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TRADE LIBERALIZATION AND DOMESTIC SUPPLIERS: EVIDENCE FROM CHILE

by Andrea Linarello*

Abstract

I examine the effect of reducing export tariffs on the productivity of domestic suppliers of exporting firms. Using a panel of Chilean firms during a period of trade liberalization with the European Union, the United States, and the Republic of Korea, I show that the average reduction in the export tariff of downstream industries (1.1 percentage points) increases the productivity of intermediate input suppliers by 1.5 percent. The increase in productivity among domestic suppliers accounts for 22.5 percent of aggregate productivity gains. I find that tariff cuts induce firms to acquire new machinery and pay higher wages to skilled workers. These findings are consistent with a simple model in which lower export tariffs increase the sales of exporting firms and increase the derived demand for intermediates through input-output linkages.

JEL Classification: D21, F12, L60.
Keywords: productivity, trade liberalization, exports; input-output linkages.

Contents

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1 Introduction[1]

During the last decade, a large number of empirical studies have analyzed the effects of trade liberalization on productivity (Pavcnik, 2002; Trefler, 2004; Amiti and Konings, 2007; Lileeva and Trefler, 2010). In line with recent theoretical work (Melitz, 2003; Bernard et al., 2007), they have shown that a reduction of input or output tariffs leads to large productivity gains by increasing competition or by facilitating access to cheaper or better inputs. A reduction in export tariffs also opens new markets, implying an increase in revenue, what provides incentives for investing in new technologies. These direct effects, however, do not correspond to the full impact of trade liberalization on productivity, and several indirect channels remain unexplored. Consider for example a drop in the export tariff of wine: it may affect the productivity of wine exporters, but it may also increase the productivity of input suppliers of label and bottle makers due to the expansion in derived demand for intermediates from exporting firms.

In this paper, I examine the effect of reducing export tariffs on the productivity of domestic input suppliers. I focus on the case of Chile, which provides a good empirical setting. Between 2003 and 2004, Chile signed free trade agreements (FTAs) with the European Union, the United States, and the Republic of Korea. Export tariff elimination following the entry into force of the FTAs provide a good source of exogenous variation for the identification of productivity gains generated by the FTAs. These export tariffs apply to all countries, not only Chile, and vary extensively across industries. The aggregate data from this period suggest that exports increased along the intensive and extensive margin. Between 2002 and 2006, aggregate exports tripled, and the number of exporting firms increased by almost 10 percent.

The main source of data is the Chilean annual manufacturing census of all plants with more that 10 employees. In addition to standard plant-level information on output and employment, I observe detailed quantities and revenues for each good produced and for each intermediate input at the product level. I use this product information to construct a plant-specific productivity measure that reflects technical efficiency and is not affected by output and input price heterogeneity. One of the

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main limitations of previous empirical studies has been to estimate firm productivity using proxies that blended technical efficiency with firm markups and prices (Foster et al., 2008; De Loecker, 2011). I also use product information to construct a tariff measure that is plant-specific. I aggregate tariffs for each product at the plant level using revenue shares as weights. This allows me to adopt a difference-in-difference identification strategy that includes 4-digit industry fixed effects. I exploit the differential changes in tariffs across plants within each industry. The presence of industry fixed effects accounts for several confounding factors, such as the increase in import competition at the industry level following the FTAs, that might drive changes in productivity. The main identification assumption is that changes in these tariffs are exogenous to Chilean plant characteristics.

My main finding is that the average decrease in the export tariffs faced by downstream industries in the production chain (1.1 percentage point) increases firms' productivity by 1.5 percent per year between 2002 and 2006. This effect explains 22.5 percent of aggregate productivity growth during this period. The gains are heterogeneous across the firm productivity distribution: the productivity of the ex-ante less productive firms increases more than that of the other firms in my sample. I also show that the direct export tariff cuts (5.2 percentage points) increase firm productivity by 1.2 percent, confirming the findings of previous studies (Lileeva and Trefler, 2010; Bustos, 2011).

I explore the possible channels underlying productivity gains. Following the entry into force of the FTAs, domestic suppliers receive a shock to their demand generated by the export tariff cuts in downstream industries. If they do not have the necessary machinery and equipment in place to serve this high demand, they need to update it. If there is new technology embodied in this new machinery, they will also become more productive. The technological content of new machinery might also require skilled operators. The rise in the demand for skilled workers, as well as the increase in their productivity generated by the capital-skill complementarity, can increase the wages skill premium and can be partly responsible for the observed increase in productivity. I find evidence that is consistent with this channel. In particular, I find that the indirect export tariff cuts increase firms investment in machinery, as well as the wages of skilled workers. I find no effect on the wages of unskilled workers. These findings are consistent with a simple model in which firms must pay a fixed cost to invest in productivity. The export tariff cuts increase the demand of exporters, as well as the derived demand for intermediate input suppliers through input-output linkages, thus making investment more profitable.

This is, to my knowledge, the first attempt to estimate the impact of the increase in derived demand on firm productivity. Other papers stress how international trade increases industry productivity through *selection* (Melitz, 2003; Pavcnik, 2002; Trefler, 2004). The most productive firms export; the least productive firms are forced to exit; and market shares are reallocated toward incumbent firms. These forces lead to an increase in the average industry productivity and a more efficient allocation of resources.

Several papers investigate how international trade increases the productivity of exporting firms. Lileeva and Trefler (2010) document a rise in the labor productivity of Canadian firms after an FTA with the United States went into force. Bustos (2011) finds that Argentinean firms that start to export in response to the MERCOSUR agreement invest in technology upgrades, which allows them to lower their marginal costs and become more competitive both in the domestic and foreign market. Another channel that enhances productivity of exporting firms is *learning-by-exporting*. The idea is that exporting firms acquire new knowledge and expertise from their trading partners. Among others, De Loecker (2007) provides empirical evidence supporting this mechanism using Slovenian data. Finally, another line of research investigates how international trade increases the productivity of importing firms. Using Indonesian data, Amiti and Konings (2007) show that a decrease in input tariffs increases the imports of intermediate inputs and the productivity of importing firms. Halpern et al. (2011) go one step further, showing that the increase in productivity of importing firms is mainly due to the imperfect substitution of intermediate inputs. Thus, the use of foreign inputs increases the productivity of importing firms.

The idea that input-output linkages can amplify the effect of trade shocks has also been explored by other papers. Caliendo and Parro (2012) find that accounting for intersectoral linkages substantially increases the welfare effects of the implementation of NAFTA. In a recent paper, Acemoglu et al. (2014) show that accounting for indirect effects of Chinese import competition doubles the U.S. manufacturing job losses in manufacturing sectors.

The remainder of the paper is organized as follows. Section 2 describes the FTAs. In section 3, I present the conceptual framework that guides the empirical analysis. In section 4, I describe measurement issues and the identification strategy. Section 5 and 6 discuss the results.

2 Chilean Free Trade Agreements

To assess the impact of international trade on the performance of Chilean firms, I exploit three important episodes of trade liberalization between Chile and three foreign governments: the E.U., the United States, and the Republic of Korea. These free trade agreements (FTAs) were entered into force between February 2003 and April 2004. I use the level of tariffs in 2002, before the FTAs, as a proxy to measure improved access to foreign markets among Chilean firms.

Chile has a long tradition of integration into international trade. Starting in the late 1970s, it eliminated non-tariff barriers and implemented a single import tariff rate (Pavcnik, 2002; OECD, 2003). Chilean Most Favoured Nations (MNF) tariffs applied to imports from abroad in 2002 were 7 percent for all industries. Together with other market-oriented reforms and a strong commitment to macroeconomic stability, Chile experienced sustained high growth from 1984 to 1997. Since the late 1990s, Chile has signed several FTAs with its most important trading partners. These policies were implemented in response to the economic slowdown and were designed to help diversify the Chilean economy, which relies heavily on natural resources.[2]

This paper focuses on three important FTAs Chile signed with the E.U., the United States, and the Republic of Korea. The negotiation with the E.U. started in November 1999; the agreement was signed in November 2002; and the FTA went into force in February 2003. The negotiation with the United States started in December 2000; the agreement was signed in June 2003; and it went into force in January 2004. The FTA with the Republic of Korea entered into force in April 2004 after seven rounds of negotiations, which started in 1999. By the date of entry into force of the three FTAs, almost all barriers to trade had been removed.[3]

Figure 1 shows the dynamics of aggregate export flows. The vertical lines show when the FTAs went into effect. Between 2002 and 2006, the value of aggregate exports almost tripled. Although Chilean exports to other markets also increase substantially,[4] these three markets account for 50 percent of the country's total

[2]Chilean exports are highly concentrated in copper, wood, and some agro-food products.

[3]While tariffs were completely eliminated after the entry into force of the FTAs with the United States and Korea, the same was not true for the E.U. For some goods, tariff elimination was scheduled in 2006. These goods accounted for less than 8 percent of total exports toward the E.U. Moreover, for a wide range of agricultural and food products, quota protections were defined. Quotas were increasing over time, and scheduled to be eliminated within 5 to 8 years. All products imported within quotas were tariff free, but tariffs were applied to extra quantities. Quotas were applied on the basis of arrival time. Finally, the entry into force of the FTA with the E.U. was provisional and became definitive in 2006. This caveat had no impact on tariff eliminations.

[4]These are the years in which many developing countries started to grow and increase their importance in world trade: the *Asian Tigers* experienced rapid growth after the financial crisis of

exports.[5]

One possible concern about aggregate trends is the role of copper. The export of copper products accounts for half of aggregate exports in 2002. Chile is among the world's largest exporters of copper, and the price of this metal, in line with other raw materials, greatly increased during the last decade. When I omit copper products from my calculations, aggregate exports double.[6]

I use the change in the export tariffs to identify the effect of the FTAs on Chilean firms. I combine data on MFN tariffs applied by partner countries to construct a weighted export tariff, i.e., the tariffs faced by Chilean firms. For each products p, I define the export tariff as

$$\tau_p^e = \frac{\tau_p^{E.U.} \cdot M_p^{E.U.} + \tau_p^{U.S.} \cdot M_p^{U.S.} + \tau_p^{KOREA} \cdot M_p^{KOREA}}{M_p^{U.S.} + M_p^{E.U.} + M_p^{KOREA}},$$

where τ is the MFN tariffs and M is the value of imports in the destination countries (EU, USA, and Korea). Variables are measured in 2002, the year before the FTAs were entered into force. Tariffs fall on average by 4.1 percent, ranging from 0 percent to 25 percent (the median tariff was 2.8 percent and the standard deviation 3.8). Table 1 shows the five industries with the highest and the lowest tariff cuts. The heterogeneity across industries reflects different protection schemes applied by destination countries and are not specific to Chile. Indeed the share of Chilean imports is less than 1 percent for the E.U., the United States, and Korea.

