Firm Heterogeneity and Ricardian Trade: The Impact of Domestic Competition on Export Performance*

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Abstract

This paper develops a model of relative productivity differences both within and across industries. Residing in a relatively productive industry in a given country entails a key tension for a firm: this firm is likely to be relatively more productive than firms in other industries but so are its peer firms and potential competitors. In a sample of Chilean and Colombian firms, we find that, *conditioning on own-plant productivity*, higher productivity of peer firms in an industry reduces a firm's propensity to export and its volume of exports. This contradicts a small open economy version of the canonical model of firm heterogeneity. We rationalize these results by introducing industry-specific factors of production and non-standard product market competition that assumes varieties from within the same country are more substitutable than varieties from different countries. We find empirical evidence for each of these mechanisms.

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1 Introduction

Common models of comparative advantage imply that relatively more productive industries expand as countries open up to trade. The Ricardian model places its emphasis on the fact that these industries have access to a relatively superior technology level.[1] Models of firm heterogeneity examine a different margin in that firms can be divided into those that are competitive enough to export and those that are not. On the one hand, firms in comparative advantage industries thrive based on industry affiliation. On the other hand, the mechanism exposited in Melitz (2003) emphasizes within-industry productivity differentials as determinants of whether firms fail or thrive in response to trade liberalization.

This paper combines these two views by examining theoretically and empirically how firm performance depends not only on its own productivity, but also on whether it resides in its country's Ricardian comparative advantage industry. We summarize the question and the identification strategy with a simple thought experiment. Assume that comparative advantage is defined by average productivity across industries as in the Ricardian model, and that one country (Chile) possesses a comparative advantage in one industry (machinery) relative to other industries. If we consider two *equally productive* firms in machinery, one residing in Chile, one residing in Colombia, will the firm residing in Chile have superior, equal, or inferior export-related outcomes on World markets relative to the firm in Colombia? Because we look at productivity differences between Chile and Colombia in a given industry and compare that difference across industries, we examine comparative and not absolute advantage.

Using plant level data for Chile and Colombia for 1990 and 1991, we find that, *conditional on own productivity*, plants with relatively more productive domestic peer firms sell *less* at home and abroad and have a *lower* propensity to export. Because comparative advantage models maintain an assumption of a representative firm within an industry they are unable to address this question. As we show in this paper, existing models of firm heterogeneity that integrate comparative advantage predict that industry affiliation should have no impact on external performance after conditioning on own-firm characteristics. This is because while industry productivity might affect the domestic price level, it is unlikely that a small open economy can affect the World price level for an industry. Consequently, a basic model of firm heterogeneity makes the wrong prediction.

We focus on two modifications to the canonical model to rationalize our results. Specifically, we

[1] e.g. Dornbusch, Fischer, and Samuelson, 1977 and Eaton and Kortum, 2002.

focus on non-standard competition in product markets and in factor markets. We argue that relatively imperfect substitutability between foreign and domestic varieties and inclusion of industry-specific inputs are intuitively appealing ways of amending the canonical model to be consistent with the data. Because we do not depart substantially from the canonical model, we do not invoke technology "spillovers" nor any technology transfer.[2]

The product market competition channel relies on the simple proposition that two varieties produced within the same national border are more substitutable than two varieties produced in different countries. When a country possesses relatively higher productivity in a given industry, this will shift in the residual demand curve for all firms exporting in this industry but will shift it in more for firms producing relatively similar varieties than for firms producing less substitutable varieties. Our model offers a testable implication of this channel: this effect should be stronger in industries where domestic peer firms are more important than World competitors in determining the overall level of competition. We hypothesize that this is true for more differentiated products, where there is more scope for national differentiation. For differentiated goods such as wine, for example, it is plausible that producers face two distinctive tiers of competitors. Chilean wine varieties represent a more substitutable product with each other than with wines produced in other countries. Conversely, we posit that for very homogeneous goods, such as commodities, domestic competitors are just a subset of the relevant competitors a producer faces. For this type of good, having particularly productive domestic peers does not affect the performance of individual firms: what matters is competition in the World market. We find evidence of this channel: the effect of productivity of peer firms has a stronger negative impact for industries that are more differentiated using a classification introduced by Rauch (1999).

Examining factor market competition, higher relative productivity in an industry leads to a relatively higher wage of the specific factor associated with that industry. This increases the fixed and marginal costs of exporting leading to a lower probability of exporting and lower exports conditional on that firm's productivity level. In theory, industry-specific inputs can be thought of as factors of production that cannot easily be moved from industry to industry. These can be industry-specific knowledge of workers or physical capital that diminishes in capacity if moved from one industry to another.[3] We find evidence of this channel in the data, as the industry wage

[2]See Keller (2002) for a summary of the technology transfer literature literature.

[3]Ramey and Shapiro (2001) and Neal (1995) explore the specificity of capital and labor, respectively, and find such specificity to be important. In addition, Heckman and Pages (2000) look at labor market regulations in Latin America. They find that labor market regulations in Chile and Colombia make labor quite immobile due to extensive

negatively affects firm performance.

Examining and comparing productivity and export performance in Chile and Colombia is appropriate for two reasons. First, because we are working with detailed plant level data, we can verify that definitions of output, employment, and capital stock are comparable across countries. This will assist in the development of comparable measures of productivity across countries. Second, these two countries export in similar industries to similar markets and are likely to face similar competitive conditions in World markets based on their geographic location and level of development. Also, trade between Chile and Colombia is negligible relative to trade with the rest of the World which motivates our assumption of small open economies exporting to a large World market. From 1990-1991, Colombian exports to Chile comprise less than 1% of its total exports and Chilean exports to Colombia comprise less than 3% of its total exports. In contrast, exports to G7 countries, Brazil, and Argentina combined comprise 71.3% of Chilean exports and 63.4% of Colombian exports.[4]

Figure 1 plots Chilean and Colombian exports at the SITC one-digit level to their ten largest destination markets, normalized by World exports to that destination in that industry. An upward sloping relationship suggests that these two countries compete in similar countries and industries.

Section 2 briefly reviews the literature that we draw upon and derives aspects of the canonical model against which we contrast our framework. Section 3 presents the model. Section 4 describes the data, offers empirical evidence, and offers a strategy to distinguish the two channels. Section 5 concludes.

2 Relation to the Literature

Our model integrates elements of two established literatures: one that examines industry-level Ricardian productivity differences as a force for comparative advantage and another that models heterogeneous firms. While the Ricardian model has experienced a renaissance recently with the work of Eaton and Kortum (2002) and Costinot and Komunjer (2009), this literature has not asked how one can think about the interaction of existing heterogeneity both within and across industries. The literature on firm heterogeneity (e.g. Bernard, Eaton, Jensen, and Kortum, 2003, Melitz, 2003

hiring and firing costs based on seniority.

[4]IMF Direction of Trade Statistics Database (2008). In addition, while both countries experienced substantial macro-economic turbulence associated with the Latin American debt crisis, much of this turbulence had subsided by 1990.

and Melitz and Ottaviano, 2008) models heterogeneous firms in a given industry but does not ask how firms respond to residing in comparative advantage or disadvantage industries. Notable exceptions include Demidova (2008) and Okubo (2009). However, these papers do not examine the empirical validity of their predictions.

