Exporting Firms and the Demand for Skilled Tasks*

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Abstract

This paper explores the skilled tasks demanded by Chilean exporting firms. Production involves many different tasks and tasks are executed by workers with different skills. Some tasks are skill-intensive, while others are unskilled-intensive. Firms produce goods of varying quality and exporters tend to produce higher quality goods. In turn, the production of quality is intensive in skilled-intensive tasks. Finally, firms are heterogenous and more productive firms become exporters and have a higher demand for skilled workers in skilled tasks. We provide evidence in support of these theories using the Chilean Encuesta Nacional Industrial Anual (ENIA), an annual census of manufacturing firms. We show that Chilean exporters utilize more skills than Chilean non-exporters and we show that exporters require the services of skilled specialized workers as opposed to skilled administrative workers. In addition, exporters demand less unskilled labor in unskilled-intensive tasks.

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1 Introduction

This paper explores the skilled tasks demanded by Chilean exporting firms. We build on a framework that combines various strands of recent trade literature. Production involves many different tasks, such as managing, accounting, clerical activities, design, packaging, logistics, sales representation, operational production, input control, monitoring, supervision, services. Tasks are executed by workers with different skills, some tasks are skill-intensive, while others are unskilled-intensive. Firms produce goods of varying quality and exporters tend to produce higher quality goods. In turn, the production of quality is intensive in some, but not necessarily all, skilled-intensive tasks. Firms are heterogeneous and differ in the efficiency of factor use: some firms are more productive in skill-intensive tasks than others. More productive firms become exporters and hire more skilled workers overall. The demand for skilled workers will, however, be biased towards those skilled tasks required to produce exportable goods. Using a panel of Chilean firm, we document these mechanisms.

A strand of recent trade theories postulates the higher quality of exporting goods and studies the implications for wage inequality and the demand for skills. Verhoogen (2008) shows that exports in Mexico are associated with a higher skilled composition of employment because firms upgrade product quality, a task that is intensive in skills. Using Argentine firm-level data, Brambilla, Lederman and Porto (2012) argue that exporting per se may not necessarily lead to higher skill utilization but, rather, that what matters is the destination of a firms' exports. In particular, for developing countries, exporting to high-income countries requires skills but exporting per se does not. This is because firms need to increase product quality, as in Verhoogen (2008), and because firms need to use skilled labor to execute exports, as in Matsuyama (2007). In a panel of Latin American countries, Brambilla, Dix-Carneiro, Lederman, and Porto (2011) document that the intensity of an industry's exports is positively correlated with the skill premium paid in such industry. Finally, Bastos, Silva and Verhoogen (2014) establish a positive causal link between exports and input quality (not only of labor but also more generally) among Portuguese firms.

Another strand of recent trade theories advocates models of trade and tasks. Pioneering studies of intermediate inputs as tasks can be found in Feenstra and Hanson (1996) and Feenstra and Hanson (1997). Modern models can also be found in Antras, Garicano, and Rossi-Hansberg (2006), Grossman and Rossi-Hansberg (2008) and Grossman and Rossi-Hansberg (2012). In these papers, tasks are tradable and tasks offshoring affects wage inequality and the wages of unskilled workers.

Empirically, Autor, Levy and Murnane (2003) and Ebenstein, Harrison, McMillan and Phillips (2014) find that firms in the U.S. do indeed offshore unskilled-intensive tasks or routine tasks and document that occupational exposure to globalization is associated with large wage losses, especially for unskilled and routine-task workers. Artuc and McLaren (2012) study these same issues with a structural model of workers mobility across industries and occupation and find that occupations (tasks) matter, but not so much as industry affiliation. A different line of research formulates a general model of international trade where goods are produced by combining various tasks using assignment models. Notable examples include Acemoglu and Zilibotti (2001), Acemoglu and Autor (2011) and Costinot and Vogel (2010).

We propose a theory of exports and the demand of skilled tasks that merges these two strands of data. From the first strand, we assume that firms export higher quality products and that the provision of quality requires skilled-intensive tasks. From the second strand, we work with a model that assigns workers of varying skills to different tasks depending on factor prices, firm productivity, and the skill intensity of tasks. The main prediction of the model is that exporters have a higher demand of skilled tasks and thus employ more skilled workers relative to unskilled workers than non-exporters. We provide evidence in support of these theories using the Chilean Encuesta Encuesta Nacional Industrial Anual (ENIA), an annual census of manufacturing firms. We use data from 2001 to 2005 and exploit detailed information of the firm demand of tasks such as directors, specialized workers (engineers, professionals), administrators, blue-collar operatives, and maintenance services workers. The firm data from the ENIA is combined with administrative customs data on firms exports. This allows us to link the exporting status of a firm with the demand for skilled tasks and to track this link for several years.

We show that Chilean exporters utilize more skills than Chilean non-exporters. However, the skill composition of employment matters. In particular, we show that exporters require the services of skilled specialized workers as opposed to skilled administrative workers. In addition, exporters demand less unskilled labor in unskilled-intensive tasks. We establish these results with an instrumental variable estimator, where we instrument the firm's exports (as a share of total sales) with the weighted average of, first, the changes in the exchange rate of all the firms international partners and, second, the level of income of those partners (Brambilla, Lederman, Porto, 2012; Park, Yang, Shi and Jiang, 2010).

The rest of the paper is organized as follows. In Section 2, we lay out the model of exports, quality, and the demand for selected skilled tasks. In section 3, we introduce the data, we discuss the econometric model, and we present the main results. Section 4 discusses extensions and concludes.

2 A Model of Exports and Skilled Tasks

We illustrate the link between exports and the demand for skilled tasks with a simple partial equilibrium model. We combine elements from Verhoogen (2008) with elements from Acemoglu and Autor (2011) and Costinot and Vogel (2010). From Verhoogen (2008), we adopt the theoretical framework underlying the idea that exporting requires quality upgrades that are inherently intensive in skilled labor. This framework can also be found in Kugler and Verhoogen (2012), Brambilla, Lederman and Porto (2012) and Bastos, Silva and Verhoogen (2014). From Acemoglu and Autor (2011) and Costinot and Vogel (2010), we adopt an assignment model of skills to tasks. In this setting, quality for exports is produced with a collection of tasks that can be performed by workers with different skills. Exporting firms assign higher skilled workers to fundamentally similar tasks to achieve higher quality. As a consequence, exporting firms hire more skilled workers relative to unskilled workers than non-exporters and, within exporters, a higher export intensity is also associated with higher skilled tasks utilization. As in the rest of this literature, a firm exporting status depends on its attributes, such as productivity (Verhoogen, 2008; Kugler and Verhoogen, 2012; Bastos, Silva and Verhoogen, 2014), specialization in skill utilization (Brambilla, Lederman, and Porto, 2012; Harrigan and Reshef, 2014), and caliber (Hallak and Sivadasan, 2013).

To simplify the exposition, we present the model in partial equilibrium. We want to establish theoretical links between export intensity and skilled tasks, rather than to formulate a general theory of exporting.[1] As in Verhoogen (2008), we adopt a multinomial logit utility specification. The utility that consumer h derives from purchasing product j depends on its quality θ, its price p, and a random deviation that follows a type-I extreme value distribution, ϵ. Utility is given by

$$(1) \quad U_{hj} = \alpha\theta_j - p_j + \epsilon_{hj}.$$

These assumptions yield the well–known multinomial–logit aggregate demand function

$$(2) \quad x_j(p_j, \theta_j) = \frac{M}{W}\exp(\alpha\theta_j - p_j),$$

[1] For related theories in general equilibrium, see Baldwin and Harrigan (2011), Fajgelbaum, Grossman and Helpman (2011), Hallak and Sivadasan (2013), and Johnson (2012).

where M is market size and W is an index that summarizes the characteristics of all available products in that market (i.e. $W = \sum_{z \in Z} \exp(\alpha\theta_z - p_z)$, where Z is the set of available products). The parameter α captures quality valuation. As in Verhoogen (2008), we assume that exports face a higher α.