Another important effect of the FTAs was the elimination of Chilean import tariffs, which likely granted foreign firms access to the Chilean market and increased domestic competition. Between 2002 and 2006, aggregate imports from the FTA partners almost doubled. This increase was smaller than the rise in aggregate exports. In addition to the elimination of import tariffs on goods from the three FTA partners, Chile also reduced import tariffs on goods from other countries. During 1998–2005, the Chilean government gradually, unilaterally reduced import tariffs from 11 percent to 6 percent. This policy was part of the government's economic growth strategy.

The FTAs brought about a bilateral elimination of tariffs. These policies are

late 1990s; China joined the World Trade Organization in December 2001; and Latin American countries saw a period of rapid growth and macroeconomic stability after the Argentinean crisis in 2001. Aggregate exports between 2002 and 2006 increased by 231, 194, and 314 percent for the E.U., the United States, and Korea, respectively. During the same period, exports to the rest of the world increased by 157 percent.

[5]Manufacturing export shares toward the E.U., the United States, and Korea in 2002 were 26.5, 19.9, and 4 percent, respectively.

[6]I exclude 86 HS products (6-digit) that contain the word *copper* or *molybdenum* in the description.

expected to have two main effects on firms and the competitive environment: (i) it creates new export opportunities for domestic firms, and (ii) it opens the domestic market to foreign competition. The evidence discussed above suggests that the FTAs signed by Chile had a big impact on export opportunities of Chilean firms. Although Chile was already open to international trade before the FTAs and the overall level of protection was very low compared to other developing countries, in the empirical analysis I will show that the effect of export tariff cuts on productivity are robust when controlling for the change in imports from abroad.

3 Conceptual Framework

This section discusses the conceptual background that guides my empirical analysis. To simplify the analysis, I focus on one intermediate input industry that uses labor to produce a differentiated good. The output of this industry can be either consumed or used as intermediate input in the production of other goods.[7]

I use a simplified version of Melitz's (2003) model, as discussed in Helpman (2006). Firms face an isoelastic demand function $q(i) = p(i)^{-\sigma}\tilde{A}$, where $p(i)$ is the price charged by firms, and $\sigma > 1$ is the elasticity of substitution between any two varieties sold in the market. $\tilde{A}$ is a measure of market size that depends on three different components ($\tilde{A} \equiv \tilde{A}^h + \tilde{A}^m + \tilde{A}^x$): final domestic consumption $\tilde{A}^h$, domestic intermediate input demand $\tilde{A}^m$, and demand in a foreign market for both final and intermediate consumption $\tilde{A}^x$ (see fig. 2). Following existing trade models, I assume that foreign demand is decreasing in the export tariffs $\tilde{A}^x = (\tau_i^{exp})^{-\sigma} A^x$. Firms must pay τ_i^{exp} in order to deliver a unit of goods in the destination market. Lower tariffs allow firms to reach a larger share of foreign consumers. Intermediate input demand comes from all firms in all other sectors that use output $q(i)$ as an intermediate input. Intermediate demand for good i from industry j can be expressed as a share α_{ij} of its total revenues $\tilde{A}^m = \sum_j \alpha_{ij}\tilde{r}_j$, where $\tilde{r}_j$ is nominal revenues in industry j. Notice that the revenues of any industry j can also be expressed as a function of the export tariff faced by each firm in industry $\tilde{r}_j(\tau_j^{exp})$. This notation clearly shows that the derived demand for intermediate inputs also depends on the export tariff faced by downstream firms in the production chain (see fig. 2).

The market structure is monopolistic competition. Firms differ in productivity. The total cost function is given by $\frac{w}{\varphi_0'} q(i)$, where φ_0' indicates productivity. Firms set the optimal price equal to a constant mark up $(\frac{\sigma}{\sigma-1})$ over the marginal cost. I set the

[7] Flour, for example, is an intermediate good that bakeries purchase to produce bread, but it is also consumed by households for producing baked goods at home.

wage to unity $w = 1$. Profits can be written as $\pi(0) = \varphi_0 \tilde{A}$ (where $\varphi_0 = \frac{\sigma^{-\sigma}}{(\sigma-1)^{1-\sigma}} \varphi'_0$).

Firms can invest and increase their productivity. I follow the literature and assume that upon paying a fixed cost (F^I), firms can increase their productivity to φ_1 and earn profits equal to $\pi(1) = \varphi_1 \tilde{A} - F^I$. In equilibrium, a firm is indifferent between investing or not if

$$\pi(0) = \pi(1) \quad \Rightarrow \quad \varphi_1 - \varphi_0 = \frac{F^I}{\tilde{A}},$$

which is represented by the horizontal solid line in fig. 3, panels (a) and (b). If the gains exceed the costs (above the solid line), firms find it profitable to invest. If, instead, the productivity gains are small relative to the cost (below the $\frac{F^I}{\tilde{A}}$ curve), then no firms find it appealing to invest. When the gains are independent of the initial productivity level φ_0, either all firms invest or none do. Equilibrium outcomes in which only some firms invest in productivity arise if the gains depend on the initial productivity level ($\varphi_1 - \varphi_0 = f(\varphi_0)$).[8] The intersection of the two curves is the productivity ($\overline{\varphi_0}$) of the marginal firm, which is indifferent between investing or not.

Consider now the effect of an increase in market size, $\tilde{A}' > \tilde{A}$. When market size increases, investment becomes profitable for smaller productivity gains (the horizontal line shifts down). This happens because while gains are proportional to revenues, the cost is fixed. A new productivity cutoff for investment ($\overline{\varphi'_0}$) is pinned down. In panel (a), firms with productivity between the two cutoffs now find it profitable to invest. These firms are middle-productivity firms. Also in panel (b), new firms start to invest in productivity, but in this case, they are ex-ante the least productive.

Existing models of international trade focus on the increase in market size generated by new export opportunity, $\frac{\partial \tilde{A}^x}{\partial \tau^{exp}} < 0$. In contrast, this paper examines how derived demand for intermediate inputs can lead to increased productivity among domestic firms. More formally, consider the total differential for the intermediate

[8]Productivity gains can be increasing or decreasing in the initial level of productivity. In panel (a), I plot an increasing gain function following Bustos (2011), which arises when firms invest and improve upon their productivity. For example, they might reorganize their processes or invest in R&D in order to introduce process innovations, as is likely when firms expand their technological frontier. In panel (b), I plot a decreasing gain function following Lileeva and Trefler (2010). This assumption is reasonable when investment in productivity is thought of as the acquisition of new machinery at the forefront of technological innovation.

input demand:

$$\begin{aligned}
\tilde{A^m} &= \sum_j \alpha_{ij}\tilde{r_j}(\tau_j^{exp}) \\
\frac{d\tilde{A^m}}{\tilde{A}} &= \sum_j \frac{\alpha_{ij}\tilde{r_j}}{\tilde{A}} * (-\sigma_{\tau_j^{exp}}^{\tilde{r_j}}) * \frac{d\tau_j^{exp}}{\tau_j^{exp}}. \qquad (1)
\end{aligned}$$

Equation 1 defines the change in derived demand for intermediate inputs as the weighted average change in the export tariff faced by downstream firms. The magnitude of the change depends on three components: the relative importance of downstream industry in the demand for intermediates ($\frac{\alpha_{ij}\tilde{r_j}}{A}$); the elasticity of output to the tariff change ($\sigma_{\tau_j^{exp}}^{\tilde{r_j}}$); and the magnitude of the trade shocks, i.e., the change in export tariffs faced by downstream firms ($\frac{d\tau_j^{exp}}{\tau_j^{exp}}$).

4 Variable Definition and Estimation

4.1 Measuring the derived demand

I measure the increase in the derived demand for intermediate inputs using information on the export tariffs faced by downstream firms and an input-output matrix. The idea is that market size for intermediate input suppliers will increase if, all else equal, downstream firms increase their exports.[9] Formally, let U be an I x J input-output matrix, where I is the number of intermediate inputs used in production and J is the number of output products. Let u_{ij} be an entry in matrix U that represents the value of input i used in the production of product j. The value of the input purchased can be expressed as a share of total output $u_{ij} = \alpha_{ij}y_j$. Total output for good i is equal to A_i, which is the sum of all intermediate usage and final consumption. Finally, let τ_j^e be the export tariff faced by product j. The derived demand for product i, denoted as τ_i^{ie}, can be written as:

$$\tau_i^{ie} = \sum_j \frac{u_{ij}}{A}\tau_j^e = \sum_j \frac{\alpha_{ij}y_j}{A}\tau_j^e, \qquad (2)$$

which is the weighted average export tariff faced by all products that use intermediate i as an input.[10] To understand this, suppose that export tariff τ_j^e falls for some

[9] Amiti and Konings (2007) and Halpern et al. (2011) show that the increase in market size also depends on the elasticity of substitution between domestic and foreign intermediates, since downstream firms can start to source intermediate inputs abroad.

[10] The main difference between eq. (2) and eq. (1) is that the former assumes that the elasticity of output is equal to one for all products. This assumption can introduce attenuation bias in my

product j. The derived demand will increase for those intermediates i used in the production of j (which corresponds to a drop in τ_i^{ie}). The variable τ_i^{ie} can be interpreted as an *indirect export tariff*, meaning that it is a tariff faced by downstream firms.

It is important to stop here and provide some additional intuition about these measures. Focus, for example, on Chilean wine. Chile has become a worldwide competitor in wine production. After the FTAs went into effect, wine experienced the largest drop in export tariffs, mainly due to the high protection of agricultural products applied by the E.U., whose market for wine is among the largest worldwide. Chilean wine producers experienced a huge drop in the export tariff, which helped them enter foreign markets ($\tau_{wine}^e = 25.5$). At the same time, they experienced virtually no change in derived demand: wine is not used as an intermediate input in the production of any other good.[11] Now consider the intermediate inputs used in the production of wine: labels and bottles. Export tariffs on these products dropped by 2.2 and 4.2 percent, respectively, after the FTAs. Both tariff cuts were smaller than the average export tariff cuts. On the contrary, labels had an indirect tariff cut of 2.8 percent, more than twice the average change in the indirect export tariff (equal to 1.1). Producers of bottles, in comparison, experienced an indirect tariff cut of 1.5 percent, almost 50 percent above the average drop in the indirect export tariff.

I build the indirect export tariff using the Chilean symmetric Use-Supply Input-Output matrix for year 1996, the last year it was compiled before the FTAs were introduced. I work with the table for national transactions at basic prices. The matrix includes 36 manufacturing and 11 agriculture and mining sectors.[12]

estimates, which could be interpreted as lower bound estimates. However to my knowledge, such estimates are not available.