We also note the similarities and differences between this work and voluminous literature on "spillovers."[5] Generally, work in this tradition looks at the effect of peer performance on firm or plant outcomes and is quite mixed in its results (e.g. Clerides, Lach, and Tybout, 1998). This paper differs from much of that literature in that we do not examine technology transfer nor any sort of knowledge spillovers; all inputs are paid based on competitive factor markets and there are no externalities. In addition, our thought experiment is quite different. Many papers on spillovers are concerned with how peer firms affect the characteristics of "target" firms. In our paper, we are deliberately holding the characteristics of firms constant and changing the competitive pressures they face given the composition of their peer firms.[6]

We now briefly sketch the elements of a canonical firm heterogeneity model for small open economies exporting to a common market to illustrate its empirical predictions with which we contrast our results. Suppose that one of multiple small open economies exports to a large "World" market. Assume that any small open economy examined is small enough that it does not affect the World equilibrium. Market structure is Dixit-Stiglitz with an elasticity of substitution across varieties of $\sigma > 1$ where each firm produces a unique variety. The parameter σ governs the substitutability across varieties and does not vary depending on whether one is comparing two varieties from the same country or two varieties from different countries; ϕ_{fic} represents productivity for firm f in industry i in country c; w_c is a country-specific wage. A firm's revenue from exports to the World can be described using a revenue function where A_i is a demand shifter in the World market that each small open economy takes as given:[7]

$$r_x(\phi_{fic}) = A_i \left[\frac{\rho \phi_{fic}}{\tau w_c} \right]^{\sigma - 1}.$$

[5] We refer to "spillovers" because it is often nearly impossible to distinguish whether any technology or knowledge transfer is truly an externality or if it is priced through the market-based transactions be they through workers, blueprints, or other means.

[6] In this way, our paper resembles Aitken and Harrison (1999) who find a negative impact of foreign direct investment on firms *who are not the targets of the investment*.

[7] $A_i = \frac{E_i}{P_i^{1-\sigma}}$ where E_i is World expenditure in industry i and P_i is the CES price index, τ represents iceberg transportation costs, and $\rho = \frac{\sigma - 1}{\sigma}$. Similar notation is used by Helpman, Melitz, and Yeaple (2004).

Consequently, relative export revenue from the World market for two firms in different countries but the same industry is as follows, where we assume that countries c and c' face the same iceberg transportation costs:

$$\frac{r_x(\phi_{fic})}{r_x(\phi_{f'ic'})} = \left[\frac{\phi_{fic} w_{c'}}{\phi_{f'ic'} w_c}\right]^{\sigma-1}.$$

In this case, industry productivity should have *no effect* on relative export performance as relative demand is determined by firm- and country- but not industry-country-level characteristics. We refer to this as the prediction of the "baseline model" in the small open economy case.[8]

Alternately, Demidova (2008) presents a rich North-South model that predicts that industry productivity in the country where the firm resides should have a *positive* effect on exporting probability conditional on own firm productivity. If the Northern market is filled with relatively productive firms, this will dampen the incentive for Southern firms to enter the export market, leading to a lower rate of entry in the South, and less competitive conditions for the reasons exposited in Melitz (2003). This will then provide greater incentive for Northern firms to export to the South. This will result in Northern industry productivity having a *positive* effect on the probability of exporting conditional on firm and country characteristics. We do not believe that the model of Demidova (2008) is incorrect or misleading. Rather, we believe that it is simply inappropriate in this context of two small open economies exporting to a large common market given the rich general equilibrium interactions in her model.

Bernard, Redding, and Schott (2007) present a two-industry, two-country model with Heckscher-Ohlin based comparative advantage and firm productive heterogeneity. In their model, entry into the comparative advantage industry causes endogenous Ricardian productivity to be higher in that industry. As long as the fixed costs of exporting are in the same factor proportions as variable costs of production, the minimum productivity necessary for exporting will be lower in the comparative advantage industry that in the other industry as fixed and marginal costs will be lowest in the industry what uses the relatively abundant factor relatively intensively. Consequently, their model predicts that, conditional on firm productivity, industry productivity should be positively correlated with the probability of exporting.

We now present our framework. This model is consistent with the empirical evidence presented in Section 4 that industry productivity has a *negative* effect on plant level outcomes both at home

[8] We can also derive a similar result for the probability of exporting. In a small open economy model, the relative "cutoffs" for exporting will depend on firm- and country- but not industry-country effects.

and abroad.

3 Model

The preferences of a representative consumer in country c are defined over three aggregates of differentiated goods according to a Cobb-Douglas utility function:

$$U_c = \prod_{i=0}^{2} Q_{ic}^{\alpha}$$

where Q_{ic} is the nested CES aggregator for industry i. Specifically Q_{ic} takes the following form:

$$Q_{ic} = \left[\sum_{c' \in C} \left[\left(\int_{\omega \in I_{ic'}} q_{ic}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \right]^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \quad \text{with } \sigma > 1, \epsilon > 1$$

where c is the consuming country, c' is the producing country, i is the industry, and ω indexes varieties. C is the set of all countries from which c consumes. We allow the substitutability between varieties in a given industry to depend on whether these varieties are produced in the same country or in different countries. In particular, we indicate by σ the elasticity of substitution between two varieties produced in the same country while ϵ is the elasticity of substitution between the CES aggregates of varieties produced by different countries.

Home produces, consumes and exports goods 1 and 2. Good 0 is imported from the rest of the World to balance trade.[9] Varieties in industry i are produced with labor, freely mobile across industries, and a factor specific to industry i, that we denote by K_{ic} and earns return s_{ic}. This specific factor can be physical or human capital or any factor of production that is immobile over the time span considered. The labor endowment of the economy is equal to L_c. Each worker earns a wage w_c.

Within each industry i, there is continuum of firms, each producing a different variety, and characterized by a productivity level denoted by ϕ as in Melitz (2003). A firm with productivity ϕ

[9] This assumption aims at minimizing general equilibrium effects across industries. Good 0 is not a homogenous good introduced to pin down the wage level.

produces quantity q and faces the following homothetic total cost function:

$$TC_{ic}(q,\phi) = \left(f + \frac{q}{\phi}\right) w_c^{1-\eta} s_{ic}^{\eta}$$

where f is a fixed cost and η is the share of costs spent on the specific factor K_{ic}. The higher ϕ is, the lower total costs of producing quantity q. The parameter η is restricted to be the same across industries. We normalize w_c to one for this country.[10]

We introduce Ricardian productivity differences by allowing the distribution of productivity draws to vary across both countries and industries. We follow a large number of papers (e.g. Chaney (2008) and Helpman, Melitz, Yeaple, 2004) in assuming that, within each industry i, the productivity parameter ϕ follows a Pareto distribution with parameters k and $\phi_{m,ic}$. The cumulative density function of parameter ϕ is therefore:

$$G_{ic}(\phi) = 1 - \left(\frac{\phi_{m,ic}}{\phi}\right)^k. \tag{1}$$

The parameter $\phi_{m,ic}$, which we allow to vary across industries and countries, represents the lower bound of the support of the distribution.[11] Therefore in a industry with higher $\phi_{m,ic}$, firms draw from a distribution with a higher average productivity. This is the source of Ricardian productivity differences in our model.

We allow for free entry into each industry i. Firms must pay a fixed cost $f_e s_{ic}^{\eta}$ to draw a level of productivity in industry i. Once firms observe their level of productivity they can produce or, if the productivity parameter is too low, exit without producing. If they decide to produce, then each year they face an exogenous probability of exiting the market δ. We consider the steady-state equilibrium where entry is equal to exit in each industry and aggregate industry-wide variables are constant. Therefore in the steady state a prospective entrant can expect a constant profit each year, conditional on surviving.