Firms produce a differentiated product and markets are monopolistically-competitive. Firms can choose the level of vertical differentiation of their products θ, which includes physical product quality, packaging, design, advertising, customer support, timely delivery. By choosing the level of vertical differentiation, firms shift their residual demands. The degree to which a residual demand is shifted depends on the quality valuation parameter α, which gives firms the option to provide more vertical differentiation to exports markets here it is valued more highly. Exporting, in turn, incurs a fixed cost F.

As in Verhoogen (2008), production of output of quality θ requires activities to produce physical units and activities to produce quality itself. We assume that the production of quantity (physical units of output) is separated from the production of quality. In line with Acemoglu and Autor (2011), firms produce quantity and quality with tasks. Managing, accounting, clerical activities, sales representation, and services are examples of non-production activities. Design, packaging, marketing, engineering, logistics, operational production, input control, monitoring, and supervision are examples of production activities.

These tasks are produced with workers of varying skills. The production function of x physical units of a good of quality θ is

$$(3) \qquad x = \exp \int_0^1 \ln y_x(i) di,$$

where $y_x(i)$ is the production or services of task i. Tasks are produced, or performed, by skilled workers H or unskilled workers L with the following production functions

$$(4) \qquad y_x(i) = a_{Lx}(i) l_x(i) + a_{Hx}(i) h_x(i),$$

where $l_x(i)$ and $h_x(i)$ are the number of unskilled and skilled workers, respectively, allocated to task i in physical production; a_{Lx} and a_{Hx} are the productivity of unskilled and skilled workers in task i in physical production. We rank tasks i in increasing order of skill intensity so that $a_{Lx}(i)/a_{Hx}(i)$ is strictly decreasing in i. At the bottom of the ranking, then, we can find tasks such as cleaning services or building maintenance; at the top of the ranking, we can find engineering activities, product testing and so on.

Equations (4) are Ricardian task production functions. To determine the assignment of skills to tasks, we assume that wages are exogenous to the firm. The wage paid to one skilled worker is w_H and the wage paid to one unskilled worker is w_L. In an equilibrium, which resembles the many-good comparative advantage chain, there is a cutoff task i_x^* such that all tasks $i_x < i_x^*$ are produced exclusively by unskilled workers, and $i_x \geq i_x^*$ are instead performed by skilled workers. To see this, note that, given the fixed coefficient technology and the exogenous factor prices, unskilled and skilled workers never share tasks, that is, it is optimal to allocate skilled workers to some tasks and unskilled workers to different ones. The cutoff task is determined by the equality of the unit cost of producing i_x^* with either skilled and unskilled workers

$$(5) \qquad \frac{w_L}{a_{Lx}(i_x^*)} = \frac{w_H}{a_{Hx}(i_x^*)}.$$

Given that tasks are ranked in decreasing order or unskilled intensity, it follows that, for $i < i_x^*$, $w_H/a_{Hx}(i) > w_L/a_{Lx}(i)$ and thus all these tasks are filled with unskilled labor. The numbers of employees in each of these tasks is

$$(6) \qquad l_x(i) = \frac{y_x(i)}{a_{Lx}(i)},\ h_x(i) = 0.$$

By contrast, for $i \geq i_x^*$, $w_H/a_{Hx}(i) < w_L/a_{Lx}(i)$ so that it is relatively cheaper to use skilled labor to perform these tasks. The numbers of employees in each $i \geq i_x^*$

$$(7) \qquad l_x(i) = 0,\ h_x(i) = \frac{y_x(i)}{a_{Lx}(i)}.$$

We work out the solution for skilled and unskilled labor demand below, but for the moment, note that the cost function associated with the production function (3) is given by

$$(8) \qquad c = \exp \int_0^1 \ln p_x(i) di,$$

where $p_x(i)$ is the implicit price of task i in physical production. These prices are given by

$$(9) \qquad w_L = p_x(i) a_{Lx}(i),$$

for $i < i_x^*$, and by

$$(10) \quad w_H = p_x(i) a_{Hx}(i),$$

for $i \geq i_x^*$. As a result,

$$(11) \quad c = \exp\left(w_L i_x^* + w_H (1 - i_x^*)\right) \exp\left(\int_0^{i_x^*} \frac{1}{a_{Lx}(i)} di + \int_{i_x^*}^{1} \frac{1}{a_{Hx}(i)} di\right).$$

The cost function depends on factor prices and on the cutoff i_x^*, which, from (5) is in turn only a function of relative prices (and technology). We conclude that the marginal cost of producing a unit of output x depends on factor prices, but it is independent of the quantity (and quality) produced.[2] We can therefore write the marginal cost as

$$(12) \quad c = c(w_L, w_H).$$

We now turn to the technology to produce quality. To simplify the analysis, we assume that the production of quality requires the same collection of services produced by tasks i as in output production. Janitors clean machine rooms as well as the desks where designed are developed; engineers supervise machines and robots that contribute to both physical output and its quality.[3] The production function of quality is

$$(13) \quad \theta = \lambda \left(\exp \int_0^1 \ln y_\theta(i) di\right)^\beta,$$

where λ is firm productivity in quality production. Firms differ in λ and these differences allow firms to select themselves into exporters and non-exporters and, within exporters, to define their export intensity (the share of exports in sales). To achieve an interior solution, we assume that $\beta < 1$, so that there are decreasing returns to scale in quality production and, thus, increasing

[2]This assumption simplifies the solution of the model, but it is not strictly necessary for our conclusions. Extensions where the marginal cost of quantity production depends on quality can be found in Verhoogen (2008), Brambilla, Lederman, and Porto (2012), Kugler and Verhoogen (2012), Bastos, Silva and Verhoogen (2014). See for instance the review in Brambilla and Porto (2014).

[3]Alternatively, we can assume that tasks are different in nature. Output production tasks can include machine operation, while quality production tasks machine maintenance and specification. For our purposes, we need to be able to rank tasks according the skill utilization. Assuming that tasks are conceptually similar just simplifies the structure of those rankings.

marginal cost of quality.[4] As before, $y_\theta(i)$ is the services of task i in quality production and tasks are performed by skilled workers H or unskilled workers L with production functions

$$(14) \quad y_\theta(i) = a_{Lx}(i) l_\theta(i) + \psi a_{Hx}(i) h_\theta(i),$$

where $l_\theta(i)$ and $h_\theta(i)$ are the number of unskilled and skilled workers, respectively, allocated to task i in quality production. As argued above, we simplify the presentation of the model by assuming that the productivity of unskilled and skilled workers in task i are the same as in production. However, we introduce $\psi > 1$ to capture the fact that quality production is intensive in skilled tasks relative to physical production. In other words, ceteris paribus, firms will have to hire skilled workers to perform certain quality tasks that can be performed by cheaper unskilled workers in production. To see this, we determine the cutoff i^*_θ when the unit cost of producing i^*_θ with skilled labor is the same as with unskilled workers

$$(15) \quad \frac{w_L}{a_{Lx}(i^*_\theta)} = \frac{w_H}{\psi a_{Hx}(i^*_\theta)}.$$

Since tasks are ordered such that a_{Lx}/a_{Hx} is decreasing in i and $\psi > 1$, we conclude that $i^*_x > i^*_\theta$. Some tasks are filled with unskilled labor in production and with skilled labor in quality. This is depicted in Figure 1. In particular, for $i < i^*_\theta$,

$$(16) \quad l_\theta(i) = \frac{y_\theta(i)}{a_{L\theta}(i)}, \;\; h_\theta(i) = 0,$$

while, for $i \geq i^*_\theta$

$$(17) \quad l_\theta(i) = 0, \;\; h_\theta(i) = \frac{y_\theta(i)}{a_{L\theta}(i)}.$$

Following the steps shown for the allocation of tasks to production, we denote the total cost function of quality θ as

$$(18) \quad F(\theta) = \left(\frac{\theta}{\lambda}\right)^{1/\beta} \exp(w_L i^*_\theta + w_H(1 - i^*_\theta) \exp\left(\int_0^{i^*_\theta} \frac{1}{a_{Lx}(i)} di + \int_{i^*_\theta}^1 \frac{1}{\psi a_{Hx}(i)} di\right).$$

Having determined the technology of producing physical units and quality, we can now study firm

[4] This assumption guarantees that the choice of quality is bounded. A similar assumption is in Verhoogen (2008).

choices of quality and price to maximize profits.[5] The objective function is

$$(19) \quad \pi = (p - c)x(p, \theta) - F(\theta).$$

The first order conditions are

$$(20) \quad p = 1 + c,$$

$$(21) \quad \alpha x(p, \theta) = F'(\theta).$$

In this simple setting, thus, firms charge the same price for goods of any quality. This price is a markup over the marginal cost c (given by (8)). Since it is costly to produce quality, vertical differentiation occurs because firms can sell higher quantities of higher-quality products. The optimal choice of quality θ is determined by the equality of the marginal cost ($F'(\theta)$) and the marginal benefit (higher sales measured by $\alpha x(p, \theta)$) of quality provision. For an interior solution, we assume that the marginal cost increases in θ at a sufficiently high rate (concretely, the second order condition for profit maximization is $F''(\theta) > \alpha^2 x(p, \theta)$). The equilibrium choice of quality is depicted, ceteris paribus, in Figure 3.