[11] Although wine is not used as an intermediate product, the IO table has a positive entry for intermediate usage of wine in the production of wine. The CPC product code 24212 that is used by the INE to contract the IO table includes both wine and grape must (see below and the appendix for data description). I also checked for this in the output and input data. The INE generated two different codes for this CPC product, one ending with 01 to refer only to wine, and one ending with 02 that corresponds with grape must. Almost all output products are recorded using the INE wine-specific code 2421201. In the input dataset, instead, grape must is the most used input. Only a few firms report purchasing wine as an intermediate product.

[12] The matrix is created by the Central Bank of Chile. Further information can be found at `http://www.bcentral.cl/publicaciones/estadisticas/actividad-economica-gasto/aeg06.htm`. Although quite aggregated compared to IO tables available for other developed countries, the classification of industries is very informative about the Chilean economy. First, each of the 17 food manufacturers has its own entry. These firms account for 30 percent of the total. Second, each sector accounts for less than 6 percent of total firms except for the bread industry.

4.2 Productivity estimation

Estimating productivity can be problematic, as pointed out by De Loecker (2011) among others, when real output is measured using aggregate price deflators. In this case, estimated productivity can reflect variation both in technical efficiency and in firm markups and market power. Another possible concern arises when material expenditure is computed using aggregate price deflators. The estimated productivity can reflect input price heterogeneity across firms mainly due to quality differences. In a recent paper, Smeets and Warzynski (2013) show the importance of using firm-specific price deflators: when productivity is estimated using aggregate price deflators, the export premia as well as the productivity gains from trade are largely underestimated.

One of the main advantages of the Chilean data set used in this work is that it allows me to compute plant-specific output and input price deflators and avoid these estimation problems. For each plant in my data, I observe unit values for output produced and intermediate inputs used in production. I follow the methodology used by Eslava et al. (2004) to build plant-specific price indices. Let P_{ipt} and P_{ipt-1} be the prices charged by plant i for product p at times t and $t-1$, respectively. The weighted average of the growth in prices for all individual products is defined as

$$\Delta P_{it} = \sum_{p} \bar{s}_{ipt} \Delta \ln(P_{ipt}),$$

where $\Delta \ln(P_{ipt}) = \ln P_{ipt} - \ln P_{ipt-1}$ and $\bar{s}_{ipt} = \frac{s_{ipt}+s_{ipt-1}}{2}$ (s_{ipt} and s_{ipt-1} are the shares of product p in plant total revenues at time t and $t-1$, respectively). The price indices for each plant are then constructed using the following formula:

$$\ln P_{it} = \ln P_{it-1} + \Delta P_{it},$$

where the price for the reference year is standardized ($P_{i'0} = 100$). The same methodology can be used to construct intermediate input price deflators using information on prices for intermediate input. I compute two plant-specific price indices: one for output $\ln P^{o}_{it}$ and one for intermediate inputs $\ln P^{m}_{it}$.

With these indices, I compute real variables as follows. Real output is defined as $y_{it} = \ln R_{it} - \ln P^{o}_{it}$, where R_{it} is nominal revenues. Intermediate input expenditure is defined as $m_{it} = \ln M_{it} - \ln P^{m}_{it}$, where M_{it} is the nominal intermediate input expenditure. I estimate productivity as a residual of a gross output production function. I follow the Wooldridge (2009) methodology to estimate output elasticities.[13]

[13]See the appendix for a detailed description of the methodology and results.

4.3 Plant-specific Tariffs

I use the information on products' portfolios for each plant to construct plant-specific tariff variables.[14] These tariffs vary across plants within an industry for two reasons. First, plants may produce products with different export tariffs. Second, plants can produce multiple products. For each plant, I define the export tariff as

$$\tau_i^e = \sum_p \omega_{ip} \tau_p^e, \tag{3}$$

where ω_{ip} is the share of product p in total revenues. I also construct a plant-specific indirect export tariff:

$$\tau_i^{ie} = \sum_p \omega_{ip} \tau_p^{ie}. \tag{4}$$

It is important to stress the differences between the two measures. The export tariff is applied to Chilean exports before the FTAs. The indirect export tariff is the export tariff faced by downstream firms that use other firms' output as intermediate inputs in production.

4.4 Estimation Strategy

To establish a link between implementation of the FTAs and firm productivity, I proceed as follows. Consider the following equation:

$$\ln TFPQ_{ijt} = \gamma_0 + \gamma_1 \tau_{ijt}^e + \gamma_2 \tau_{ijt}^{ie} + \delta_{jt} + \delta_i + \eta_{ijt}, \tag{5}$$

where i indexes firms, j industries, and t time. The dependent variable is firm productivity, $TFPQ_{ijt}$. The main variable of interest is τ_{ijt}^{ie}, which is the plant-specific indirect export tariff. Finally, τ_{ijt}^e is the plant export tariff; δ_{jt} is 4-digit industry-time fixed effects, and δ_i is an unobservable time invariant plant fixed effect.

Estimating eq. (5) using OLS has several drawbacks. Tariffs drop to zero after the FTAs go into effect for all firms, introducing serial correlation across observations. Moreover, productivity is likely to be highly serially correlated across time within a firm. The presence of such problems makes estimation of the coefficients with OLS unbiased but will not yield the correct standard errors. Following a solution proposed by Bertrand et al. (2004), which they show performed well in their Monte Carlo study, I ignore time series information. Instead, I consider one year

[14]Only a few works use firm-specific tariffs to identify the impact of FTAs. Among others, see Lileeva and Trefler (2010).

before the FTAs (2002) and one year *after* (2006). Finally, I estimate eq. (5) using the differences to eliminate the unobservable plant fixed effect. The final estimation equation is

$$\Delta \ln TFPQ_{ij} = \gamma_1 \Delta\tau_{ij}^{e} + \gamma_2 \Delta\tau_{ij}^{ie} + \delta_j + \Delta\eta_{ij}, \tag{6}$$

where the change in firms productivity is:

$$\Delta \ln TFPQ_{ij} = \frac{1}{4}(\ln TFPQ_{ij06} - \ln TFPQ_{ij02}).$$

I argued in section (2) that the main variables of interest (τ_{ij}^{e} and τ_{ij}^{ie}) are likely to be uncorrelated with plant unobserved heterogeneity and the error term η_{ij}. The variation in tariffs reflects the implementation of the FTAs that is exogenous to firms; thus I can use OLS. The equation also includes industry fixed effects δ_j (at four-digit ISIC rev 3), which is possible because tariffs vary at the firm level. The variability I will exploit to identify the parameters is therefore within firms. The specification is parsimonious, as it includes only the tariff variables and the industry fixed effects, but it is sufficient to identify the effect of an increase in derived demand and the new export opportunity generated by the FTAs.

The presence of industry fixed effects, δ_j, will absorb several confounding factors that might lead to biased estimates. The first is an increase in competition in the domestic market due to the elimination of output tariffs imposed by Chile on imports. An increase in domestic competition can lead to a reduction of production inefficiencies (Rodrik, 1988). Chilean tariffs were a flat 7 percent across all industries before the FTAs because of the single tariff policy rate. Including δ_j in the regression is sufficient to control for the change in the output tariff. A second confounding factor could be the effect of a fall in import tariffs on intermediate inputs, which allowed firms to source high-quality inputs abroad. Increases in productivity can arise through learning, variety, or quality (Amiti and Konings, 2007; Halpern et al., 2011). Again δ_j is sufficient to control for this mechanism because the level of Chilean tariffs on imports was flat across industries before the FTAs. Finally, even if the variation in tariffs is exogenous, the level of the change reflects the protection scheme applied by partners, i.e., it is correlated with industry characteristics. Thus, the presence of industry fixed effects controls for the initial differences in tariff levels across industries.

4.5 Data Description and Summary Statistics

Plant-level information comes from the manufacturing survey *Encuesta Nacional Industrial Annual* (ENIA) conducted each year by the Chilean Statistical Agency (INE). The survey, which plants are required by law to fill out, collects information on the universe of plants with 10 or more employees. Data cover the period from 2001 to 2007, with an average of $5,000$ observations per year. Chilean plant data are considered of high quality and have been widely used in the literature (Pavcnik, 2002; Petrin and Levinsohn, 2003; Fernandes and Paunov, 2012; Ackerberg et al., 2006) with only minor data cleaning needed.[15] In addition to information such as employment, revenues, and capital, for each plant I observe *output* produced and intermediate *inputs* used in production at the detailed product level. For each output, I have data on quantities (produced and sold), total revenues, and quantities exported. For each input, I have data on quantities (purchased and used in production), total expenditures, and quantities imported. I use information on outputs and inputs at the product level to build *plant-specific* tariff and price indices for revenues and intermediate input expenditures.

Figure 4 shows the export market participation of Chilean firms along the extensive and the intensive margins. The number of exporting firms increases from 19.7 percent in 2002 to 22.1 percent in 2006. The average export share jumps from 6.4 percent to 7.8 percent in 2006.

In the empirical analysis, I use two waves of survey data: 2002 and 2006, the year before the first FTA went into effect and one year after the last went into force. I use these two years for several reasons. First, I did not use 2001 data because several changes were made to the survey that year, which could have affected the results and the response rate. In addition, the Argentinian financial crisis reached its peak that year and could have affected Chilean firms. I also exclude the three years between 2002 and 2006 because the FTAs went into force at varying times during this period and their effects could take time to be felt. Finally, I exclude 2007 because in this year two other important FTAs between Chile and China and Japan entered into force. My final sample includes only firms that I observe in both periods, because I am interested in within-firm productivity dynamics.

Table 2 presents the means for several key variables for the $3,340$ firms in my final sample. Means are reported separately for the years before and after the FTAs, with the standard errors in parentheses. The average firm size increases slightly from 3.52 to 3.58 (measured as log employment in efficiency units). The log of real output, the value added per worker, and other variables exhibit similar patterns. The log

[15]See the appendix for a detailed description of data cleaning.

investment per capita jumps to 5.92 in 2006 from 5.79 in 2002. Neither the number of multi-product firms nor the overall number of products varies, but the number of exported products slightly increases. The last row reports average productivity, which rises from 1.49 to 1.51.

5 Tariff Cuts and Productivity Growth

Table 3 presents the results of the OLS regressions of (6) that explore the relationship between tariff cuts and the increase in productivity. Column 1 shows that a decrease of export tariffs in downstream industries increases productivity among input suppliers. The coefficient of the indirect export tariffs is negative (-1.3) and significant, implying that the average drop in the indirect export tariff increases productivity by 1.44 percent. In column 2, I add firm-level controls in the initial year (2002), such as size measured by the number of workers, dummies for exporting firms, importing firms, and foreign-owned firms. The point estimate is not significantly affected by their inclusion. Columns 3 and 4 include only the export tariff, and the point estimates remain negative and significant. The implied increase in productivity is about 1.17 percent ($-0.222 * 5.2$). Although the extant literature sometimes has struggled to find a positive effect between exports and productivity (for a review of the literature see Bernard et al. (2011)), my estimates show that productivity increases for Chilean firms directly affected by the FTAs. The last two columns assess the robustness of the baseline results when both tariffs are added contemporaneously to the regression. The coefficients remain negative and significant. The point estimates are similar to the specifications when the tariffs are included separately. The implied increase in productivity is 1.40 percent for the indirect effect and approximately 1.03 percent for the direct effect.