Upon drawing a productivity level ϕ, a firm makes two decisions. First, it decides whether to produce or not for the domestic market where profits are:

$$\pi_{d,ic}(\phi) = \frac{\alpha E_c}{\sigma}\left(\frac{s_{ic}^{\eta}}{P_{ic}\rho\phi}\right)^{1-\sigma} - f s_{ic}^{\eta}.$$

[10] Note that productivity asymmetries will prevent us from normalizing the wage of the mobile factor to 1 in all countries.

[11] We restrict $k > \sigma - 1$ to ensure that all integrals converge.

We indicate by $\phi_{d,ic}$ the productivity threshold for domestic production. The threshold $\phi_{d,ic}$ is such that profits in the domestic market of a firm with that level of productivity, $\pi_{d,ic}(\phi_{d,ic})$ are zero. Firms with productivity below $\phi_{d,ic}$ exit immediately. Firms with productivity above $\phi_{d,ic}$ continue to operate. Second, the firm decides whether to export or not. Firms that export have to bear an additional fixed cost $f_x s_{ic}^{\eta}$ and a per-unit iceberg transport cost. For each unit sold abroad, a firm must ship τ units, with $\tau > 1$. We indicate by $\phi_{x,ic}$ the threshold for exporting. The threshold $\phi_{x,ic}$ is such that profits in the foreign market for a firm with that level of productivity, $\pi_{x,ic}(\phi_{x,ic})$, are zero. Firms with productivity below $\phi_{x,ic}$ do not export. Since marginal costs are constant in the quantity produced, the two decisions are independent.

Since the focus of the empirical section is on a small open economy, we consider a partial equilibrium setting, where the World represents an export market for firms in the country, but the country is too small to affect aggregate variables in the World market.[12] We impose that imports from the World are zero in industries 1 and 2 because we are not interested in differences across industries coming from differential import penetration. The focus of the paper is on understanding exporting behavior of firms in a small open economy characterized by productivity differences across industries and we aim to simplify the other elements of the model as much as possible.

Revenues in the World market for an exporting firm with productivity ϕ in industry i are as follows, where we absorb the top-tier CES price index into the industry constant A_i:

$$r_{x,ic}(\phi) = A_i \left(\frac{\tau s_{ic}^{\eta}}{\rho \phi} \right)^{1-\sigma} (P_{x,ic})^{\sigma-\epsilon} \tag{2}$$

where $P_{x,ic}$ is the price index associated with varieties supplied by country c in industry i on *World* markets. World market conditions, A_i, are not affected by firms' export decisions in country c, due to the small open economy assumption.[13]

The free entry condition for industry i is summarized by the following equation, which states that, conditional on producing (drawing a productivity parameter higher than $\phi_{d,ic}$), the expected

[12] In Melitz (2003) the analysis considers many symmetric countries, with each country exporting to and importing from every other country. Demidova (2008) and Okubo (2009) consider a World consisting of two asymmetric countries trading with one another. Their setup is appropriate to analyze the interaction among large countries.

[13] $A_i = E_i(P_i)^{1-\sigma}$ where P_i is the World price index over all varieties from all source countries and E_i is World expenditure in industry i. All exporting countries face the same P_i on World markets.

stream of profits is equal to the entry cost:

$$[1 - G(\phi_{d,ic})] \frac{\overline{\pi}_{ic}}{\delta} = f_e s_{ic}^{\eta}, \tag{3}$$

where $\frac{\overline{\pi}_{ic}}{\delta}$ is the discounted constant expected profit. The expected profit is comprised of sales in the domestic market, where expected profits are $\overline{\pi}_{d,ic}$, and sales in the foreign market, where expected profits are $\overline{\pi}_{x,ic}$, weighted by the probability of exporting:

$$\overline{\pi}_{ic} = \overline{\pi}_{d,ic} + \underbrace{\frac{1 - G(\phi_{ix})}{1 - G(\phi_{id})}}_{p_{x,ic}} \overline{\pi}_{x,ic} \tag{4}$$

where $p_{x,ic}$ represents the probability of exporting.

Expected profits in each market coincide with the profits of a firm characterized by composite productivity level, where this composite for firms producing in the domestic market, $\overline{\phi}_{d,ic}$, is defined as $\overline{\phi}_{d,ic}^{\sigma-1} = \frac{1}{1-G(\phi_{d,ic})} \int_{\phi_{d,ic}}^{\infty} \phi^{\sigma-1} g(\phi)\, d\phi$ and the composite productivity of exporting firms, $\overline{\phi}_{x,ic}$, is defined analogously.

The zero profit cutoff conditions $\pi_{d,ic}(\phi_{d,ic}) = 0$ and $\pi_{x,ic}(\phi_{x,ic}) = 0$, yield the following relationships between the cutoffs, industry specific wages, and average profits in the domestic and foreign markets:

$$\overline{\pi}_{d,ic} = s_{ic}^{\eta} f \left[\left(\frac{\overline{\phi}_{d,ic}}{\phi_{d,ic}} \right)^{\sigma-1} - 1 \right], \tag{5}$$

$$\overline{\pi}_{x,ic} = s_{ic}^{\eta} f_x \left[\left(\frac{\overline{\phi}_{x,ic}}{\phi_{x,ic}} \right)^{\sigma-1} - 1 \right]. \tag{6}$$

In Melitz (2003) $\phi_{x,ic}$, $\overline{\phi}_{d,ic}$, and $\overline{\phi}_{x,ic}$ are functions of the domestic cutoff $\phi_{d,ic}$.[14] Therefore the four equations (3), (4), (5) and (6) uniquely determine the equilibrium cutoffs and the mass of firms is determined residually in a two-step procedure.[15] In our case, because of the lack of symmetry between the domestic market and the World market, the cutoffs are determined simultaneously with the mass of firms. This is because both the mass of firms and the cutoffs are partially determined

[14] See equation (19) on page 1711 of Melitz (2003). This condition holds only under symmetry, otherwise total expenditure and price indices are not the same across countries and the relationship between exporting and domestic cutoff depends on endogenous variables.

[15] The mass of firms is determined employing the condition that, in the absence of profits, total revenues are equal to total labor income.

by the return to the specific factor.

To solve for the equilibrium we employ a industry-specific factor market clearing condition. In the steady state the free-entry condition guarantees that there are no pure profits (positive profits of operating firms are equal to the total cost of entry into the market), so that firms' revenues are split between the mobile factor and the specific factor, with a share η earned by the specific factor. Aggregating up to the entire industry i, the following equation states that a share η of total revenues in industry i are paid to K_{ic}:

$$\eta M_{ic}\overline{r}_{ic} = s_{ic}K_{ic} \tag{7}$$

where $\overline{r}_{ic}$ are the expected revenues of a firm operating in industry i.