To end, we explore the differences between firms, and between exporters and non-exporters, and we lay out the implications of these differences across firms for the demand for skilled tasks. To streamline the exposition, we assume firms only differ in λ, the quality productivity factor. (Firms could also differ in ψ, the efficiency in skill utilization, or in the factor prices they face.) From the first order conditions for profit maximization, a higher λ implies a higher optimal quality provision (which in virtue of the fixed markup is sold at the same price $p = 1 + c$). In Figure 3, the marginal cost of quality production shifts down because of the higher productivity, and the firm can profitably increase quality at the optimum.

To look at the role of exporting, we assume, as it is standard in the trade-quality literature, that export markets demand higher quality and that firms need to incur a fixed cost of exporting. As a consequence, higher λ firms can afford to cover this fixed cost because of the higher quality of their products. This result is typically subsumed with the determination of a productivity cutoff λ_{min} so

[5] See Brambilla and Porto (2014) for a literature review and various alternative specifications of the theory of quality and exports.

that firms with $\lambda > \lambda_{min}$ become exporters and firms with $\lambda < \lambda_{min}$ only fill the domestic market.[6] This means that, on average, exporters produces higher quality products than non-exporters. In addition, within exporters, firms with higher quality-productivity λ will ship a larger share of their sales abroad and will produce even higher quality output.

For our purpose in the empirical work of section 3, we need to work out the implications for the demand of skilled tasks. Equations (6) and (7) determine the utilization of unskilled and skilled labor in production task i, while equations (16) and (17) determine the utilization of unskilled and skilled labor in quality provision task i. In the Chilean data, we have information on employment of skilled and unskilled workers in various activities and tasks, but we do not necessarily know the fraction of employment of each type of worker in output or in quality production. We just know aggregate employment across tasks. For this reason, we now study the implications of the model at an aggregate level.

Consider first the production of physical units. To pin down total skilled demand, note that the expenditure in each task is equal across tasks and is equal to total cost expenditures (by virtue of the Cobb-Douglas production function)

$$(22)\quad p_x(i)y_x(i) = p_x(i')y_x(i') = c(w_L, w_H)x(p, \theta).$$

Consequently, we have that

$$(23)\quad l_x(i) = l_x = \frac{(p-1)x(p,\theta)}{w_L},$$

and

$$(24)\quad h_x(i) = h_x = \frac{(p-1)x(p,\theta)}{w_H}.$$

This means that all unskilled *output production* tasks are performed by the same number of unskilled employees, and all *output production* skilled tasks are similarly performed by the same number of skilled employees. Similarly, we find that

$$(25)\quad l_\theta(i) = l_\theta = \frac{F(\theta)}{w_L},$$

[6] This cutoff is determined by the marginal firm with productivity λ_{min} who is indifferent between not exporting its product and exporting it and paying the fixed cost.

and

$$(26) \quad h_\theta(i) = h_\theta = \frac{(F(\theta)}{w_H}.$$

This means that all unskilled *quality production* tasks are performed by the same number of unskilled employees, and all *quality production* skilled tasks are similarly performed by the same number of skilled employees.

It is useful to plot relative skilled utilization for different tasks i. We do this is Figure 2. For the lowest skill tasks, $i < i^*_\theta$, only unskilled workers are utilized, both for output production and for quality production. This could be the case of cleaning or simple maintenance tasks. For the highest skill tasks, $i > i^*_x$, only skilled workers are utilized. This can reflect activities such as machine supervision, software development and so on. For intermediate tasks, $i^*_\theta < i < i^*_x$, unskilled workers are utilized in output production and skilled workers in quality production. This can refer to an engineer, who monitors production, and a trainee, that operates machines. Figure 2 shows how the share of total skilled employment is increasing in tasks i. Moreover, as firms become more productive (i.e., have a higher λ) and choose to produce higher quality θ, the share of skilled labor utilization increases. In this simple model, this happens in the intermediate range of tasks $i^*_\theta < i < i^*_x$.

The same implication takes places for aggregate firm employment (summing across tasks). Total unskilled labor demand is

$$(27) \quad L_x = \int_0^{i^*_x} l_x(i)di = \frac{(p-1)x(p,\theta)}{w_L} i^*_x,$$

and total skilled labor demand is

$$(28) \quad H_x = \int_{i^*_x}^1 h_x(i)di = \frac{(p-1)x(p,\theta)}{w_H}(1 - i^*_x).$$

Similarly, for quality production, we have that

$$(29) \quad L_\theta = \frac{F(\theta)}{w_L} i^*_\theta,$$

and that

$$(30) \quad H_\theta = \frac{F(\theta)}{w_H}(1 - i_\theta^*).$$

Clearly, from expressions (27)-(30), higher productivity firms are larger in that they hire more employees of any skill in any tasks. This is because of two factors. High productivity firms can afford to produce higher quality goods which requires both skilled and unskilled labor. In turn, a higher quality product has a higher total demand and producing physical units also requires both types of labor. To get more meaningful testable implications from the model, the result that we want to emphasize is that as λ grows higher, firms expand skilled labor disproportionately more than unskilled labor. To see this, let total unskilled labor L be the sum of unskilled labor in production and in quality, $L = L_x + L_\theta$; let total skilled labor H be the sum of skilled labor in production and in quality, $H = H_x + H_\theta$. We have that

$$(31) \quad \frac{\partial \ln H}{\partial \lambda} - \frac{\partial \ln L}{\partial \lambda} = \left(\frac{H_\theta}{H} - \frac{L_\theta}{L}\right)\left[\frac{\partial \ln F(\theta)}{\partial \lambda} - \frac{\partial \ln x}{\partial \lambda}\right].$$

To derive the sign of this derivative, note that the first term in parenthesis on the right-hand side of this expression is positive because quality provision is skill intensive relative to physical production. Formally,

$$(32) \quad i_x^* > i_\theta^* \Longleftrightarrow \frac{L_x}{H_x} > \frac{L_\theta}{H_\theta} \Longleftrightarrow \frac{H_\theta}{L_\theta} > \frac{H}{L}.$$

Next, note that the term in brackets captures the effect of a higher λ on factor utilization via two channels, the effect on quality costs ($F(\theta)$ and on the derived impact of quality on demand ($x(p, \theta)$. In fact, a higher λ increases the cost of producing quality

$$(33) \quad \frac{\partial \ln F(\theta)}{\partial \lambda} = \frac{1}{\beta\theta}\frac{\partial \theta}{\partial \lambda} - \frac{1}{\beta\lambda} > 0.$$

On the one hand, higher productivity has a direct cost-saving effect on quality production (the second term on the right-hand side) and, in equilibrium, it induces firms to provide higher quality, which is costly to produce (the first term on the right-hand side). The net effect is positive so that higher productivity creates in equilibrium higher gross costs of quality provision. To see this, we need to show that $\partial\theta/\partial\lambda > \theta/\lambda$. Using the first order condition (21), we find that

$$(34) \quad \frac{\partial\theta}{\partial\lambda} = \frac{\theta}{\lambda}\frac{1}{1-\beta-\alpha\beta\theta} > \frac{\theta}{\lambda}.$$

The intuition underneath this result is that, even though λ has cost-saving effects, the resulting choice of higher quality in equilibrium induces an sufficiently large increase in total quality provision costs.