To show that the tariff cuts capture different demand shocks, I classify industries as either comparative advantage (CA) or disadvantage (CD) industries and estimate (6) separately.[16] Chilean exports are highly concentrated in a few products: salmon, wine, avocados, pulp wood, and copper.[17] In CA industries, the share of exporting firms is three times larger than the rest of the industries (about 45 percent vs. 15 percent). The most exported Chilean products are either final consumption goods (salmon, wine, and avocados), or they are intermediate inputs not used in the production of any other exported products (pulp wood and copper). Table 4, columns 1 and 2 shows the results with the sample of CD industries and CA

[16] I use Baci-Cepii data to compute the Balassa revealed comparative advantage index in 2002.

[17] These products account for 88 percent of manufacturing exports.

industries, respectively. In CD industries, the coefficient of indirect export tariff is negative and significant (-1.353), implying an increase in productivity of 1.49 percent. The coefficient of the direct export tariff is positive but not significant, meaning that the decrease in the export tariff does not boost firm productivity in CD industries. Column 2 shows the effect of tariff cuts on CA industries. The coefficient on the indirect export tariff is negative but insignificant, while the drop in the export tariff increases firm productivity by 1.75 percent. The Chilean export market is structured such that in CA industries I find that the decrease in the export tariff positively affects firm productivity; however, the derived demand plays no role.

In column 3 and 4, I split the sample according to the share of products that require relationship-specific investment. Borrowing from Nunn (2007), for each industry, I compute the average number of products not sold on an organized exchange using the Rauch (1999) classification. When an intermediate input requires specific investment, the relationship between buyers and sellers is stronger and long lasting. The increase in the derived demand should be more important in industries that produce complex intermediate inputs because of the lower degree of substitutability. Column 3 shows the results for industries that produce more differentiated goods. I use the median value to split the sample. The indirect export tariff is negative and significant, suggesting a productivity increase of 2.58 percent. The coefficient for firms that operate in industries with a share of differentiated products below the median (column 4) is negative and insignificant. The estimated coefficient on the direct export tariff moves from being insignificant for differentiated goods, to being significant, implying an increase in productivity of 1.48 percent.

The baseline results show that the increase in the derived demand for intermediate inputs boosts firm productivity among domestic suppliers. Both sample splits show that the export tariff cuts and the increase in derived demand are different demand shocks that hit different types of firms. Surprisingly, even though the shocks are very different, I find that the magnitude of the increase in productivity is almost the same. The indirect export tariff depends on the input-output linkages between firms and the tariffs faced by downstream exporting firms. The export tariff, instead, depends on the protection scheme applied by the partner countries. Because of the structure of its exports, Chile is an ideal case study for examining the implications of such differences. Previous works examining the relationship between exports and productivity have focused mainly on exporting firms, which tend to increase their productivity in response to an export shock. Because Chilean exports are concentrated in a few well-defined industries, I can split the sample and further analyze how export shocks shape firms' productivity. These are firms affected *di-*

rectly by the export shocks. This paper contributes to the literature by showing that productivity also increases for firms that do not export but that are connected to exporting firms through input-output linkages. These firms are *indirectly* affected by the export shock.

5.1 Heterogenous Effects across Initial Productivity Distribution

The conceptual background shows that export tariff cuts can have heterogenous effects on productivity. In table 5, I divide firms within each four-digit industry by initial productivity. I estimate the effect of the change in the derived demand on each quartile of the distribution using the following equation:

$$\Delta TFPQ_{ijt} = \sum_{q=1}^{4} \gamma_q^{ie} \left(\Delta\tau_{ijt}^{e} * Q_{ij}^{q}\right) + \sum_{q=2}^{4} \delta_q Q_{ij}^{q} + \delta_j + \Delta\eta_{ijt}, \tag{7}$$

where q indexes each of the four quartiles of the productivity distribution and Q_{ij}^q are dummy variables equal to one when firms belong to the quartile q. Column 1 shows the OLS results of (7). The coefficient of the indirect export tariff is two to three times larger in the first two quartiles of the initial firm productivity distribution. The point estimates are -1.493 and -0.811, respectively. The average fall in the indirect export tariff increases productivity by 1.65 and 0.89 percent. Column 2 includes the vector of firm-level controls. The point estimate increases slightly, but the overall picture remains unaltered. In columns 3 and 4, I include only the interactions between the quartile of the productivity distribution and the export tariff. The stronger effect is on firms in the first quartile of the initial productivity distribution. The coefficient is negative (-0.291) and significant, and the point estimates are at least 50 percent larger than those on the other quartiles. Productivity increases on average by 1.52 for firms in the first quartile. In the last two columns, I add the indirect and the direct export tariff contemporaneously to (7), and I estimate it with OLS. The coefficients of the indirect export tariff remain negative and significant for the first and second quartile of the initial productivity distribution. The estimated coefficient for export tariff continues to be negative and significant for the first quartile. The point estimates are remarkably similar to the specifications when the effects are analyzed separately. The results suggest that only ex-ante less productive firms increase productivity after the implementation of the FTAs.

5.2 Investment in Machinery and Skill Premium

The goal of this section is to investigate why an increase in demand should translate into higher productivity for intermediate input suppliers. The conceptual framework emphasizes the increase in output induced by the tariff cuts and the increase in productivity for those firms that pay the fixed cost of investing and enhance productivity. Chilean producers of bottles, for example, could have experienced an increase in their sales after Chilean wine started to be exported in foreign market after the implementation of the FTAs. An increase in firm revenues, might have induced bottle producers to invest in new machinery and equipment. If the new machineries embed better technologies, this can be partly responsible for the documented increase in productivity.[18] Aggregate and plant-level data show patterns that are consistent with this mechanism; indeed, output and investments increase substantially after the FTAs. In plant-level data, aggregate nominal sales increase by 52.8 percent between 2002 and 2006, while the average plant sales increase by 18.6 percent. The investment- to-GDP ratio soars by 12 percentage points after 2004 (Di Bella and Cerisola (2009)). In the plant-level data, about 55 percent of the firms invest in machinery and equipment and the average value of investment increases by 23% between 2002 and 2006.

The first two columns of table 6 show the OLS estimates of (6) using as the dependent variable the log change in machinery and equipment capital stock.[19] The coefficient of the indirect export tariff is negative (-1.188) and significant. The point estimate implies that the average reduction in the indirect export tariff increases machinery capital stock by 0.013 log points. The coefficient of the export tariff is close to zero and statistically insignificant. In column 2, I add firm-level controls. The coefficient of the indirect export tariff slightly decreases to -0.985, and the estimates are less precise. The point estimate of the export tariff becomes negative, but remains non-significant. Taken altogether, the results suggest that the increase in the derived demand induces firms to accumulate machinery capital stock. The results for the direct export tariff are less clear-cut. The point estimates pass from being nearly equal to zero to being negative, although in both cases none of the coefficients is statistically different from zero.

When the new machineries embed advanced technologies, skilled workers are of-

[18]Sakellaris and Wilson (2004), taking into account differences in capital vintages, use U.S. plant-level data and estimate that capital efficiency increases between 8 and 17 percent per year.

[19]I also estimate (6) using the change in real output as the main dependent variable. I find that both indirect and direct export tariff cuts have a significant effect on output. The average indirect export tariff cuts increase real output by 1.3%. The average drop in the export tariff increases real output by 1.5%.

ten required to operate them. The complementarity between technology and the skill level of the workforce can lead to an increase in the wage skill premium (Acemoglu, 1998). Several papers have linked international trade to the increase in wage inequality in developing countries (Goldberg and Pavcnik, 2007). Skilled workers can also have a direct effect on productivity that is independent of the capital stock. In the last columns of table 6, I test this hypothesis. For each plant, I observe total wage bills and hours worked for eight categories of employees that I group into skilled and unskilled workers.[20] The average wage per hour of skilled workers is three times larger than that of unskilled workers. Within a firm, the average skill premium is about .54 log points.

Columns 3 and 4 report the OLS estimation of (6) using as the dependent variable the log change in the wage per hour of skilled workers. The estimated coefficient of the indirect export tariff is negative (-1.263) and significant. The average increase in the derived demand increases the wages of skilled workers by 1.3%. The results are robust when I add to the regression the vector of firm-level controls (column 4). The increase in the wage of skilled workers is not explained by the change in the direct export tariff. The estimated coefficients are positive, close to zero, and statistically insignificant. In columns 5 and 6, I report the estimates of the change in wage per hour of unskilled workers. I do not find any evidence of the impact of the indirect and direct export tariff on the wage of unskilled workers.

Table 7 shows that the accumulation of capital and the change in the skill premium is heterogenous across firms. In columns 1 and 2, I estimate (7) using OLS by contemporaneously adding the interactions of the quartiles of the initial productivity distribution with the indirect and the direct export tariff. The coefficients of the reduction of the indirect export tariff are always negative. The point estimates are larger for the second quartile of the initial productivity distribution and precisely estimated. In table 5, I show that these plants also experience an increase in productivity. In columns 3 to 6, I estimate the effect on the wage per hour of skilled and unskilled workers. Column 3 and 4 show that the wage of skilled workers increases for plants in all quartiles. The point estimates are larger for plants in the second quartiles. The last two columns show the results for the wage of unskilled workers. All estimated coefficients are positive. The point estimate for the plants in the fourth quartile is 1.469 and statistically significant, implying that the average wage of unskilled workers decreases by 0.162 log points. The estimates of the export

[20]The plant-level data include employee information for several categories of workers. I include in the skilled workers category executives, skilled production workers, white collar workers, and sales agents. Unskilled workers are defined as unskilled production workers and auxiliaries workers not directly employed in the production process.

tariffs suggest that capital accumulation and the increase in the skill premium are not directly affected by the implementation of the FTAs.