Consider now a second small open economy c' exporting to a large World market. We assume that the two countries do not export to each other and that they only export to a common third market, facing the same transport costs.[16] We allow the two countries to differ in size, both in terms of population and specific factor endowments. We assume that the countries productivity distributions are such that country c' has a comparative advantage in industry 1 while country c has a comparative advantage in industry 2. Specifically, we assume, without loss of generality, that

$$\frac{\phi_{m,1c}}{\phi_{m,2c}} < \frac{\phi_{m,1c'}}{\phi_{m,2c'}}. \tag{8}$$

The question that we address is whether, given individual firm productivity, firms in industry 1 in country c are more or less likely to export than firms in industry 2, relative to firms in these two industries in country c'. In this model this question is equivalent to investigating whether $\frac{\phi_{x,1c}}{\phi_{x,2c}} \gtreqless \frac{\phi_{x,1c'}}{\phi_{x,2c'}}$. Since the revenues of the least productive exporting firm in c can be expressed as $r_{x,ic}(\phi_{x,ic}) = \sigma f_x s_{ic}^{\eta}$ and a similar expression holds for country c', then the ratio between the revenues of two marginal exporting firms in c and c' is given by $\frac{s_{ic}^{\eta}}{w_{c'}^{1-\eta}s_{ic'}^{\eta}}$.[17] Using the expression for export revenues in equation (2), the relationship between the export cutoffs in the two countries in industry i is then given by the following equation:

$$\frac{\phi_{x,ic}}{\phi_{x,ic'}} = \left[\frac{P_{x,ic}}{P_{x,ic'}}\right]^{\frac{\epsilon-\sigma}{\sigma-1}} \left[\frac{w_c^{1-\eta}s_{ic}^{\eta}}{w_{c'}^{1-\eta}s_{ic'}^{\eta}}\right]^{\frac{\sigma}{\sigma-1}}. \tag{9}$$

[16] Recall that in our sample, Chile and Colombia export to each other in small values.

[17] This relationship derives from the fact that $\pi_{x,ic}(\phi_{x,ic}) = \frac{r_{x,ic}(\phi_{x,ic})}{\sigma} - f_x s_{ic}^{\eta}$.

Notice that, holding $\frac{P_{x,ic}}{P_{x,ic'}}$ constant, the larger the relative return to the specific factor in industry i, the higher the relative exporting cutoff.

We now assume that $\sigma > \epsilon$ such that varieties produced in the same country are more substitutable than varieties produced in different countries.[18] We do this for two reasons: first, it offers a method to test an alternative hypothesis to the specific factors model. Second, it is not hard to believe that at this high level of aggregation, baskets of goods will be more comparable within borders than across borders. Holding factor prices constant, the country with a relatively lower CES price index for its exports will have a higher exporting cutoff if domestic varieties are more substitutable than a domestic and a foreign variety ($\epsilon < \sigma$). The opposite will hold if two domestic varieties are less substitutable than a domestic and a foreign variety.[19] Because we are interested in the effect of being in the comparative advantage industry on relative export performance across industries and countries, we take the ratio of (9) across the two industries 1 and 2 and rearrange to obtain the following relationship between relative export cutoffs and relative specific factor returns across:

$$\frac{\phi_{x,2c}/\phi_{x,2c'}}{\phi_{x,1c}/\phi_{x,1c'}} = \left[\frac{s_{2c}/s_{2c'}}{s_{1c}/s_{1c'}}\right]^{\frac{\eta\sigma}{\sigma-1}} \left[\frac{P_{x,1c}/P_{x,2c}}{P_{x,1c'}/P_{x,2c'}}\right]^{\frac{\sigma-\epsilon}{\sigma-1}} \tag{10}$$

Assumption 1 Within each country c each industry i is endowed with the same amount of specific factor: $K_{ic} = K_c \ \forall i, c$.[20]

We now derive two propositions that will motivate our empirical work. The first proposition shows that for a country possessing a comparative advantage in a given industry, the relative specific factor price is relatively higher in that industry. The second proposition shows that the ratio of export price indexes is relatively lower in a country's comparative advantage industry than in that country's comparative disadvantage industry.

Proposition 1 *If* $\frac{\phi_{m,1c}}{\phi_{m,1c'}} < \frac{\phi_{m,2c}}{\phi_{m,2c'}}$ *then the relative return to the specific factor in c is higher in*

[18] This assumption is similar to the Armington (1969) assumption that goods are perfectly substitutable if they are produced in the same country but are differentiated by source country.

[19] Naturally, the price index will depend on the wages of the factors employed in that industry but, to the extent that these wages do not cancel out with the relative factor prices in the second bracket (which they do do not), we find equation (8) to be useful for partially decomposing factor market and product market competition.

[20] This assumption is made for analytical tractability. In the long run, as specific factors migrate to the sector with the highest return, there should be no effect of industry productivity on export-related performance as the factor price equates across industries.

industry 2 *than in industry* 1 *, compared to* c'*, i.e.*

$$\frac{s_{1c}}{s_{1c'}} < \frac{s_{2c}}{s_{2c'}}$$

Proof. In Appendix. ■

Proposition 2 *If* $\epsilon < \sigma$ *and* $\frac{\phi_{m,1c}}{\phi_{m,1c'}} < \frac{\phi_{m,2c}}{\phi_{m,2c'}}$*, then the ratio of relative export price indexes will be less in country* c' *than in* c *such that*

$$\frac{P_{x,1c}}{P_{x,2c}} > \frac{P_{x,1c'}}{P_{x,2c'}}$$

Proof. In Appendix. ■

The intuition for these results is simple. First, as firms in a industry draw from a productivity distribution with a higher average, firms in the industry are on average more productive, produce more and have a high demand for the specific factor, which is available in fixed amount. Higher demand for this input's services drives up the return to the specific factor. Second, if $\epsilon < \sigma$, then a relatively productive group of peer firms will shift the residual export demand curve "in" more for other domestic firms than for foreign firms in export markets for the same industry. Everything else equal, a firm in a relatively more productive industry is less likely to be able to cover the fixed cost of exporting, reducing its probability of exporting. This is stated and proven in Proposition 3.

Proposition 3 *If* $\sigma > \epsilon$ *and* $\frac{\phi_{m,1c}}{\phi_{m,1c'}} < \frac{\phi_{m,2c}}{\phi_{m,2c'}}$ *then the ratio of export cutoffs will be less in country* c' *than in* c *such that*

$$\frac{\phi_{x,1c}}{\phi_{x,1c'}} < \frac{\phi_{x,2c}}{\phi_{x,2c'}}$$

Proof. The result follows from Propositions 1 and 2 and equation 10. ■

The same mechanism explains why firms in comparative advantage industries export less, for a given level of productivity. The following proposition establishes the result that, conditional on exporting, export revenues are relatively higher for Home firms in industry 1 than in industry 2, compared to Foreign, conditional on own firm productivity.