Going back to the employment effect (31), note that, given that quality production is intensive in skills relative to physical output production ($H_\theta/H > L_\theta/L$), this quality provision effect implies that more productive firms expand skilled labor relatively more than unskilled labor.

By contrast, the model also implies that higher quality boosts output

$$(35) \quad \frac{\partial \ln x}{\partial\lambda} = \alpha\frac{\partial\theta}{\partial\lambda} > 0,$$

and, consequently, given the factor intensities, there is an output production effect whereby more productive firms expand unskilled labor relatively more than skilled labor.

In the model, it turns out that the effect on employment of higher quality provision dominates the effect of higher output production. Indeed, if $\beta > 0$, then,

$$(36) \quad \frac{\partial \ln F(\theta)}{\partial\lambda} - \frac{\partial \ln x}{\partial\lambda} = \frac{1}{\beta\theta}\frac{\partial\theta}{\partial\lambda} - \frac{1}{\beta\lambda} - \alpha\frac{\partial\theta}{\partial\lambda} > 0.$$

To conclude then, we have shown that increases in productivity λ lead to increases in skilled labor relative to unskilled labor utilization. This is because high-productivity firms need to expand quality and production, but quality is more intensive in skilled tasks. Furthermore, higher productivity firms can also afford to export their output because being more profitable, they can cover the fixed costs of exporting. In the end, exporting firms have a larger demand for skilled tasks than non-exporting firms and, in addition, higher export intensity among exporters is also associated with higher demand for skilled tasks.

Another interesting implication of the theory is that the type of tasks in which the increase in skills takes place. Tasks are ranked in decreasing order of skill intensity so that the most skilled-intensive tasks are always performed by skilled labor both in exporters and in non-exporters. For instance, this implies less significant differences in the characteristics of managers or CEOs across export intensity. A firm exporting most of its output may hire similar management than a firm exporting half of its output or than a firm exporting very little. The differences in skilled utilization will most likely take place in interior of the task space. We interpret this result as suggesting a higher utilization of specialized workers, such as engineers, chemists, designers. Similarly, the theory predicts less significant differences in unskilled utilization in the most unskilled intensive tasks, i.e., cleaning, maintenance, repairs. By contrast, in marginal blue-collar unskilled tasks, exporters may hire more workers with more skills, with more expertise or tenure.

3 Evidence on Exports and The Demand for Skilled Tasks

In this section, we investigate the tasks demanded by Chilean exporters. We first describe the data and present the basic correlations between skills, tasks, and exports. Then, we introduce our econometric model where we explore causality behind the underlying correlations. To this end, we rely on an instrumental variable approach where we use changes in exchange rates faced by Chilean exports in world markets as exogenous variation in export exposure of Chilean firms.

3.1 The Chilean Data

We use two sources of data, firm-level data and customs records. The firm-level data come from the Encuesta Nacional Industrial Anual (ENIA), an annual industrial census run by Chile's Instituto Nacional de Estadística that interviews all manufacturing plants with 10 workers or more. It is a panel. The customs data provide administrative records on firms exports by destination. We manually matched both databases for the period 2001-2005. As a result, we built a 5-year panel database of Chilean manufacturing firms.

The data have several modules. The main module contains information on industry affiliation, ownership type, sales, exports, input use, imports of materials, workers and wages. Industry affiliation is defined at the 4-digit ISIC Revision 3 level, which makes up for a total of 113 industries.

We are mostly interested in the employment information. The data on workers are presented at detailed categories, which allows us to explore the demand for different skills and tasks. From the detailed employment records, we define the following tasks: management (directors), administrative services (accountants, lawyers), engineers (specialized skilled production workers), blue-collar activities (non-specialized unskilled production workers), and general maintenance services (unskilled non-production workers). The first three categories, managers, administrative workers, and engineers, comprise skilled labor. To enrich the analysis, we also define a highly-skilled group, which includes managers and engineers. Unskilled workers are blue-collar, non-specialized and general maintenance workers. In turn, production workers include engineers and blue-collar operatives, while non-production workers include managers, administrative workers and maintenance workers.

Table 1 briefly presents some key summary statistics for the key variables in our model. We present the unconditional averages as well as averages for exporting firms and non-exporting firms. On average, Chilean firms hire 39 percent of skilled workers and 61 percent of unskilled workers. As expected, exporters utilize a higher share of skilled workers (41 percent) than non-exporters (39 percent). Exporters are also larger and they hire, on average, more workers in all skilled categories than non-exporters. Employment of unskilled workers in also higher among exporters, but only marginally. Production workers account for 73 percent of employment of all Chilean firms, and of 70 percent of the employment of exporters. In addition, exporters employ more managers, engineers and administrative services workers than non-exporters. Employment of unskilled blue-collar workers is very similar while maintenance employees are slightly more among exporters. Finally, the average exporter ships around 32 percent of its sales abroad. Among all firms, exports accounts for only 5 percent of total firm sales.

3.2 Correlations

To motivate and to summarize our findings, we begin with the presentation of simple panel-data correlations between the outcomes of interest and exporting. The outcomes of interest are the employment of workers and tasks of varying skills. We show these correlations with the panel linear fit of an outcome and our measure of export intensity (the ratio of exports to sales at the firm level). These linear fits are estimated with the following regression

$$(37) \quad y_{it} = \gamma E_{it} + \phi_i + u_{it},$$

where i is a firm, t is year, y be the outcome of interest, E is export intensity and ϕ_i is the firm fixed-effect. We plot Δy_t against $\widehat{\gamma} \Delta E_t$, where $\widehat{\gamma}$ is estimated with OLS-FE. Results are in Figures 4-9.

Figure 4 shows that exports are positively associated with skilled employment and negatively correlated with unskilled employment. Moreover, we find separate positive correlations with highly skilled employment as well as with skilled employment more generally. In turn, Figure 5 shows that higher export intensity is associated with higher employment of both production and non-production workers.

In Figure 6, we learn that, within skilled labor, exports demand more engineers (specialized workers) and services (accounting, IT), but not necessarily managers. In Figure 7, we learn that, within unskilled labor, exports demand less blue-collar workers and maintenance services (janitors, repair workers) in general. In addition, for production, exports demand engineers over blue-collars (Figure 8), while, for non-production, exports demand services more than maintenance workers (Figure 9).

3.3 Regression Results

We now set out to study the correlations outline above with formal regression models. We first want to explore if the correlations are robust to other correlates and, second, to test for causality. To do this, we expand our mode as follows

$$(38) \quad y_{ijt} = \mathbf{x}'_{ijt}\beta + \gamma E_{ijt} + \phi_i + \phi_{jt} + \epsilon_{ijt},$$

where indices i and t are as above and j is an industry. We add the vector $\mathbf{x}$, which includes firm level variables such as log total employment, log sales, and initial conditions (sales and exporting status) interacted with year dummies to account for firm-specific trends. The regression includes firm fixed effects, ϕ_i and industry year effects, ϕ_{jt}.

Before turning to causality, we explore the correlations with these extended OLS-FE estimation. Results are in Table 2. In column 1, we show the basic correlation corresponding to the graphs above. These regressions only include export intensity, firm fixed-effects and year-effects and we report them for consistency with the graphical analysis. For the first robustness experiment, in column 2, we add log employment to control for size. This means we compare firms of equal size, with different export intensity. As it can be seen, the correlation between exports and highly-skilled and skilled employment is positive and statistically significant. The results show that a firm with 10 percentage points higher export intensity hire 1.9 percent more highly-skilled workers and 1.6

percent higher skilled workers than a similar-size firm. Exporters tend to hire less unskilled labor, but this coefficient is weak statistically. In terms of specific tasks, we find that exports hire more engineers and administrative service workers and hire less maintenance service workers. There are no statistically discernible difference in managerial and unskilled blue-collar employment.