6 Robustness of the Baseline Results

6.1 Controlling for Import Competition

The entry into force of the FTAs decreased the tariff Chile applied to its imports. Output and input tariffs can affect firms in two different ways. They can have a pro-competitive effect by increasing the number of foreign firms selling their products in the domestic market. Tariff cuts can also push firms to source intermediate inputs abroad. It is possible that part of the increase in productivity that I have documented could be due to import tariff cuts and not to the export shock. I have already argued that the main effect of the FTAs was generating new export opportunities for Chilean firms. Unfortunately, I cannot add the change in output and input tariffs to my main specification, because Chile was applying a single import tariff rate during my sample period. All tariffs dropped from 7 percent in 2002 to zero. Although the tariff cuts were of equal magnitude across industries, the effect could have been heterogeneous across industries. The presence of industry fixed effects in the baseline specification should control for this heterogeneity.

Nonetheless, I perform two additional exercises to test the robustness of my results to the change in imports. Table 8 shows the results. In the first two columns, I split the industries below and above the median change in aggregate import flows.[21] If the results were driven by a pro-competitive effect, then I expect to find a significant coefficient for tariffs only in those industries that were most affected by the increase in imports from abroad (those above the median). The increase in the derived demand has a statistically significant impact on firm productivity in industries with smaller changes in imports. The point estimates are positive for industries above the median, but the estimates are less precise. The increase in foreign competition in the domestic market, measured as the change in aggregate import flows, does not seem to be the main driver behind the documented increase in productivity.

My second robustness test controls for changes in imports of intermediate input products. For each industry, I compute the share of importing firms before the FTAs

[21] I report the results for changes in import flows from the E.U., the United States, and Korea, because these are the countries affected by the tariff elimination. I also repeat the exercise considering the imports from other countries, because during this period Chilean import tariffs dropped by 2 percent. Finally, I also consider total imports, and the results are identical.

and then split the industries below and above the median share. I consider the share of importing firms measured ex ante, because this proportion remains fairly constant at the industry level. Columns 3 and 4 of Table (8) show the results. The indirect export tariff is always negative. The effect is larger for firms in industries with a low share of importing firms. This is consistent with the fact that these firms are the ones with ex-ante lower productivity. Both exercises provide some empirical evidence that import tariff cuts following implementation of the FTAs was not the main driver of the observed productivity gains.

6.2 Alternative Productivity Measures

The results are robust across different productivity measures. In the first column of Table (9), I use the gross output production function specification and investment to construct the proxy for unobservable productivity, following the two-step estimation procedure proposed by Ackerberg et al. (2006). In the second column, I use the approach described in the previous section (Wooldridge, 2009) but with a value-added production function. Finally, in the last two columns, I consider the change in labor productivity measured using the change in real output per worker and the real value added per worker, respectively. The general pattern remains unchanged. The results of the first column are almost identical to the baseline specification. The point estimates using a value-added production function, as expected, are bigger with respect to TFPQ measured using the gross output specification. Productivity almost doubles in response to the increase in the derived demand and the export tariff cut. The increase in output per worker caused by an increase in derived demand almost mimics the productivity gains (-1.244), but the direct effect is smaller and not significant (-0.143). The last column shows the result for labor productivity. Again, the derived demand shock has a positive effect on firms' labor productivity, increasing it by 2.77 percent.

6.3 Alternative Tariff Measures

The indirect export tariff used in Tables (3)–(9) is calculated using eq. (4) and the 1996 IO table, the last year for which the matrix is available before the FTAs. One possible concern is that after several years of economic slowdown and the 2000 Argentinean crisis, this table might not be representative of the Chilean economy in 2002. For robustness, I compute the indirect export tariff using the 2003 IO table. This year's matrix is likely to be partly affected by the implementation of the E.U. FTA, but it can show that the results are not sensitive to the use of the 1996 IO table. The second column of Table (10) shows that the main results remain unchanged when using this alternative measure. The indirect export tariff is negative and significant, and the point estimates are larger than in the baseline regression (reported in column 1 for reference), implying an increase in productivity of 2.23 percent ($-2.017 * 0.9$). The coefficient of the direct export tariff remains identical.

I aggregate the tariffs at the plant level using sales shares measured before the FTAs as weights, which could bias my results by introducing some correlation with unobservable firm characteristics. In Table (10), column 3 shows that using unweighted tariffs does not alter the main results. Both coefficients, although smaller, remain negative. The point estimate of the derived demand is comparable to the baseline specification both in magnitude and significance. The direct effect, however, is smaller and insignificant.

Column 4 computes the indirect export tariff using as weights the total output sold as intermediates ($\tilde{\tau}_i^{ie} = \sum_j \tau_j^e \frac{u_{ij}}{A^m}$). The coefficient on the indirect export tariff remains negative and significant. The point estimate is -0.432, and the implied increase in productivity is 3.80 percent. The effect is larger because this measure does not take into account that there are industries that sell a small fraction of their output as intermediates. Formally, the two measures are linked by the following relation:

$$\tau_i^{ie} = \sum_j \tau_j^e \frac{u_{ij}}{A^t} = \frac{A^m}{A^t} \sum_j \tau_j^e \frac{u_{ij}}{A^m} = \frac{A^m}{A^t} \tilde{\tau}_i^{ie}. \tag{8}$$

When all output is sold as intermediates, the two measures are identical. In contrast, when only a fraction of the output is sold as intermediate inputs, no matter the value of $\tilde{\tau}_i^{ie}$, the value τ_i^{ie} will always be close to zero. When measuring the impact of the derived demand, it would be misleading not to account for how much of the product is sold as an intermediate input. For example, imagine two different industries (say A and B) that sell their output to a third industry (say C). Industry C faces an export tariff of $\tau^x = 10\%$. The main difference between A and B is that while A sells all of its output as an intermediate to C, industry B sells 50 percent of its output as an intermediate to C and the rest to final consumers. In this simplified example, $\tilde{\tau}_i^{ie}$ is the same for industry A and B, while τ_i^{ie} for industry A is twice as large as that of B. The reason is that the increase in derived demand for industry A is much larger than that of industry B.

7 Aggregate Implications

In table 11, I quantify the size of the productivity gains. To avoid double counting problems, I compute the aggregate implication using the sample split between comparative advantage and disadvantage industries presented in table 4.[22] Column 1 reports the estimated productivity gains generated by the indirect and direct export tariff cuts. These numbers correspond to the estimated coefficients in table 4, columns 1 and 2, multiplied by the average tariff cuts, and by 4 to convert annual productivity changes into 2002–2006 changes ($\hat{\beta} \cdot \bar{\Delta\tau} \cdot 4$). The aggregate productivity growth can be calculated by multiplying the average effect by the share of output for comparative advantage and disadvantage industries reported in column 2. The average fall in the indirect export tariff increases aggregate productivity by 2.6 percent (reported in column 3 of table 11). This effect corresponds to the implied increase in productivity (6.0 percent) multiplied by the share of output in 2006 of comparative disadvantage industries (42.8 percent). The effect of the export tariff cut is larger. Average productivity rises by 7 percent in comparative advantage industries. These plants accounted for 57.2 percent of output in 2006; therefore, aggregate productivity increases by 4.0 percent.

The implementation of the FTAs affected aggregate productivity in different ways. Several studies analyzed both theoretically and empirically the effect of trade liberalizations on exit and reallocation. Exit increases aggregate productivity because exiting firms are, on average, the least productive. Exporters are more productive than non-exporters; therefore, when exporters increase their sales in foreign markets, they increase market shares, and aggregate productivity grows. I quantify these additional effects using the aggregate productivity decomposition proposed by Melitz and Polanec (2014).[23] The exit of the least productive firms increased aggregate productivity by 0.1 percent. Reallocation of resources among surviving firms increased productivity by 4.8 percent.

The sum of all these effects is ($2.6+4.0+0.1+4.8 = 11.4$ percent) over the period 2002–2006. The indirect export tariff cuts accounted for 22.5 percent of aggregate

[22] I exclude all plants belonging to the 2-digit sector 27 (basic metal industry), which corresponds to the copper industry. The total share of copper industry in aggregate output in 2006 is more than 40 percent, while the number of plants is less than 5 percent. Output shares are used to compute aggregate productivity index from plant data, therefore, any aggregate productivity decomposition including the copper industry would reflect changes in this industry rather than in the economy overall.

[23] Melitz and Polanec (2014) propose an extension of the Olley and Pakes (1996) decomposition that accounts for entry and exit. This decomposition reduces the biases of other decomposition methods such as that of Foster et al. (2008) that are widely used in the literature. I compute the aggregate decomposition using all plants that I observe in 2002 or 2006. I aggregate plant TFPQ using as weights the real revenues shares.

productivity growth. This is one of the most valuable results of my paper, and despite its importance, this is the first attempt to quantify it. The export tariff cuts accounted for 35.1 percent of aggregate productivity growth. This effect is almost double the indirect effects in aggregate terms, reflecting the fact that exporters are larger, and therefore account for a substantial share of total output. The direct effect of export tariff cuts on firms' productivity confirms previous findings in the literature. Reallocation is another important driver of aggregate productivity, accounting for 41.6 percent. Finally, in Chile during the period under study, the contribution of exit is quite limited. This result might be due to the asymmetric effect of the FTAs on the Chilean economy. The bilateral elimination of tariffs created many export opportunities for Chilean firms in the E.U., U.S., and South Korean markets, while it had a small impact on the competition from foreign firms in domestic markets.

8 Conclusion

In this paper, I examine how export tariff cuts in downstream industries affect productivity of domestic input suppliers. To identify this effect, I exploit the implementation of FTAs between Chile and three foreign markets: the E.U., the US, and the Republic of Korea. I measure the indirect export tariffs as the average export tariff faced by downstream industries, using as weights the sales share in the total output that goes to that particular industry. Using a difference-in-difference identification strategy that exploits differential tariff changes across firms within four-digit industries, I find that the drop in the indirect export tariff increases firm productivity. This finding is consistent with a simple model in which an increase in revenues makes investment in productivity more profitable.

The results of this paper contribute to the growing literature attempting to assess the amplification effects of input-output linkages of trade shocks. These effects have been found to be sizeable for other countries in regard to welfare and employment. This is the first paper to study the indirect effect of export tariff cuts on productivity using detailed plant-level data.

A simple quantification exercise shows that the decrease in the export tariff of downstream industries accounts for 22.5 percent of aggregate productivity growth. The aggregate implications of my finding are non-trivial, even though I document that others mechanisms widely studied in this literature—namely, reallocation and the direct effect on exporters—explain a large part of the productivity gains (41.6 and 35.1 percent, respectively). I investigate the possible underlying channels of the documented productivity gains. I find that the indirect export tariff cuts increase firms' investment in new machinery and the wage per hour of skilled workers. They have no effect, however, on the wage of unskilled workers. These additional findings suggest that the increase in derived demand for intermediates, possibly generated by the export tariff cuts in downstream industries, allows firms to invest in machinery that embodies more advanced technology and requires skilled workers to operate.