Proposition 4 *If* $\frac{\phi_{m,1c}}{\phi_{m,1c'}} < \frac{\phi_{m,2c}}{\phi_{m,2c'}}$*, then, given its productivity level* ϕ_0*, a firm in* c *has higher export revenues in industry* 1 *than in industry* 2*, compared to* c'*, i.e.*

$$\frac{r_{x,1c}(\phi_0)}{r_{x,1c'}(\phi_0)} > \frac{r_{x,2c}(\phi_0)}{r_{x,2c'}(\phi_0)}$$

Proof. We employ the definition of export revenues in (2) to find the following relative export performance measure across industries and countries:

$$\frac{r_{x,1c}(\phi_0)}{r_{x,1c'}(\phi_0)} / \frac{r_{x,2c}(\phi_0)}{r_{x,2c'}(\phi_0)} = \left[\frac{s_{1c}}{s_{1c'}} / \frac{s_{2c}}{s_{2c'}}\right]^{\eta(1-\epsilon)} \left[\frac{P_{x,1c}}{P_{x,2c}} / \frac{P_{x,1c'}}{P_{x,2c'}}\right]^{\sigma-\epsilon}$$

Since we showed in propositions (1) and (2) that $\frac{s_{1c}}{s_{1c'}} / \frac{s_{2c}}{s_{2c'}} < 1$ and $\frac{P_{x,1c}}{P_{x,1c'}} / \frac{P_{x,2c}}{P_{x,2c'}} > 1$, and we assumed that $\epsilon > 1$ and $\epsilon < \sigma$, then the result follows. ■

Proposition 4 suggests that, conditional on own productivity, firms in comparative advantage industries should have lower levels of exports due to higher industry-specific wages (s_{ic}) and relatively low prices by competing exporters ($P_{x,ic}$). Log-linearizing equation (2) offers a first step towards our empirical specification:

$$\ln r(\phi_{fic}) = \ln A_i + (\sigma - 1)\ln \phi_{fic} + (\epsilon - \sigma)\ln P_{x,ic} + (1-\epsilon)\left[\eta \ln s_{ic} + (1-\eta)\ln w_c)\right]. \tag{11}$$

Proposition 1 suggests that s_{ic} is an increasing function of productivity while Proposition 2 shows that $P_{x,ic}$ is inversely related to productivity. For simplicity, we assume that $\ln s_{ic} = \Psi \ln \phi_{ic}$ $\ln P_{x,ic} = \Lambda \ln \phi_{ic}$. We can then rewrite equation (11) as:

$$\ln r(\phi_{fic}) = \ln A_i + (\sigma - 1)\ln \phi_{fic} + [\Lambda(\epsilon - \sigma) + (1-\epsilon)\eta\Psi]\ln \phi_{ic} + (1-\epsilon)(1-\eta)\ln w_c + \nu_{fic} \tag{12}$$

where ν_{fic} represents a random disturbance. The next section examines the empirical validity of equation (12), that industry productivity affects firm performance, and subsequently explores the separate contributions of product market and factor market competition.

4 Empirical Results

This section explores the empirical predictions of Section 3 that, *controlling for own productivity*, a plant in a comparative advantage industry has a lower probability of exporting and exports lower volumes. Section 4.1 describes the data employed and our measures of productivity. Section 4.2 presents empirical results that are inconsistent with the baseline model of firm heterogeneity. Section 4.5 explores the robustness of our results. Section 4.3 explores the factor market and product market competition channels between industry-level productivity and plant-level outcomes,

conditional on own plant productivity.

4.1 Data

Plant-level data come from the statistical agencies *Instituto Nacional de Estadistica* and *Departmento Administrativo Nacional de Estadistica* for Chile and Colombia, respectively. These data have been used extensively in the trade literature.[21] Industry affiliation is at the ISIC (Rev. 2) 3-digit level. Because plant-level exports are only available for Chile *starting* in 1990 and the Colombian export data is available *until* 1991, we only use 1990 and 1991 in our analysis. Table 1 presents summary statistics for the data including the total number of observations in each year and the country composition of each industry.[22] Due to the respective sizes of the countries, approximately 70% of the observations are for Colombian plants and the remainder are Chilean.

The focus of this study is on plant- and industry-level productivity. Because of difficulties in comparing capital stocks across countries, our preferred specifications use value added per worker as a measure of productivity. In order to compare productivity differences across countries, we ensure that the data are comparable.[23] We want to remove non-productivity related relative price differences in output. To do so we use 3-digit output deflators from the central bank of each country to put all output data in 1980 constant country-specific pesos for each country. We then use the average December exchange rate for 1980 in each country to transform output in each industry into non-PPP adjusted 1980 U.S. dollars.[24] Finally, we use constructed disaggregated 1980 PPP price indexes from the Penn World Tables to transform these values into PPP adjusted 1980 U.S. dollars. We construct these PPP price indexes at the 3-digit ISIC level. Because these deflators are country-industry specific, they will control for price differences that are not controlled for by the separate introduction of country and industry fixed effects. See the Data Appendix for more details. Because of our difference-in-difference strategy, all (multiplicative) country-specific and industry-specific terms in productivity (and all outcome variables) will be differenced out. In the robustness section, we examine measures of total factor productivity that also take differences in

[21] E.g. Tybout and Roberts (1996), Levinsohn (1993), Hsieh and Parker (2007), Levinsohn and Petrin (2003, 2009), Hallak and Sivadasan (2009).

[22] We drop industries related to tobacco and petroleum refining. (ISIC 314, 353, and 354).

[23] We have ensured that the plant level measures of output, value added, employment, and investment aggregate to virtually the same numbers as the UNIDO 3-digit data set which has been used widely to conduct cross country studies e.g. Antweiller and Trefler (2002), Hanson and Xiang (2004), and Morrow (2008).

[24] We put prices in PPP adjusted 1980 real dollars because this is the year for which the Penn World Tables provides the finest level of disaggregation in terms of the number of goods.

capital intensity across firms and industries into account.

To create measures of value added per worker, we also need to create measures of labor input. For each country, skilled and unskilled workers are proxied by non-production and production workers. We have verified that unskilled and skilled labor are similarly defined across Chile and Colombia. Production and non-production workers are weighted by their shares in the total wage bill by country and industry to create a Cobb-Douglas composite labor input.

Industry value added per worker is measured as the weighted arithmetic average of plant level value added per worker within that ISIC 3-digit industry-country-year panel where the weights correspond to value added.[25] Because a small number of plants in an industry-country panel might lead to a collinearity problem between the plant and industry productivity measures, we drop industries with less than 25 plants in either country.[26] An analysis of variance reveals that 16% of the overall variation in value added per worker across plants and industries is explained by differences across industries with the remaining 84% due to within industry variation. To partially mitigate measurement error in the productivity measures, we instrument for plant-level value added per worker using its one year lagged value for the same plant. In the robustness section we also examine measures of total factor productivity.

4.2 Results

We now present the empirical results that test our model and discuss how they contrast with the baseline model. In the following specifications observations are indexed by plant (f), industry (i), country (c). Given that all of our predictions are cross sectional, we suppress the time subscript t for the moment. As a domestic performance benchmark, equation (13) estimates value added (va_{fic}) as a function of plant and industry productivity:

$$va_{fic} = \beta_{plant}\phi_{fic} + \beta_{ind}\phi_{ic} + \beta_{chile}C_c + \beta'_{ind}\Delta_i + \epsilon_{fic}, \tag{13}$$

where ϕ_{fic} and ϕ_{ic} are plant and industry level productivity, C_c is a binary variable taking a value of 1 for Chilean plants and 0 for Colombian plants, and Δ_i is a vector of industry-specific fixed effects that control for factors including but not restricted to World demand and scale at the industry

[25] Results are unchanged when we take a geometric instead of an arithmetic mean.

[26] This leads to us droping ISICs 361, 362, 371, and 372. Eslava et al. (2009) make an identical restriction on industry size.

level. This vector also transforms all productivity related variables into deviations from the cross-country within-industry mean. All standard errors are heteroskedasticity consistent and clustered at the country-industry level to correct for the repeated values of industry productivity for each plant within the industry.

Table 2 presents results for equation (13). As expected from numerous firm/plant level studies, plant productivity is a very strong determinant of value added at the plant level. Conditional on plant productivity, industry productivity is estimated to have a *negative* effect on plant production where this estimate is significantly different from zero at least at the 5% level of significance. This suggests that higher productivity peer firms shift in the residual demand curve for plants selling domestically.