These correlations may be driven by industry trends, such as industry-specific growth processes. To account for those trends, we add in column 3 interactions between year dummies and industry dummies. The results are robust. In column 4, we also add initial conditions to account for firm-specific trends (Brambilla, Lederman, and Porto, 2012). The results are also very robust. The magnitudes of the coefficients are also stable across specifications.

While these correlations are very robust, they are still correlations, not necessarily causal effects. To get to these causal effects, we need to instrument the variable E_{ijt}. This is because, for instance, there might be omitted variables creating biases. More productive firms are, for example, more likely to export and, at the same time, be more efficient in the use of skilled labor. To build instruments, we follow a strategy similar to Revenga (1992), Revenga (1997), Bastos, Silva and Verhoogen (2014), Brambilla, Lederman and Porto (2012), Brambilla and Porto (2014), and Park et al. (2010), among others. Intuitively, the argument runs as follows. Exogenous export opportunities for a firm are likely to arise when its foreign export markets expand. In turn, this will happen when the income of the destination country grows and when exchange rate changes make Chilean exports relatively cheaper. Given any of these exogenous changes, a firm will be more likely to take advantage of these export opportunities if it is exposed to those markets. A natural measure of destination exposure in this case is the share of a firm's exports to that destination in total firm sales. Formally, we define two instruments

$$(39) \quad z^0_{jt} = \sum_d s_{dj} \ln g_{dt},$$

and

$$(40) \quad z^1_{jt} = \sum_d s_{dj} \ln r_{dt},$$

where z^0 and z^1 are the instruments, s_{dj} is the share of exports of firm j to export destination d at the initial time period (year 2001), g_{dt} is the real GPD of destination d at time t, and r_{dt} is the bilateral exchange rate between Chile and country d at t. Hence, z^0_{jt} and z^1_{jt} are weighted averages of the real gdp and the real exchange rate face by Chilean exporters, where the firm-specific weights are the initial shares of exports in sales. As in Brambilla, Lederman and Porto (2012), we also interact z^0 and z^1 with initial firm sales (i.e., log sales in 2001) to include any firm advantages in profiting from export opportunities based on firm size. To assess the power of these instruments, we can look at the first stage results for the same four specifications used in the OLS-FE model. The results are in Table 3. As it can be seen, the instruments have a lot of explanatory power in this first stage. They also easily satisfy the test of joint significance. The real GDP of the export destination market appears to be a stronger determinant of export intensity than the real exchange rate. However, it is the combination of all these instruments together that performs very well and we consequently use this specification in what follows.

The causal impacts of export intensity of employment are reported in Table 4. Conditional on size, firms that export a higher share of their total sales utilize more skilled (and also highly-skilled) workers, and less unskilled workers. This implies that exporters need to perform skill intensive activities and tasks. By contrast, there are not discernible causal impact of exports on production or non-production employment. This means that, ceteris paribus, a firm utilizes roughly the same type of production and non-production workers to produce goods for exports or for the local domestic market.

Among skilled workers, exporters utilize significantly more engineers (specialized workers), conditional on size. However, employment of specialized service workers tends to be higher but this is not statistically significant. Similarly, managerial employment is relative smaller as exports grow, but not significantly so (statistically). Among unskilled workers, the bulk of the difference takes place among non-specialized blue-collar workers.

Table 5 reports results using shares of employment, instead of log employment. We confirm that the share of skilled labor is statistically higher among exporters. The share of highly-skilled workers is also higher. Instead, the shares of production and non-production workers are not statistically different. The share of engineering employment is much higher among exports. This is compensated with lower shares of blue-collar employment, while the shares of all other types of employments are not statistically different.

4 Conclusions

In this paper, we have explored the link between exports and the demand for skilled tasks in Chile. Chilean exports require skills. Foreign consumers value product quality and are willing to pay for it. In turn, quality is intensive in skilled labor. As a consequence, exporters demand more skilled workers relative to unskilled workers. However, exports do not necessarily require any skill. In particular, exporting leads to a more intensive use of skilled tasks in the production process. This leads to a higher demand of engineers vis-à-vis unskilled workers (blue-collar or maintenance services workers) as well as non-production skilled workers (administrative services workers). We have developed a simple partial equilibrium model to formalize these mechanisms and we have provided evidence from a panel of Chilean firms in support of the model.

Our findings have implications for trade theory and emphasize the importance of recent assignment models of factors to tasks in international trade. They also have implications for empirical research and policy design. The notion that trade, and exports in particular, affects the wage premium and thus wage-inequality needs to be carefully assessed. Exporting in developing countries may raise the demand for specific sets of skills, thus creating potential inequality even within skilled labor categories. In Chile, our results show that export opportunities boost the demand for technical skills such as engineering skills but not for other profession skills such as "desk" skills. Obviously, engineers are more likely to benefit from trade in export-oriented firms than accountants, who can perform well in more domestically-oriented firms instead. These conclusions should contribute to our understanding of the skilled tasks needed to exports, the role of potential education policies consistent with a successful long-run export performance (e.g., fostering technical careers), and the design of social policies to reduce wage inequality and help the losers from trade.

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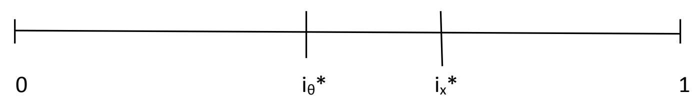
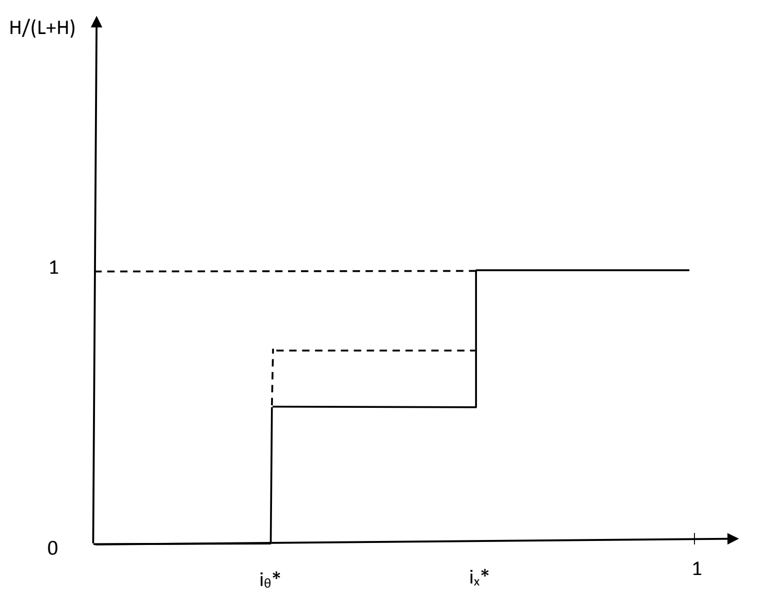
Figure 1
Tasks Allocation: Output and Quality Production



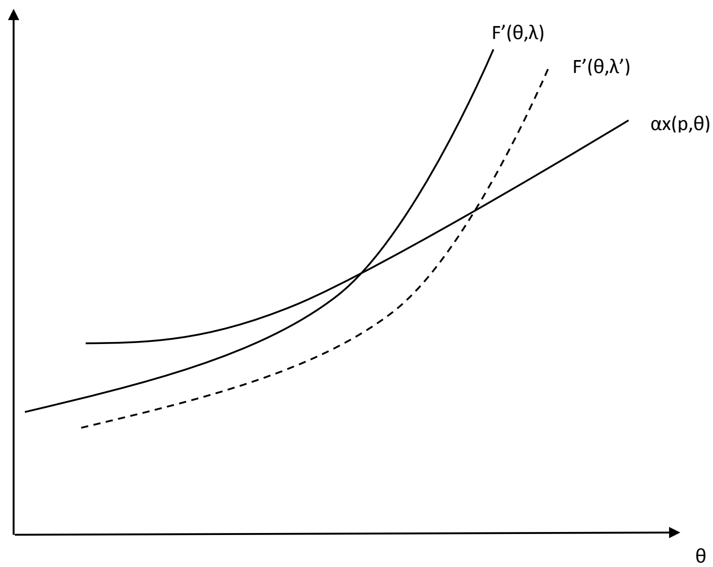
Note: Determination of cutoff tasks in output (i_x^*) and quality (i_θ^*) production. Tasks are arranged in decreasing order of skilled intensity. Tasks above i_x^* in output production and above i_θ^* in quality production are performed exclusively by skilled workers. The quality cutoff is lower than the output cutoff because quality production is more skilled intensive than output production.