Since the mid-1990s, the number of regional trade agreements around the world has increased enormously, and currently the European Union and the United States are debating the possibility of implementing transatlantic trade agreements. Understanding and accounting for the effects of trade agreements on firm productivity can contribute to this current public debate. Policymakers often struggle when attempting to discuss the benefits of implementing these agreements. Stronger empirical evidence about the effects of trade agreements can help policymakers, who often face political discontent among groups of workers and industries that fear they will lose from these agreements. This study contributes to this debate by establishing a new channel for firm productivity growth and making an additional step toward understanding the effects of trade agreements on firms' productivity. More research is still needed to show how firms adjust prices and markups and how these efficiency gains are transmitted to consumers.

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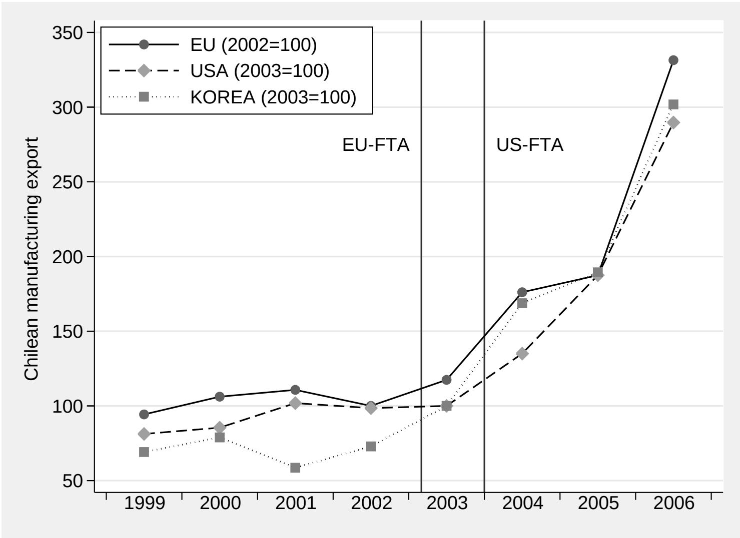
Figures and Tables

Figure 1: Aggregate Export Flows



Notes: Data from Baci-Cepii. I aggregate export flows across all HS 6-digit products. Index numbers equal 100 the year before the entry into force of the FTAs: 2002 for the EU and 2003 for the United States and Korea.

Figure 2: Input-Output Linkages

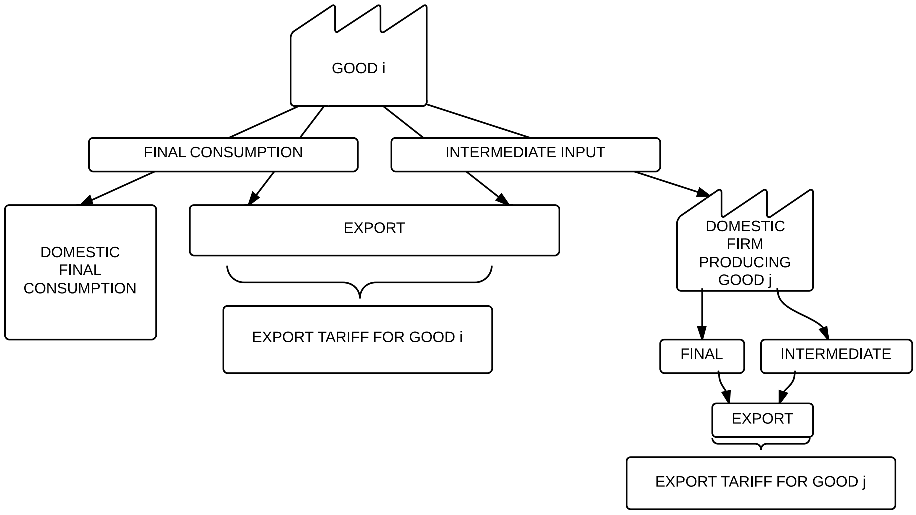


Figure 3: Optimal Investment Decision

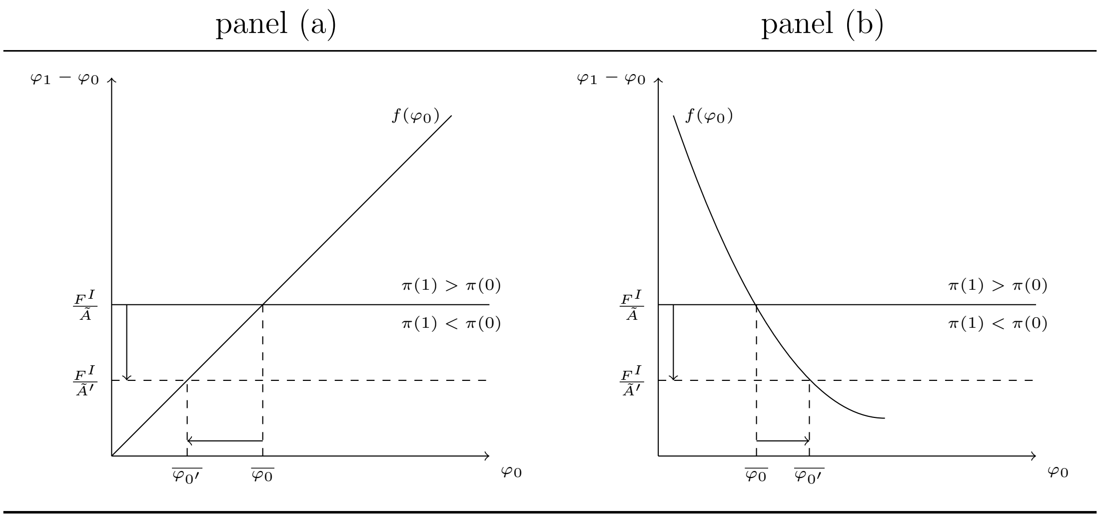
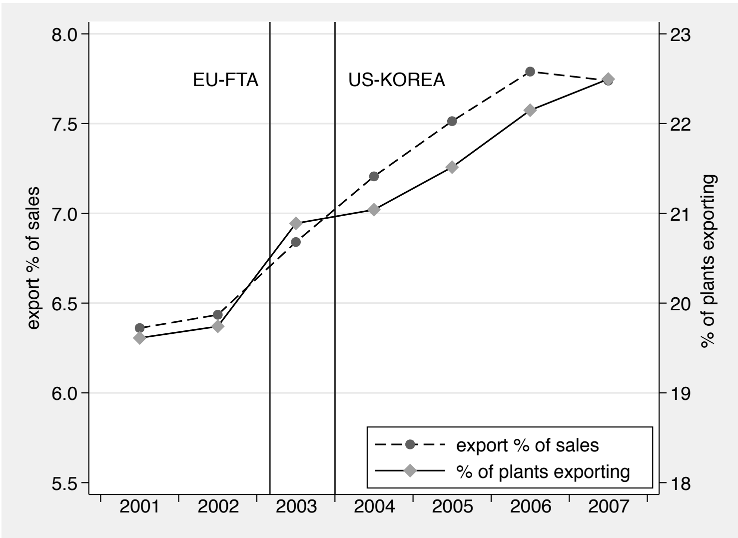


Figure 4: Extensive and Intensive Margins of Trade



Notes: Data from ENIA. The solid vertical lines represent the entry into force of the FTAs. The export percentage of sales is the average across firms, calculated as (total exports)/(total sales). Plants with positive exports are classified as exporting.

Table 1: Export Tariff for Selected Industries in 2002

Industry description	Tariff
Panel (a) : five industries with highest tariff cuts	
Manufacture of wines	24.7
Manufacture of starches and starch products	18.6
Processing and preserving of fruit and vegetables	15.1
Manufacture of knitted and crocheted fabrics and articles	12.3
Manufacture of wearing apparel, except fur apparel	11.7
Panel (b) : five industries with lowest tariff cuts	
Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy	0.1
Manufacture of coke oven products	0.1
Publishing of books, brochures, musical books, and other publications	0.0
Publishing of newspapers, journals, and periodicals	0.0
Manufacture of machinery for mining, quarrying, and construction	0.0

Notes: Tariffs are aggregated at the industry level according to the 4-digit ISIC Rev.3 classification.

Table 2: Means of Key Variables

Variable description	2002	2006
log (employment)	3.525	3.584
	(1.119)	(1.193)
log (real output)	13.348	13.387
	(1.703)	(1.829)
log (value added per worker)	8.616	8.630
	(1.090)	(1.191)
log (capital per worker)	8.678	8.698
	(1.515)	(.535)
log (investment per worker)	5.796	5.924
	(1.968)	(1.943)
% multi-product firms	0.492	0.492
	(0.500)	(0.500)
number of products	2.220	2.221
	(1.889)	(1.887)
number of exported products	0.304	0.318
	(0.779)	(0.805)
TFPQ	1.493	1.511
	(1.314)	(1.360)

Notes: The table uses the final sample of ENIA firms used in the empirical analysis, those that are present both in 2002 and 2006 after data cleaning. Multi-product refers to firms that report more than one output. Number of products is the overall number of outputs reported by the firms. Number of exported products refers only to products with positive exports. Standard errors are reported in parentheses.

Table 3: Tariff Cuts and Productivity Growth

Dependent Variable: Change in log TFPQ						
$\Delta\tau_{it}^{ie}$	-1.302**	-1.369**			-1.199**	-1.266**
	[0.515]	[0.520]			[0.526]	[0.534]
$\Delta\tau_{it}^{e}$			-0.222**	-0.225**	-0.195*	-0.196*
			[0.109]	[0.110]	[0.113]	[0.116]
Firm Controls		yes		yes		yes
Implied change in TFPQ						
$\Delta\tau_{it}^{ie}$	1.44	1.52			1.33	1.40
$\Delta\tau_{it}^{e}$			1.17	1.18	1.02	1.03
R^2	0.042	0.044	0.041	0.043	0.043	0.045
Observations	3340	3340	3340	3340	3340	3340

Notes: The dependent variable is the log change in firm productivity. All regressions include industry fixed effects. Firm controls include the log of employment in efficiency units, and dummies for exporting, importing, and foreign-owned firms measured in 2002. The implied change in productivity is the estimated coefficient in the above panel multiplied by the corresponding mean tariff cuts ($\Delta\tau_{it}^{ie} = 1.1$ and $\Delta\tau_{it}^{e} = 5.2$). Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 4: Tariff Cuts and Industry Characteristics

Dependent Variable: Change in log TFPQ				
	Comparative Advantage		Differentiated Industries	
	CD	CA	Above	Below
$\Delta\tau_{it}^{ie}$	-1.353***	-0.929	-2.333***	-0.920
	[0.503]	[1.333]	[0.845]	[0.617]
$\Delta\tau_{it}^{e}$	0.0258	-0.334**	0.0778	-0.283**
	[0.218]	[0.142]	[0.210]	[0.140]
R^2	0.0480	0.0285	0.0417	0.0481
Observations	2172	1168	1663	1677