Equation (14) is where we start to explore the novel implications of our model. This expression estimates a similar relationship for the probability of exporting:

$$Pr\left(EXP_{fic} > 0\right) = F\left(\beta_{plant}\phi_{fic} + \beta_{ind}\phi_{ic} + \beta_{chile}chile_c + \beta'_{ind}\Delta i\right) + \nu_{fic}, \tag{14}$$

where $F(\bullet)$ is the logit operator for export participation. Results are presented in table 3. Standard errors are clustered by country-industry as before. We also estimate linear probability of exporting models for ease of interpretation. Own-plant productivity has a positive effect on the probability of exporting while industry productivity has a negative effect. Under the baseline model of firm heterogeneity with small open economies, the coefficient on industry productivity for exporting probability should be zero as wages will be country- and not country-industry specific and all CES price indexes on World markets will be controlled for by industry-specific fixed effects.[27]

For most specifications we can reject the null that the coefficients for ϕ_{fic} and ϕ_{ic} are equal and opposite in sign. Consequently, the country possessing a Ricardian comparative advantage in an industry will have superior outcomes if there is no firm productivity heterogeneity. More precisely, if $|\beta_{plant}| > |\beta_{ind}|$, the positive effect of higher productivity will not be completely undone by higher factor prices and tougher product market competition if all firms in an country-industry panel have identical productivity. For a given industry, plants in that country will then possess

[27] For all regressions, we have experimented with weighted least squares estimation with weights corresponding to firm and/or industry size. The point estimates and standard errors change negligibly. In addition, it is not obvious that we want to place less weight on small firms (if we weight by size) because these are the firms who are most likely to suffer from having large competitive firms in their same industry-country panel. Aitken and Harrison (1999) make a similar point.

superior outcomes relative to plants in the other country who draw from a productivity distribution that has a lower minimum draw and lower average productivity.

The magnitudes in the linear probability model suggest that if plant productivity doubles holding productivity of peer firms constant, that plant's probability of exporting increases by 15.7 to 19.5 percentage points for 1990 and 1991, respectively. If the productivity of peer firms doubles holding productivity constant for a given plant, that plant's probability of exporting falls 8.5% to 14.3% for 1990 and 1991, respectively. Finally, if the productivity of all firms in an industry doubles, the probability of exporting for a representative firm increases by 7.2% to 5.2% for 1990 and 1991, respectively.

Tables 4 and 5 decompose the value of production into domestic sales and exports where domestic sales are defined as the value of production minus exports. This allows us to see if and how superior distributions of productivity affect domestic and external performance differentially. The qualitative results from Tables 2 and 3 continue to hold for both domestic and foreign sales.[28] Own plant productivity increases sales while the productivity of other plants in the industry diminishes sales both at home and abroad. While the sign on industry productivity is of the sign predicted by theory for both years, the results for 1990 are indistinguishable from zero for export levels. These results become stronger when we look at total factor productivity measures of productivity and when we explicitly examine the product and factor market competition channels in section 4.3.

Figures 2-4 present this information graphically. In each graph, we purge the left-hand side variable from Tables 2, 3, and 5 of plant productivity and the fixed effects listed. We then purge industry-level productivity of the same variables. Finally, we collapse the left hand side variables down to their industry-year-country means and transform them into Chilean relative to Colombian values. Finally, we plot them against Chilean relative to Colombian industry productivity. Data in the figures are pooled for the years 1990 and 1991.[29] Visual inspection suggests that no single industry or small group of industries is responsible for the patterns in the regressions results.

Although the mechanisms exposited in the firm heterogeneity literature take a strong stand that productivity causes exporting, the empirical literature is slightly more nuanced.[30] We stress that

[28] There are slightly fewer observations for domestic revenue than total revenue because of a small number of firms that export but do not sell domestically.

[29] As a note, the outlier ISIC 312 contains miscellaneous food products which is less likely to be comparable across countries due to its "bag" nature.

[30] Bernard and Jensen (1997) find strong evidence of the sorting into exporting of the most productive firms. Conversely, Van Biesebroeck (2005) and De Loecker (2007) find evidence of increased productivity due to exporting. Trefler (2004) finds evidence of productivity gains both within firms and due to reallocation across firms in Canada

the variable we are most interested in is *industry* and not plant productivity in these estimations. Although if plant productivity suffers from endogeneity due to reverse causation, the impact on the industry coefficient is not obvious. To address these concerns, we have estimated the regressions in this paper using industry productivity excluding the plant in question. Nearly identical results hold. In these specifications, arguments about the endogeneity of productivity in the cross section are less relevant. This is because, for a given plant, the impact of other plants' productivity upon its export-related outcomes does not depend on the source of the productivity of other firms, merely that productivity differences exist and negatively impact the outcomes of the plant in question.[31]

4.3 Decomposing Product and Factor Market Competition

The results above suggest that plants of a given productivity level attain superior economic outcomes both at home and abroad when they reside in less economically competitive industries, holding own-plant productivity constant. In this section, we explore the roles that factor and product market competition might play in generating these results. As specified in the theory section, if factors are industry-specific, a superior distribution of productivity in an industry bids up the wages of the specific factor. Conditional on a given level of plant productivity, this leads to a lower probability of exporting and a lower level of exports conditional on exporting. If two domestic varieties are more substitutable than a domestic and a foreign variety, high industry level productivity in a country will shift in the residual demand curve "in" more for competing plants from the same country than for competitors from the foreign country leading to inferior exporting outcomes for the first set of competitors.

We start by imposing a specific structure on how $(\sigma - \epsilon)$ varies across industries. We posit that $(\sigma - \epsilon)$ is likely to be larger for differentiated goods. Consider two examples: copper and wine. We hypothesize that copper is homogeneous so that Chilean varieties of this metal are virtually undistinguishable from varieties produced by other countries, (i.e. $\epsilon \approx \sigma$). On the contrary, wine possesses more scope for differentiation and is more likely to vary in the eyes of consumers depending on country of origin ($\epsilon < \sigma$, i.e. Chilean wines constitute a distinguishable type of wine compared to

following the Canada-U.S. Free Trade Agreement.

[31] We have also examined the above results including measures of firm size and capital intensity. These are not our preferred specifications for two reasons. First, we are most interested in the coefficient on industry productivity and not firm productivity. Second, if more productive firms use more capital intensive techniques or operate at a larger scale, inclusion of these variables will "over-control" and diminish our ability to compare the absolute magnitudes of the coefficients on plant and industry productivity.

wines from other countries). Another way of interpreting this hypothesis is that copper producers face World-wide competition whereas for wine producers the relevant competitors are mostly other Chilean wine producers.

To empirically test this hypothesis we construct a variable that captures the nature of the good produced by industry i as relatively homogeneous or differentiated. For this we rely on the classifications of Rauch (1999). These classifications indicate if an industry is "homogeneous" (h), "reference priced" (r), or "differentiated" (d).[32] Table 6 presents shares that reflect the degree to which a industry is composed of goods cleassified as h, r and d.[33]

We interact the percentage of differentiated goods in industry i $(\%diff)_i$ with average productivity $ln(\phi_{ict})$. Since our hypothesis implies that $(\sigma_d - \epsilon_d) > (\sigma_r - \epsilon_r), (\sigma_h - \epsilon_h)$ (where σ_d is σ for a differentiated good industry), we expect a negative sign on the interaction as country-industry productivity is likely to have more of a negative effect in industries where the relevant competitors are the other domestic producers. An alternative interpretation of our assumption is that σ is uncorrelated with ϵ in such a way that we can model it as being roughly constant and that $\epsilon_d < \epsilon_r, \epsilon_h$.[34] Consistently with this alternative interpretation, we will explicitly check the empirical validity of the assumption that σ_i does not vary across Rauch classifications.