Figure 2
Relative Skilled Labor Utilization Across Tasks i



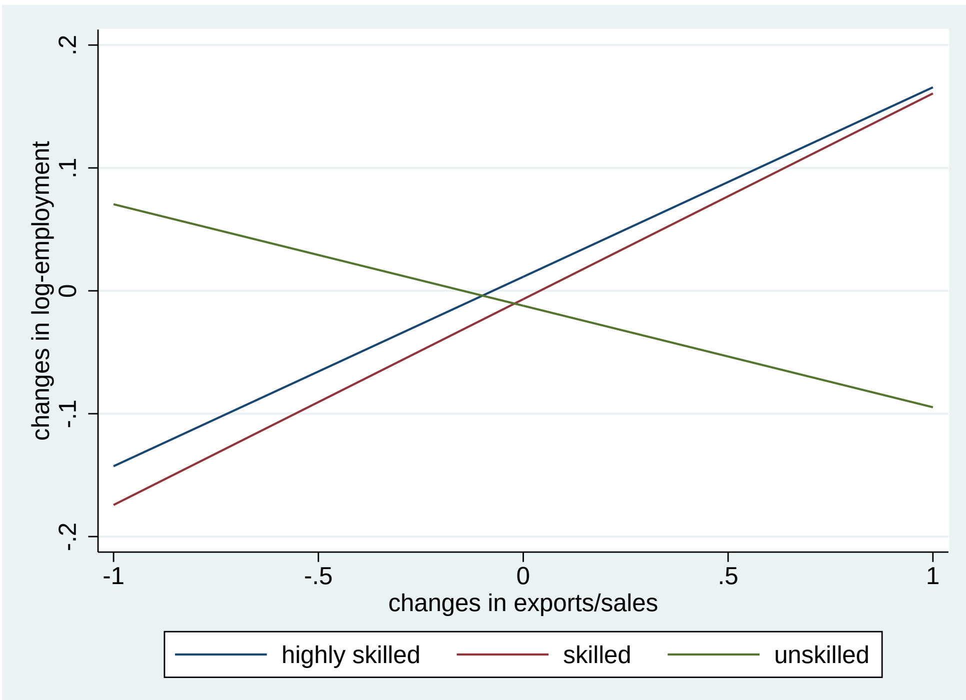
Note:

Figure 3
The Determination of Optimal Quality θ



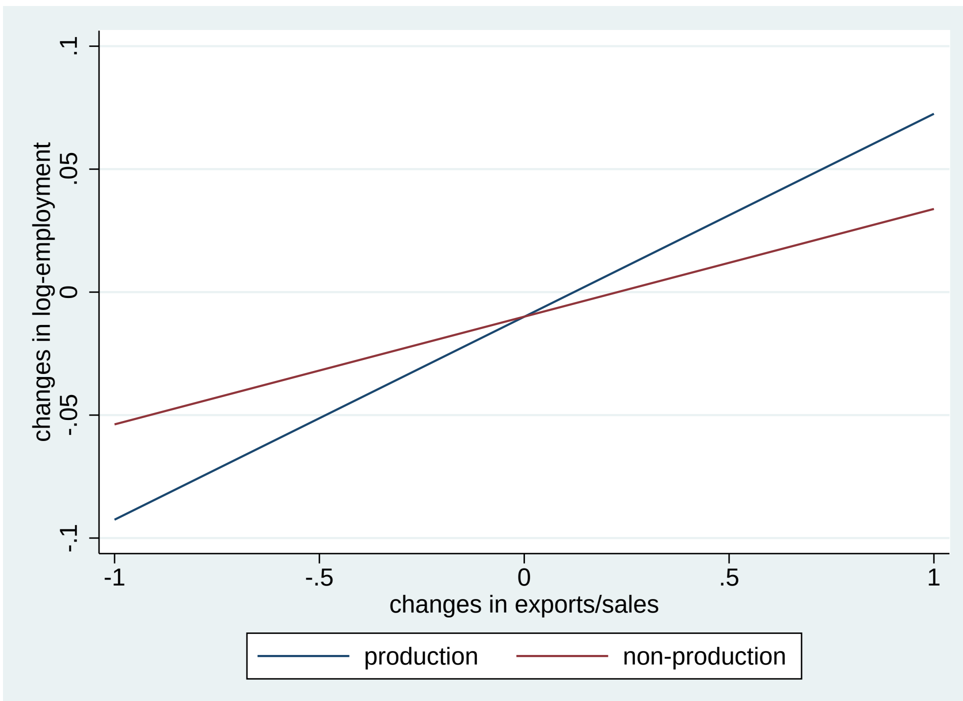
Note: Optimal quality is determined by the equality of the marginal cost of quality provision ($F'(\theta, \lambda)$) and the marginal benefit given by induced higher demand ($\alpha x(p, \theta)$). Higher productivity λ shifts the marginal cost curve down, leading to higher optimal quality in equilibrium.

Figure 4
Exports and the Demand of Skilled Workers



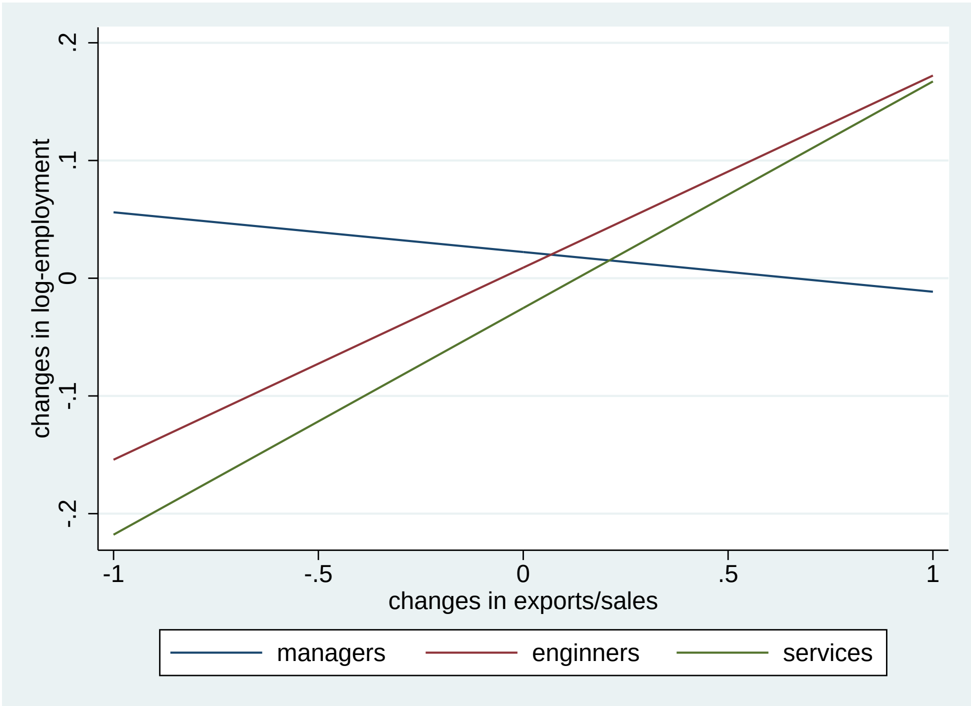
Note: Correlation between changes in changes in log employment and in export intensity (exports/sales) for highly-skilled (managers and engineers), skilled (managers, engineers, and administrative services workers), and unskilled workers (blue-collar and general maintenance workers) in Chile. The graph shows the slope of a OLS-FE regression between the reported variables.

