3.2062	3.2062

Notes: The Table provides IV estimates of an enriched version of equation (13) to which we add two interaction terms, and in particular an interaction between the change in exports and the level of revenue TFP in $t-1$ ($\Delta exp_{it} TFP^R_{it-1}$), as well an interaction between the change in imports and the level of revenue TFP in $t-1$ ($\Delta imp_{it} TFP^R_{it-1}$). For obtaining these results we use an alternative way of weighting exchange rates, GDP and tariffs changes to construct instruments based on firm-level trade data for years $t-1$ and $t-2$ (see Section B). See also Sections 4.3 and 5.3 for further details on the instruments. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal cost and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-18: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Weighted Regressions, First Group of Outcome Variables, Key Covariates

Dependent variable	Change revenue	Change quantity	Change price	Change inputs bundle	Change share skilled
Change exports	0.1080***	0.1376***	0.0296*	0.1430***	0.0077***
	(0.0309)	(0.0279)	(0.0157)	(0.0275)	(0.0020)
Change imports	0.1020***	0.0788***	-0.0231*	0.0668***	0.0010
	(0.0215)	(0.0194)	(0.0123)	(0.0194)	(0.0013)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,916	106,916	106,916	106,916	106,916
Number of firm-product couples	36,847	36,847	36,847	36,847	36,847
R-squared	0.1351	0.0197	0.0125	0.0324	0.0868
K-P LM underidentif. stat.	103.78	103.78	103.78	103.78	103.78
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	10.835	10.835	10.835	10.835	10.835

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). For obtaining these results we weigh observations by the value of log sales in $t-1$. The 5 outcomes measures considered here are changes in log revenue, log quantity, log price, log inputs bundle ($\alpha_{Lit} l_{it} + \alpha_{Hit} h_{it} + \alpha_M m_{it} + \alpha_K k_{it}$.) and the share of skilled workers in the overall wage expenditure. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

Table C-19: IV Estimations of the Response to Exogenous Trade Shocks Affecting Exports and Imports: Weighted Regressions, Second Group of Outcome Variables, Key Covariates

	Change rev. TFP	Change TFP	Change price	Change marg. cost	Change markup
Change exports	-0.0053	-0.0349*	0.0296*	0.0703***	-0.0407***
	(0.0076)	(0.0202)	(0.0157)	(0.0215)	(0.0091)
Change imports	0.0120**	0.0351***	-0.0231*	-0.0057	-0.0175***
	(0.0058)	(0.0136)	(0.0123)	(0.0143)	(0.0065)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	106,751	106,751	106,751	106,751	106,751
Number of firm-product couples	37,263	37,263	37,263	37,263	37,263
R-squared	0.0244	0.0197	0.0125	0.0324	0.0868
K-P LM underidentif. stat.	103.78	103.78	103.78	103.78	103.78
K-P LM underidentif. Df	8	8	8	8	8
K-P LM underidentif. p-value	0	0	0	0	0
K-P Wald F weak identif. stat.	10.835	10.835	10.835	10.835	10.835

Notes: The Table provides IV estimates of the parameters c_E and c_I in equation (13). For obtaining these results we weigh observations by the value of log sales in $t-1$. The 5 outcomes measures considered here are changes in revenue TFP, quantity TFP, log price, log marginal costs and log markup. The Table reports the Kleibergen-Paap LM under-identification test statistic, degrees of freedom and associated p-value as well as the Kleibergen-Paap Wald F weak identification statistic. An observation in the regressions is a firm-product-year tuple. For skilled and unskilled workers we use here our baseline definition. Standard errors (in parenthesis) are clustered at the firm-product level. $***$ p<0.01, $**$ p<0.05, $*$ p<0.1.

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