We gauge the importance of factor market competition by explicitly introducing a measure of cost of the specific factor s_{ic}. According to equation (11), the model also predict that ε_i mediates the negative effect of s_{ic} so we interact it with $(\%diff)_i$ for consistency with the theoretical framework. Because it is difficult to distinguish empirically specific from mobile factors, we adop industry wages as our measure of s_{ic}. Industry wages are measured by total salaries and benefits in the industry-country-year divided by total employment in the same dimension.[35] Because of concerns that wages might partially proxy for productivity, we also include plant level average wages as an additional

[32] "Homogenous" goods are those that are sold on established exchanges. "Reference priced" goods do not have exchanges but are those for which stated prices exist in reference publications. "Differentiated" goods comprise the remainder. We start by merging these classifications with Robert C. Feenstra's World Trade Flows data at the 4-digit SITC level to establish levels of Chilean and Colombian exports in each industry and what is the Rauch classification of this industry. We then use the SITC-ISIC concordance prepared by Marc-Andreas Muendler to derive *shares* of each ISIC classification that fall into the three Rauch classifications. We use Rauch's "conservative" classification. The Muendler concordance is available at $http://econ.ucsd.edu/muendler/html/resource.html\#sitc2isic$.

[33] While many industries are composed exclusively of differentiated goods, the weighted average industry is 66% differentiated goods where the weights correspond to the size of the industry in our sample.

[34] This assumption is in line with evidence presented in Broda and Weinstein (2004) who estimate values of ϵ that are lower for Rauch differentiated industries than homogenous or reference priced industries. We are aware of no work that seeks to estimate σ and ϵ differently using domestic *and* international data. All the work we are aware of uses international data alone which assumes that domestic varieties are perfect substitutes for each other.

[35] In accordance with equation (14), this will lead to the coefficient on wages being premultiplied by the share of the specific factor in total wages (η).

explanatory variable so that the baseline equation of interest becomes:

$$\begin{aligned} ln(r_{fict}) &= \beta_{plant} ln(\phi_{fict}) + \beta_{ind} \left(\%diff\right)_i \times \ln(\phi_{ict}) + \beta'_{ind} \ln(\phi_{ict}) \\ &+ \beta_{ind\_wage} \left(\%diff\right)_i \times ln(s_{ict}) + \beta'_{ind\_wage} ln(s_{ict}) \\ &+ \beta_{plant\_wage} ln(s_{fict}) + \beta_{chile} C_{ct} + \beta'_{ind} \Delta'_{it} + \eta_{fict} \end{aligned}$$

where we include the time subscript due to the pooled nature of the results we present. To summarize, the theory predicts that, because of product market competition, $\beta_{ind} < 0$ and that, because of factor market competition, $\beta'_{ind\_wage} < 0$ and $\beta_{ind\_wage} > 0$. Because we are only including it as an empirical control, we are unable to assign any structural interpretation to β_{plant_wage}.

Table 7 presents *pooled* results where robust standard errors are clustered by country-industry-year. The share of exports that are differentiated goods only varies by industry and is then collinear with the industry fixed effects and is dropped. Column (1) tests the product market competition channel and finds that the negative coefficient on industry productivity is higher in industries with higher shares of differentiated exports. Evaluating the coefficient on industry productivity at the average value of $\%diff_i$ delivers a value of -0.42 whose absolute value is less than the absolute value of the coefficient on plant productivity (0.822). Column (2) includes factor market competition and finds that higher industry wages lead to lower export levels. This suggests that both factor market and product market competition are at work in this sample. Column (4) asks if the coefficient on industry wages differs across Rauch classifications as predicted by theory. The coefficient is indistinguishable from zero but does possess the sign predicted by theory. Column (3) shows that estimates of σ do not seem to vary substantively with Rauch classification. This is evidence in support of our identifying assumption regarding the pattern of $\sigma_i - \epsilon_i$ across Rauch classifications. In addition, we can observe regressions of domestic sales on productivity to obtain measures of σ_{ic}. We can then see if these measures vary substantively over Rauch classifications. In results available upon request, we find that they do not.

Table 8 presents these same regressions by year. Although the point estimates are less precise, similar results with the pooled sample hold although there are three points worth making. First, it is interesting to note that the results for 1990 are in line with theory in this table relative to the results of table 5. This is because industry 321 (textiles) is a relatively homogenous/reference priced industry as indicated in table 6. It is also an outlier in figure 4, so allowing the coefficient to vary

across Rauch classifications gets rid of the fragile nature of the results for export levels. Second, the coefficients on industry productivity and industry productivity interacted with the differentiated share are *jointly* significant at the 10% level for column (5) and the 5% level for column (7). Third, the coefficient on industry wage interacted with the differentiated goods share is unstable in that it is insignificantly different from zero and flips signs across years.

4.4 Discussion of Measurement Error

Estimation of equation (13) is equivalent to estimation of equation (15) with outcome variables regressed on plant deviation from industry-country productivity and industry-country productivity and then testing whether the coefficient on industry productivity is less than the coefficient on the plant deviation

$$va_{fic} = \beta_{dev}(\phi_{fic} - \phi_{ic}) + \beta_{ind'}\phi_{ic} + \beta_{chile}C_c + \beta'_{ind}\Delta i + \epsilon_{fic} \tag{15}$$

where comparison of equations (13) and (15) shows that $\beta_{dev} = \beta_{plant}$ and $\beta_{ind} = \beta_{ind'} - \beta_{plant}$ (using the notation from those two equations). If there is pervasive measurement error in industry productivity but not in plant (relative to industry mean) productivity, this will bias $\beta_{ind'}$ to zero and, consequently, β_{ind} to $-\beta_{plant}$ offering an alternate hypothesis for our results.

We examine this by dividing possible measurement error into two types. First, unit based measurment error in which accounting differences lead to differences in physical quantities counted that do not correspond to actual quantities.[36] If this type of measurement error is driving our results, we should find it uniformly across industries. Because section 4.3 finds that this effect is more common in differentiated industries, we do not believe that this type of measurement error is driving our results.

Second, because goods produced in different countries are fundamentally different, they are valued using different prices and are not completely comparable across borders. We believe that our model is a systematic and economically based explanation for this type of "measurement error." Because varieties produced within the same border are more comparable than varieties across borders ($\sigma > \epsilon$), higher industry-country productivity will shift in the residual demand curve for domestic competitors (in foreign markets) more than for competitors from the other small open

[36] For example, if there were 50 pesos of a good produced but errors in accounting recorded only 40 pesos produced in one country but not the other.

economy.

4.5 Robustness

This section explores the robustness of our results in three ways. First, we employ value added measures of *total factor productivity* instead of value added per worker. Second, we examine the possibility that industry productivity is merely picking up higher order terms for plant productivity. Third, we analyze the results at the 4-digit level. We find that the results of section 4.2 are largely unchanged with respect to these considerations.