Notes: The dependent variable is the log change in firm productivity. All regressions include industry fixed effects, log employment, and dummies for exporting, importing, and foreign-owned firms measured in 2002. Comparative advantage (CA) and comparative disadvantage (CD) industries are defined using the Balassa index. For each industry, I divide the share of exports in a certain industry in Chile by the same share calculated using world trade flows. Due to the limited number of industries with a Balassa index greater than one, I use 0.5 as the cutoff. The results are robust to using different thresholds. In the last two columns, industries are divided according the the median share of differentiated goods at the industry level, measured as the share of differentiated products according to the Rauch (1999) classification. Standard errors are in brackets. Robust standard errors are given in the first two columns due to the limited number of clusters in column 3. Clustered standard errors are presented in the last two columns. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 5: Productivity Growth by Quartile of the Productivity Distribution

Dependent Variable: Change in log TFPQ						
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{it}^{ie}$ x						
first quartile	-1.493***	-1.592***			-1.367**	-1.466***
	[0.530]	[0.523]			[0.521]	[0.521]
second quartile	-0.811*	-0.903**			-0.710*	-0.803*
	[0.436]	[0.440]			[0.420]	[0.430]
third quartile	-0.588	-0.686			-0.512	-0.609
	[0.584]	[0.578]			[0.578]	[0.573]
fourth quartile	-0.664	-0.738			-0.625	-0.693
	[0.479]	[0.482]			[0.491]	[0.495]
$\Delta\tau_{it}^{e}$ x						
first quartile			-0.291**	-0.290**	-0.259*	-0.256*
			[0.146]	[0.139]	[0.145]	[0.140]
second quartile			-0.194	-0.193	-0.187	-0.184
			[0.133]	[0.126]	[0.129]	[0.124]
third quartile			-0.142	-0.142	-0.146	-0.144
			[0.110]	[0.111]	[0.106]	[0.107]
fourth quartile			-0.0614	-0.0711	-0.0606	-0.0701
			[0.0937]	[0.0898]	[0.0959]	[0.0922]
Firm Controls		yes		yes		yes
R^2	0.154	0.158	0.153	0.157	0.155	0.159
Obs.	3339	3339	3339	3339	3339	3339

Notes: The dependent variable is the log change in firm productivity. Firms are divided into quartiles of the within industry productivity distribution in the initial year (2002). All regressions include industry fixed effects. Firm controls include the log of employment in efficiency units; dummies for exporting, importing, and foreign-owned firms; and dummies for the second, third, and fourth quartile of the productivity distribution in 2002. Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 6: Investment and Skill Premium

	Δ Investment		Δ Skill Wage		Δ Unskill wage	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{it}^{ie}$	-1.188*	-0.985	-1.263**	-1.269**	0.940	0.932
	[0.645]	[0.618]	[0.567]	[0.568]	[0.615]	[0.612]
$\Delta\tau_{it}^{e}$	0.00180	-0.0134	0.0603	0.0578	0.0777	0.0752
	[0.128]	[0.132]	[0.186]	[0.185]	[0.160]	[0.158]
Firm Controls		yes		yes		yes
R^2	0.056	0.076	0.030	0.033	0.037	0.040
Observation	3337	3337	3094	3094	2641	2641

Notes: The dependent variables are reported at the top of the columns. Δ investment is the log change in machinery capital stock between 2006 and 2002. Δ skill wage corresponds to the log change in wage per hour of skilled workers (executives, skilled production workers, white-collars workers, and sales agents). Δ unskill wage is to the log change in wage per hour of production workers, and auxiliaries workers not directly employed in the production process. All regressions include industry fixed effects. Firms controls include the log of employment in efficiency units, and dummies for exporting, importing, and foreign-owned firms measured in 2002. Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 7: Investment and Skill Premium by Quartile of the Productivity Distribution

	Δ Investment		Δ Skill Wage		Δ Unskill wage	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{it}^{ie}$ x						
first quartile	-1.138*	-0.920	-1.196*	-1.228**	0.860	0.822
	[0.679]	[0.696]	[0.618]	[0.613]	[0.627]	[0.626]
second quartile	-2.001***	-1.851**	-1.458**	-1.498**	0.963	0.936
	[0.735]	[0.715]	[0.596]	[0.606]	[0.705]	[0.695]
third quartile	-1.017	-0.836	-0.981*	-0.994*	0.636	0.625
	[0.668]	[0.660]	[0.570]	[0.572]	[0.691]	[0.686]
fourth quartile	-1.456*	-1.227*	-1.214*	-1.194*	1.458**	1.469**
	[0.764]	[0.708]	[0.663]	[0.653]	[0.685]	[0.686]
$\Delta\tau_{it}^{e}$ x						
first quartile	0.0223	-0.00237	0.239	0.237	0.0862	0.0860
	[0.141]	[0.147]	[0.187]	[0.185]	[0.147]	[0.143]
second quartile	0.0260	0.00699	0.191	0.193	0.132	0.131
	[0.150]	[0.143]	[0.219]	[0.215]	[0.176]	[0.172]
third quartile	-0.0459	-0.0571	0.0445	0.0378	0.0557	0.0478
	[0.151]	[0.152]	[0.218]	[0.219]	[0.220]	[0.221]
fourth quartile	-0.00493	-0.0138	-0.263	-0.275	0.00544	-0.00416
	[0.169]	[0.159]	[0.212]	[0.211]	[0.176]	[0.177]
Firm Controls		yes		yes		yes
R^2	0.069	0.093	0.036	0.039	0.039	0.043
Obs.	3327	3327	3086	3086	2634	2634

Notes: The dependent variables are reported at the top of the columns. Δ investment is the log change in machinery capital stock between 2002 and 2006. Δ skill wage corresponds to the log change in wage per hour of skilled workers (executives, skilled production workers, white-collars workers, and sales agents). Δ unskill wage is to the log change in wage per hour of production workers and auxiliaries workers not directly employed in the production process. Firms are divided into quartiles of the within-industry productivity distribution in the initial year (2002). All regressions include industry fixed effects; and dummies for the second, third, and fourth quartile of the productivity distribution in 2002. Firms controls include the log of employment in efficiency units; dummies for exporting, importing, and foreign-owned firms. Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 8: Controlling for Import Competition

Dependent Variable: Change in log TFPQ				
	Δ Aggregate Import		Share Importing Firms	
	Below	Above	Below	Above
$\Delta\tau_{it}^{ie}$	-1.626***	0.0825	-2.201*	-0.868
	[0.590]	[1.046]	[1.133]	[0.533]
$\Delta\tau_{it}^{e}$	0.0423	-0.376***	-0.373**	0.0163
	[0.222]	[0.141]	[0.153]	[0.183]
R^2	0.0527	0.0397	0.0451	0.0520
N	1691	1649	1802	1538

Notes: In the first two columns, industries are split according the the change in aggregate imports from the rest of the world above and below the median change (.64). In the last two columns, industries are divided above and below the median share of importing firms (.20) before the FTAs in 2002. All regressions include industry fixed effects, the log of employment in efficiency units, and dummies for exporting, importing, and foreign-owned firms measured in 2002. Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 9: Alternative Productivity Measures

Dependent Variable: Change in log TFPQ				
	(1)	(2)	(3)	(4)
$\Delta\tau_{it}^{ie}$	-1.242**	-2.015*	-1.244**	-2.508***
	[0.561]	[1.018]	[0.493]	[0.942]
$\Delta\tau_{it}^{e}$	-0.193*	-0.343	-0.143	-0.412
	[0.110]	[0.223]	[0.174]	[0.275]
R^2	0.0367	0.0332	0.0994	0.0568
Observations	3339	3292	3354	3294

Notes: This table reports the baseline results using different productivity measures. In the first column, TFPQ is estimated using the two-step Ackerberg et al. (2006) procedure. In the second column, TFPQ is from a value-added production function. In the last two columns, the dependent variables are real output per worker and labor productivity (real value added per worker). All regressions include industry fixed effects, the log of employment in efficiency units, and dummies for exporting, importing, and foreign-owned firms measured in 2002. Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 10: Alternative Tariff Measures

Dependent Variable: Change in log TFPQ				
	(1)	(2)	(3)	(4)
$\Delta\tau_{it}^{ie}$	-1.266**			
	[0.534]			
$\Delta\tau_{it}^{ie}$ IO93		-2.017***		
		[0.701]		
$\Delta\tau_{it}^{ie}$ simple			-1.168***	
			[0.405]	
$\Delta\tau_{it}^{ie}$ intermediate				-0.432*
				[0.219]
$\Delta\tau_{it}^{e}$	-0.196*	-0.185		
	[0.116]	[0.117]		
$\Delta\tau_{it}^{e}$ simple			-0.133	-0.121
			[0.111]	[0.119]
R^2	0.0451	0.0453	0.0450	0.0437
N	3340	3340	3340	3340

Notes: Column 1 reports the baseline results from Table (3) for comparison. In column 2, the indirect export tariff is computed using the 2003 IO table. In column 3, both the indirect and the direct export tariff are aggregated at the firm level across products using simple averages. In column 4, I compute the indirect export tariff using the weight in the IO table pertaining only to intermediate production. Tariffs are then aggregated at the firm level using simple averages. All regressions include industry fixed effects, the log of employment in efficiency units, and dummies for exporting, importing, and foreign-owned firms measured in 2002. Standard errors clustered at the industry level are in brackets. Significance levels *** p<0.01, ** p<0.05, * p<0.1

Table 11: Quantifying Aggregate Productivity Gains

	$\hat{\beta} \cdot \Delta\tau \cdot 4$	Revenue Weights	Aggregate Productivity	Share
Indirect Export Tariff	6.0	42.8	2.6	22.5
Direct Export Tariff	7.0	57.2	4.0	35.1
Reallocation			4.8	41.6
Exit			0.1	0.8
Total			11.4	100

Notes: Column 1 is the estimated impact on firm productivity of the indirect and direct export tariff cut. It is calculated by multiplying the estimated coefficients from table 4, columns 1 and 2 by the respective average tariff cuts, and by 4 to convert annual changes to 2002–2006 changes. Column 2 reports the share of real output for the comparative advantage and disadvantage industries. The third column reports the aggregate productivity gains. The first two rows can be calculated by multiplying the first two columns. Rows 3 and 4 are calculated using the Olley-Pakes aggregate productivity decomposition with entry and exit following Melitz and Polanec (2014); the row "Total" is to the sum of the column. The last column reports the contribution of each row component to the total productivity growth.