Figure 5
Exports and the Demand of Production Workers



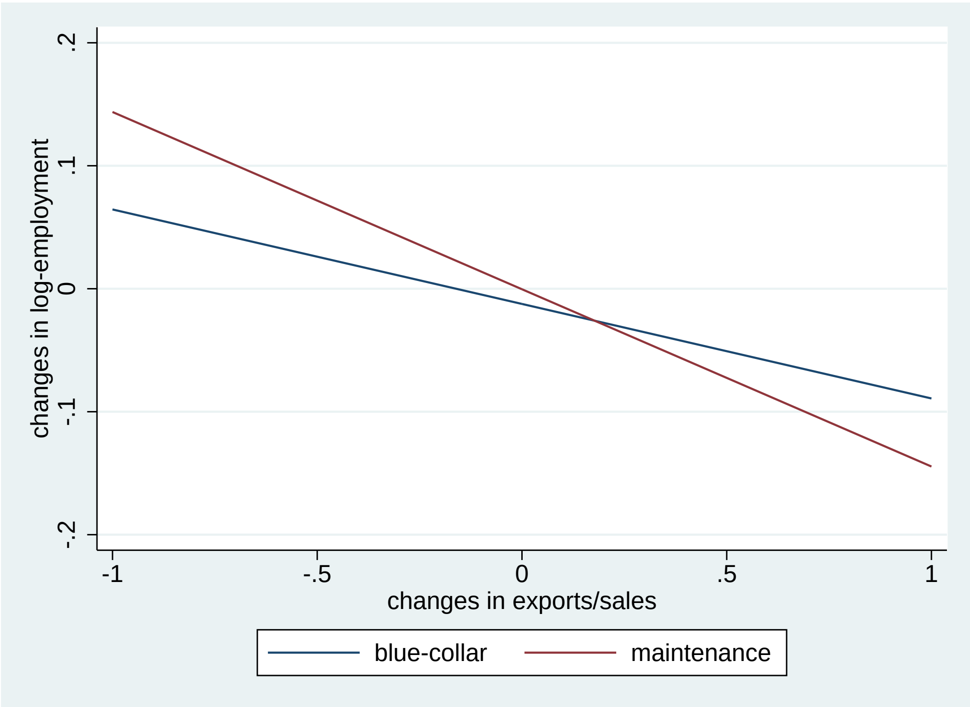
Note: Correlation between changes in changes in log employment and in export intensity (exports/sales) for production (engineers and blue-collar workers) and non-production (managers, administrative services and general maintenance workers) in Chile. The graph shows the slope of a OLS-FE regression between the reported variables.

Figure 6
Exports and the Demand of Skilled Tasks



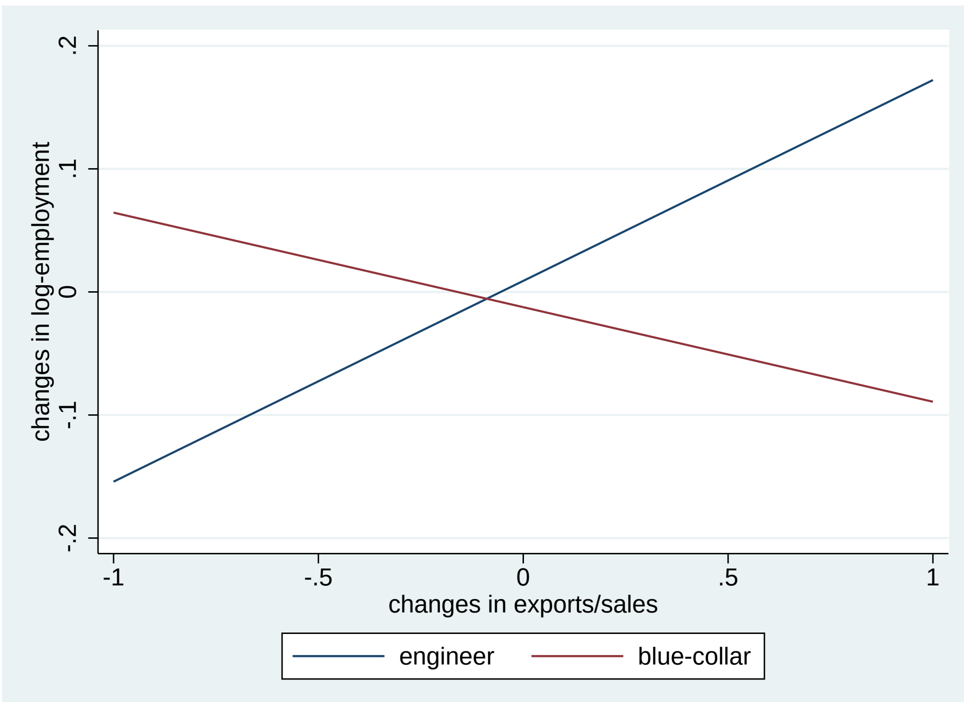
Note: Correlation between changes in changes in log employment and in export intensity (exports/sales) for skilled tasks, managers, engineers, and administrative services workers. The graph shows the slope of a OLS-FE regression between the reported variables.

Figure 7
Exports and the Demand of Unskilled Tasks



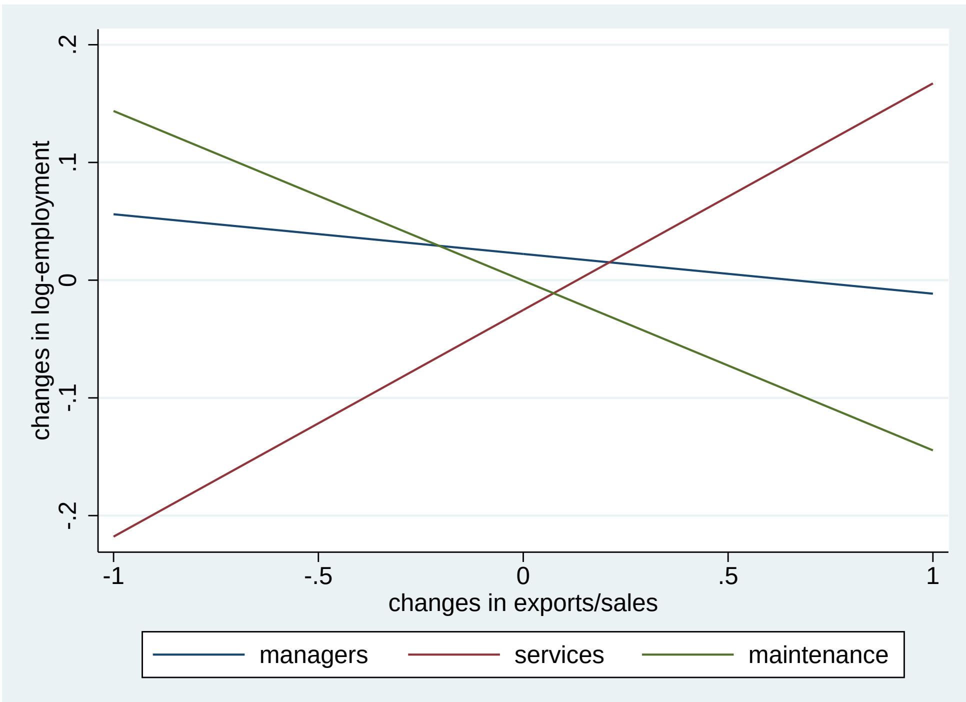
Note: Correlation between changes in changes in log employment and in export intensity (exports/sales) for unskilled tasks, blue-collar and general maintenance workers. The graph shows the slope of a OLS-FE regression between the reported variables.

Figure 8
Exports and the Demand of Production Tasks



Note: Correlation between changes in changes in log employment and in export intensity (exports/sales) for production tasks, engineers and blue-collar workers. The graph shows the slope of a OLS-FE regression between the reported variables.

Figure 9
Exports and the Demand of Non-Production Tasks



Note: Correlation between changes in changes in log employment and in export intensity (exports/sales) for non-production tasks, managers, administrative services workers, and general maintenance workers. The graph shows the slope of a OLS-FE regression between the reported variables.

Table 1
Summary Statistics
National Annual Industrial Survey
Chile 2001 - 2005

	All Firms	Exporters	Non-Exporters
A) Skilled and Unskilled Labor			
log skilled employment	2.37	2.47	2.36
log highly-skilled employment	1.78	1.91	1.77
log unskilled employment	2.88	2.88	2.87
share skilled employment	38.69	40.62	38.53
share highly-skilled employment	25.95	26.79	25.88
share unskilled employment	61.31	59.38	61.47
B) Production and Non-Production Labor			
log production employment	3.17	3.12	3.17
log non-production employment	2.03	2.16	2.02
share production employment	73.21	70.15	73.47
share non-production employment	26.79	29.85	26.53
C) Tasks			
log managerial employment	0.60	0.79	0.58
log engineering employment	1.22	1.36	1.21
log services employment	1.22	1.34	1.21
log blue-collar employment	2.71	2.72	2.71
log maintenance employment	0.46	0.48	0.46
share managerial employment	7.17	8.68	7.04
share engineering employment	18.78	18.11	18.84
share services employment	12.74	13.84	12.65
share blue-collar employment	54.42	52.04	54.63
share maintenance employment	6.88	7.33	6.85
D) Exports			
exports/sales	0.05	0.32	0.00

Source: averages calculated from the Encuesta Nacional Industrial Anual (National Annual Industrial Survey), Chile 2001-2005.

Table 2
The Demand for Tasks and Exports
(log employment)
OLS-FE

	(1)	(2)	(3)	(4)
A) Skilled and Unskilled Labor				
log highly-skilled	0.33***	0.19***	0.19**	0.19***
	(0.087)	(0.073)	(0.073)	(0.073)
log skilled	0.31***	0.16***	0.16***	0.16***
	(0.074)	(0.058)	(0.058)	(0.058)
log unskilled	0.11	-0.13	-0.13	-0.13
	(0.101)	(0.082)	(0.082)	(0.082)
B) Production and Non-Production Labor				
log production	0.27***	0.00	0.00	0.00
	(0.073)	(0.015)	(0.015)	(0.015)
log non-production	0.14**	0.03	0.03	0.03
	(0.056)	(0.041)	(0.041)	(0.041)
C) Tasks				
log managers	0.09	0.02	0.01	0.01
	(0.073)	(0.067)	(0.067)	(0.067)
log engineers	0.37***	0.22**	0.22**	0.22**
	(0.103)	(0.089)	(0.090)	(0.090)
log services	0.29***	0.16**	0.15**	0.15**
	(0.083)	(0.070)	(0.070)	(0.069)
log blue-collar	0.14	-0.11	-0.11	-0.11
	(0.111)	(0.093)	(0.093)	(0.093)
log maintenance	-0.15*	-0.20***	-0.20***	-0.20***
	(0.080)	(0.078)	(0.077)	(0.077)

Notes: OLS-FE regressions of (log) employment on export intensity (exports/sales). Column (1): firm fixed-effects and year fixed-effects; column (2): adds log total employment (firm size); column (3): adds controls for industry-specific trends (i.e., interactions between year dummies and industry dummies); column (4): adds initial conditions to control for firm-specific trends. Data are from the Encuesta Nacional Industrial Anual (National Annual Industrial Survey), Chile 2001-2005.

Table 3
First Stage Results
(exports /sales on z^0 and z^1)

	(1)	(2)	(3)	(4)
average real gdp	0.0877***	0.0880***	0.0885***	0.0879***
(z^0_{jt})	(0.0099)	(0.0098)	(0.0090)	(0.0088)
average real gdp * initial sales	0.0012*	0.0011*	0.0010*	0.0011*
($z^0_{jt} * s_{j0}$)	(0.0006)	(0.0006)	(0.0006)	(0.00068)
average real exchange rate	-0.0271	-0.0268	-0.0263	-0.0277
(z^1_{jt})	(0.0202)	(0.0201)	(0.0190)	(0.0189)
average real exchange rate * initial sales	0.0018	0.0018	0.0017	0.0018
($z^1_{jt} * s_{j0}$)	(0.0014)	(0.0014)	(0.0013)	(0.0013)
R^2	0.4682	0.4688	0.4682	0.4683
F-statistic	4703.13	4776.59	4954.79	5007.10
Prob > F	0.0000	0.0000	0.0000	0.0000

Notes: First-stage results of IV-FE regressions of (log) employment on export intensity (exports/sales). Column (1): firm fixed-effects and year fixed-effects; column (2): adds log total employment (firm size); column (3): adds controls for industry-specific trends (i.e., interactions between year dummies and industry dummies); column (4): adds initial conditions to control for firm-specific trends. Data are from the Encuesta Nacional Industrial Anual (National Annual Industrial Survey), Chile 2001-2005.

Table 4
The Demand for Tasks and Exports
(log employment)
IV-FE

	(1)	(2)	(3)	(4)
A) Skilled and Unskilled Labor				
log highly-skilled	0.45***	0.31***	0.31***	0.31***
	(0.127)	(0.101)	(0.102)	(0.102)
log skilled	0.41***	0.26***	0.26***	0.26***
	(0.108)	(0.079)	(0.079)	(0.079)
log unskilled	-0.07	-0.32***	-0.32***	-0.32***
	(0.120)	(0.123)	(0.123)	(0.123)
B) Production and Non-Production Labor				
log production	0.29***	0.02	0.02	0.02
	(0.091)	(0.017)	(0.018)	(0.018)
log non-production	0.10	-0.02	-0.03	-0.03
	(0.060)	(0.048)	(0.047)	(0.047)
C) Tasks				
log managers	-0.05	-0.12	-0.13	-0.13
	(0.107)	(0.099)	(0.099)	(0.099)
log engineers	0.55***	0.40***	0.40***	0.40***
	(0.152)	(0.126)	(0.127)	(0.127)
log services	0.25**	0.11	0.10	0.10
	(0.105)	(0.099)	(0.098)	(0.098)
log blue-collar	-0.07	-0.33**	-0.34**	-0.34**
	(0.132)	(0.137)	(0.137)	(0.137)
log maintenance	-0.03	-0.09	-0.09	-0.09
	(0.100)	(0.102)	(0.102)	(0.101)

Notes: IV-FE regressions of (log) employment on export intensity (exports/sales). The instruments are the weighted average the real exchange rate of a firm export partners and the weighted average of the real gdp of a firm export destinations. Column (1): firm fixed-effects and year fixed-effects; column (2): adds log total employment (firm size); column (3): adds controls for industry-specific trends (i.e., interactions between year dummies and industry dummies); column (4): adds initial conditions to control for firm-specific trends. Data are from the Encuesta Nacional Industrial Anual (National Annual Industrial Survey), Chile 2001-2005.

Table 5
The Demand for Tasks and Exports
(shares of employment)
IV-FE

	(1)	(2)	(3)	(4)
A) Skilled and Unskilled Labor				
share highly-skilled	0.08***	0.09***	0.09***	0.09***
	(0.029)	(0.030)	(0.030)	(0.030)
share skilled	0.07**	0.09***	0.09***	0.09***
	(0.029)	(0.031)	(0.031)	(0.031)
B) Production and Non-Production Labor				
share production	0.04***	0.01	0.01	0.01
	(0.012)	(0.009)	(0.009)	(0.009)
C) Tasks				
share managers	-0.01***	-0.00	-0.00	-0.00
	(0.005)	(0.005)	(0.005)	(0.005)
share engineers	0.09***	0.09***	0.09***	0.09***
	(0.030)	(0.030)	(0.030)	(0.030)
share services	-0.01	-0.00	-0.00	-0.00
	(0.007)	(0.007)	(0.007)	(0.007)
share blue-collar	-0.05*	-0.08***	-0.08**	-0.08***
	(0.029)	(0.031)	(0.031)	(0.031)
share maintenance	-0.01***	-0.01	-0.01	-0.01
	(0.005)	(0.004)	(0.004)	(0.004)

Notes: IV-FE regressions of employment shares on export intensity (exports/sales). The instruments are the weighted average the real exchange rate of a firm export partners and the weighted average of the real gdp of a firm export destinations. Column (1): firm fixed-effects and year fixed-effects; column (2): adds log total employment (firm size); column (3): adds controls for industry-specific trends (i.e., interactions between year dummies and industry dummies); column (4): adds initial conditions to control for firm-specific trends. Data are from the Encuesta Nacional Industrial Anual (National Annual Industrial Survey), Chile 2001-2005.