A Appendix

A.1 Plant and Product Data

The ENIA Manufacturing Census, which is considered to be of high quality, has been widely used in research (`http://www.ine.cl/`). I apply the following data-cleaning procedure to the plant data:

- I drop firms with strange patterns: firms that appear and disappear several times in the survey;
- I drop firms with missing employment, wages, revenues, and intermediate input expenditures;
- I drop firms with big variation (factor of 5) in a key variable: employment, wages, or output; and
- I drop firms with log changes in a key variable between 2002 and 2006 smaller or bigger than 5 standard deviations relative to the mean.

While plant data have been widely used, few works have used product information (Saravia and Voigtländer, 2013; Fernandes and Paunov, 2013). From 2001, all products are recorded according to the Central Product Classification (CPC, Version 1), which is an international classification produced by the United Nations. This important methodological change assures that product categories are homogeneous across time, substantially improving data quality.

Products are categorized via seven digits, corresponding to approximately 1100 different products. The first five digit correspond to the official classification as compiled by the United Nations. The last two digits are added by the National Statistical Agency to assure quantities are recorded properly for different product categories. Table A1 provides an extract of the official classification.

The product data include information on inventories, quantity produced, and its variable cost of production. Finally, I observe quantity sold, revenues, and the percentage, expressed in term of quantity, of exported products. I apply the following cleaning procedures:

- I check that product categories are recorded with the same unit of measurement;
- I drop all products from sections 6 to 9 of the CPC classification, which correspond to manufacturing services. These correspond to 902 observations, about 100 firms per year;

Table A1: CPC Classification: an Example

Division	
28	Knitted or crocheted fabrics; wearing apparel
Group	
282	Wearing apparel, except fur apparel
Class	
2822	Wearing apparel, knitted or crocheted
Sub-Class	
28221	Men's or boys' suits, coats, jackets, trousers, shorts and the like, knitted or crocheted
28222	Men's or boys' shirts, underpants, pyjamas, dressing gowns and similar articles, knitted or crocheted
28223	Women's or girls' suits, coats, jackets, dresses, skirts, trousers, shorts and the like, knitted or crocheted
28224	Women's or girls' blouses, shirts, petticoats, panties, nightdresses, dress- ing gowns and similar articles, knitted or crocheted
28225	T-shirts, singlets and other vests, knitted or crocheted
28226	Jerseys, pullovers, cardigans, waistcoats and similar articles, knitted or crocheted
28227	Babies' garments and clothing accessories, knitted or crocheted
28228	Track suits, ski suits, swimwear and other garments, knitted or crocheted n.e.c.
28229	Gloves, shawls, scarves, veils, ties, cravats and other made-up clothing accessories, knitted or crocheted; knitted or crocheted parts of garments or of clothing accessories

- I drop all products with null production or revenues in a given year;
- I drop all products with missing observations in a given year, i.e., I considered only products for which information was available in subsequent years. Such products represent a small share of total output;
- I eliminate products with a reported quantity of production of 1, 2, or 3; and
- I drop observations with big variation (factor of 5), and I winsorize revenues at the 1st and 99th percentiles.

A.2 Construction of capital series and productivity estimation

Starting from 2001, the ENIA survey annually collects information on the book value of four different categories of capital: building, land, machinery, and vehicles. For each of these categories, the survey also collected investment information. I use the perpetual inventory method to construct a capital series. I apply the following formula; $K_{it} = K_{it-1}(1-\delta) + I_{it}$, where K is capital, δ is a depreciation rate, and I is investment. I use the depreciation rate from Fernandes and Paunov (2013): 3 percent for building, 7 percent for machinery, and 11.9 percent for vehicles. Land is assumed not to depreciate.

My empirical analysis focuses on plant productivity, which I measure as follows. Consider the gross output production function:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \varphi_{it} + \varepsilon_{it}, \tag{A1}$$

where y_{it} is the log of real output, l_{it} is the log of employment measured in efficiency units, k_{it} is capital, and m_{it} is the intermediate inputs. φ_{it} is a productivity parameter, and ε_{it} is an idiosyncratic error term. k_{it} is a state variable, i.e., optimally decided one period in advance by firms. I also consider l_{it} to be a dynamic input. Petrin and Sivadasan (2013), using my same data set, treat employment as a dynamic input when estimating firm productivity due to the rigidities of the Chilean labor market. Materials, instead, are variable inputs, with the optimal choice depending on unobservable productivity: once firms become aware of productivity, they optimally choose the amount of material to use in production. The main problem in estimating eq. (A1) is the unobservable productivity term φ_{it}. This is likely to be correlated with the variable input used in production and thus will cause inconsistent estimates of the elasticities of output. The methodology proposed by Olley and Pakes (1996) and modified by Petrin and Levinsohn (2003) avoids this problem by substituting the unobservable productivity term with a control function that allows the identification of the variable input parameters. This methodology rests on two main identifying assumptions. First, the productivity evolves exogenously following a first-order Markov process, i.e., $p(\varphi_{it}|I_{it}) = p(\varphi_{it}|\varphi_{it-1})$. Second, firms optimally choose the amount of some variable, such as investment or intermediate input, that is strictly increasing in productivity.

I use the Wooldridge (2009) modified version of these two approaches, which has two main advantages: (i) all parameters can be jointly estimated with a Generalized Method of Moment (GMM) approach, and (ii) it also considers the collinearity issues raised by Ackerberg et al. (2006). More formally, let the innovation in productivity be $a_{it} = \varphi_{it} - E[\varphi_{it}|\varphi_{it-1}]$. The innovation is assumed to be uncorrelated with k_{it} and l_{it}, with the past values k_{it-1} and l_{it-1} and with past investments i_{it-1}:

$$E[\varphi_{it}|k_{it}, l_{it}, k_{it-1}, l_{it-1}, i_{it-1}] = E[\varphi_{it}|\varphi_{it-1}] \equiv f(k_{it-1}, l_{it-1}, i_{it-1}).$$

By substituting $\varphi_{it} = f(k_{it-1}, l_{it-1}, i_{it-1}) + a_{it}$ into eq. A1, it is possible to derive an estimation equation that allows me to identify all output elasticities:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + f(k_{it-1}, l_{it-1}, i_{it-1}) + a_{it} + \varepsilon_{it} \tag{A2}$$

using m_{it-1} as an instrument for m_{it} and a third-degree polynomial approximation for $f()$. Finally, productivity can be calculated as $\widehat{\varphi_{it}} = y_{it} - \widehat{\beta_l} l_{it} - \widehat{\beta_k} k_{it} - \widehat{\beta_m} m_{it}$ as a residual. The estimated output elasticities are reported in table A2. I estimate the production function for each two-digit industry separately, and I find reasonable returns to scale ranging from 0.86 for machinery and equipment to 1.2 for wood industries.

A.3 Tariff Data

Export, output, and input tariff data are constructed as follows. Tariff data come from the TRAINS database from the World Bank. All tariff data are registered according to the HS02 (6-digit) classification system, which is the native classification used by TRAINS. World trade flows comes from BACII-CEPI, which builds on UN-COMTRADE but harmonizes the data to reconcile flows reported by importing and exporting countries. These data are reported using the HS96 (6-digit) classification.

The correspondence table between HS (6-digit) and CPC (5-digit) classification comes from the UN classification registry (`http://unstats.un.org/unsd/cr/registry/`), which provides correspondence tables from HS 1996 to CPCV1 and from HS2002 to CPCV11. Product data from ENIA are collected according to the CPCV1 classification system (7-digit). The major changes between CPCV1 and CPCV11 are in section 5 to 9 of the CPC system, the services sector. Raw material and manufactured products are not affected by the change in the classification system. I aggregate raw tariff data using as weights the value of imports of the reporting country.

There are almost 5000 HS 6-digit products. These products correspond to almost 1100 CPC 5-digit products. The ENIA database reports almost 1100 CPC 7-digit products. Finally, after all conversions, I am left with tariff information on 700

Table A2: Production Function Estimates

Sector	Elasticities Material	Labor	Capital	Return to Scale
Food beverages	0.783	0.091	0.165	1.039
	(0.016)	(0.025)	(0.035)	(0.040)
Textiles	0.648	0.364	0.122	1.133
	(0.031)	(0.064)	(0.061)	(0.069)
Wearing apparel	0.599	0.281	0.205	1.086
	(0.026)	(0.068)	(0.089)	(0.108)
Leather, footwear	0.702	0.059	0.300	1.061
	(0.046)	(0.078)	(0.111	(0.130)
Wood	0.711	0.207	0.301	1.219
	(0.061)	(0.070)	(0.085)	(0.090)
Paper	0.608	0.106	0.241	0.956
	(0.036)	(0.070)	(0.060)	(0.081)
Publishing	0.616	0.307	0.278	1.201
	(0.037)	(0.064)	(0.088)	(0.097)
Chemicals	0.698	0.115	0.179	0.992
	(0.029)	(0.055)	(0.071)	(0.088)
Rubber, plastics	0.717	0.238	0.213	1.168
	(0.032)	(0.053)	(0.053)	(0.069)
Non-metallic min	0.797	0.076	0.284	1.158
	(0.025)	(0.049)	(0.081)	(0.093)
Basic metal	0.694	0.081	0.280	1.054
	(0.041)	(0.051)	(0.099)	(0.082)
Fabricated metal	0.641	0.232	0.133	1.006
	(0.032)	(0.045)	(0.092)	(0.096)
Machinery and equipment	0.630	0.311	-0.075	0.866
	(0.034)	(0.075)	(0.077)	(0.094)
Electrical mach	0.706	0.087	0.088	0.880
	(0.038)	(0.076)	(0.106)	(0.123)
Motor vehicles	0.591	0.311	0.248	1.151
	(0.053)	(0.153)	(0.142)	(0.145)
Other transport	0.572	0.281	0.232	1.085
	(0.105)	(0.166)	(0.189)	(0.220)
Furniture; man.	0.638	0.413	0.134	1.185
	(0.040)	(0.075)	(0.062)	(0.084)

Notes: The first three columns report the estimated output elasticities. The last column reports the implied return to scale. See the text for more detail about the estimation procedures. Standard errors are in parentheses.

products.

To construct the *indirect export tariff*, I use import tariff and the IO table provided by the Central Bank of Chile (`http://www.bcentral.cl`). Activities in the

IO table are registered according to the Chilean classification scheme: CAE (Clasificaciones Actividad Economica). Overall, the economy is composed of 73 sectors, 37 of which are manufacturing. The Central Bank of Chile provides correspondence between CAE and CIIU Rev. 3. I use the *supply-use* table for national transactions at basic prices. I construct the *indirect export tariff* as follows. I take tariffs from WITS. I aggregate the tariffs using import values for each reporting country at the CAE level. I am left with one export tariff for each CAE sector. I use the IO table (Tablas de Utilizacion Nacional, Precios Basicos) to construct the weight.

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