Table 9 presents results based on value added TFP instead of value added per worker. The advantage of using value added TFP is that we purge differences in capital intensity across plants and industries from value added per worker. The cost is that comparing capital inputs across countries can be problematic due to measurement error that compounds over time due to the historical nature of capital stock calculation. This cost is especially relevant given the high and variable inflation of the early to mid 1980s in these countries which will not affect flow variables in 1990 but may affect the measured capital stock based on the perpetual inventory method.

Capital stock is calculated using this perpetual inventory method. We deflate investment using country-specific investment deflators, nominal exchange rates, and the Penn World Tables country-specific PPP investment deflator in a manner similar to how we deflate output. We use the procedure outlined in Bils and Klenow (2000) and Caselli (2005) to calculate effective labor input at the country level. We estimate one physical Chilean worker to be 2.04 effective workers and one Colombian worker to be approximately 1.65 effective workers.[37]

To estimate value added total factor productivity we use the estimation procedure outlined in Levinsohn and Petrin (2003) (LP).[38] Productivity estimation occurs at the 3-digit ISIC level with regressions run within and not across countries. Since we examine 20 3-digit ISIC industries and two countries, we estimate productivity separately for 40 different panels over 1982-1996 for Chile and 1982-1991 for Colombia. This allows us to estimate input elasticities that are country-industry specific. We assume that the production function is as given in equation (16) where lower case letters are natural logarithms; real value added (va) is a function of the real capital stock (k),

[37] See Caselli (2005) for details. We augment skilled and unskilled labor equivalently.

[38] Because of identification issues with the Levinsohn-Petrin procedure (e.g. Ackerberg, Caves, and Frazer, 2009. We have also estimated TFP using OLS estimation. The results are virtually identical.

non-production workers (npw) and production workers (pw):

$$va_{ft} = \beta_0 + \beta_{npw} npw_{ft} + \beta_{pw} pw_{ft} + \beta_k k_{ft} + \epsilon_{ft}. \tag{16}$$

We use materials as the omitted proxy variable in the LP procedure. Because the regression is run at the industry-country level, industry and country subscripts (i and c) in equation (16) are suppressed.

Results are generally stronger than those in the baseline specifications. The coefficient on industry total factor productivity is negative and significant in all specifications and we can reject the equality of its absolute magnitude from the plant TFP measure at the 1% level of certainty. Export participation estimation uses logit estimation.

Table 10 presents specifications including a quadratic term for own plant productivity to control for non-log-linear effects for which industry productivity may be proxying. The results show a convexity in the relationship between own plant productivity and value added/exports. There is a slight concavity in the propensity to export. However the coefficient on industry productivity changes little relative to the results in tables 2, 3 and 5.[39]

5 Conclusion

This paper provides a theoretical and empirical framework to assess how plant- and industry-level productivity differences interact in determining plant-level outcomes. Specifically, we ask how the productivity of peer firms affects outcomes related to exporting in the context of small open economies exporting to a large World market. We do this in the context of a model where productivity varies both across industries and firms within the industries as in DFS (1977) and Melitz (2003), respectively. Using plant-level data for Chile and Colombia for 1990 and 1991, we find that more productive domestic peer plants *diminish* exports, and the propensity to export conditional on own-plant productivity. We rationalize this result by introducing two types of competition that have been used in other literatures: factor-market and non-standard product-

[39] We have also examined results at the 4-digit level of aggregation (not reported). A priori we believe that these results should be taken with extreme caution because we lose 66 of 80 possible 4-digit ISIC industries by only examining industries in which both countries export and which have at least 25 plants. Therefore the 3-digit analysis is our preferred specification. This is consistent with the preference of 3-digit specifications of Levinsohn (1993) and Fernandes (2007). While the general pattern of the coefficients does not change, we lose much precision in our results. This table is available upon request.

market competition.

Factor market competition involves factors of production that are immobile across industries within a country. Comparing industry-specific wages across countries, higher relative productivity levels in one country increase the wage of the factor that is specific to that industry. Higher wages increase sunk, fixed, and marginal costs of production and exporting causing leading to a lower probability of exporting and lower levels of exporting conditional on own firm productivity.

We introduce non-standard product market competition using a nested-CES approach in which two varieties produced within the same border are better substitutes on international markets that two varieties produced in different markets. Consequently, a higher level of relative productivity in an industry for a given country will contract residual demand for all other firms in the industry. However, demand will contract for firms producing more substitutable varieties than for varieties that are less substitutable.

We find evidence for each of these mechanisms in our data set. For factor market competition, we find that, conditional on own-plant wage, higher industry wages lead to lower exports. Using the Rauch (1999) classifications to investigate product market competition, we argue that the nested CES effect should be stronger in differentiated industries than in homogenous and reference priced industries for whom national origin is less likely to be important. We find evidence for this as well.

Avenues for future research are plentiful. First, we can ask how the short run specificity of factors at the industry-level can diminish the gains from trade liberalization given firm heterogeneity within those industries. Second, given the level of aggregation, we are unable to investigate different levels of substitutability between domestic and foreign varieties. We are unaware of any work that investigates this question and we feel that it is a potentially fruitful research area.

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6 Appendix

6.1 Proof of Proposition 1

We first derive a number of intermediate results that will be subsequently employed in the proof of the Proposition (1). From the definition of $\overline{\phi}_{d,ic}$ and $\overline{\phi}_{x,ic}$ it is useful to derive the following expressions:

$$\left(\frac{\overline{\phi}_{d,ic}}{\phi_{d,ic}}\right)^{\sigma-1} = \left(\frac{\overline{\phi}_{x,ic}}{\phi_{x,ic}}\right)^{\sigma-1} = \frac{k}{k+1-\sigma}. \tag{17}$$

We substitute (4) in (3) and replace $\overline{\pi}_{d,ic}$ and $\overline{\pi}_{x,ic}$ with their expressions in (5) and (6). Substituting (17) and the Pareto cumulative density function (1) in the resulting expression, yields the following condition:

$$\delta f_e \frac{k+1-\sigma}{\sigma-1} = f\left(\frac{\phi_{m,ic}}{\phi_{d,ic}}\right)^k + f_x\left(\frac{\phi_{m,ic}}{\phi_{x,ic}}\right)^k. \tag{18}$$

Average firm revenues $\overline{r}_{ic}$ can be rewritten as $\frac{\overline{r}_{ic}}{\sigma} = \overline{\pi}_{ic} + s_{ic}^{\eta} f + \frac{1-G(\phi_{x,ic})}{1-G(\phi_{d,ic})} s_{ic}^{\eta} f_x$. Using the free-entry condition (3) to substitute $\overline{\pi}_{ic}$ and the Pareto cdf, average firm revenues can be expressed as:

$$\frac{\overline{r}_{ic}}{\sigma} = s_{ic}^{\eta}\delta f_e\left(\frac{\phi_{d,ic}}{\phi_{m,ic}}\right)^k + s_{ic}^{\eta} f + \left(\frac{\phi_{d,ic}}{\phi_{x,ic}}\right)^k s_{ic}^{\eta} f_x. \tag{19}$$

By replacing (19) in (7) we obtain the following equation:

$$\eta M_{ic}\sigma s_{ic}^{\eta}\left(\delta f_e\left(\frac{\phi_{d,ic}}{\phi_{m,ic}}\right)^k + f + \left(\frac{\phi_{d,ic}}{\phi_{x,ic}}\right)^k f_x\right) = s_{ic}K_{ic}. \tag{20}$$

Since there are no imports in industry i, the entire share α of domestic expenditure spent on varieties produced in industry i accrues to domestic firms as revenues in the domestic market. Let us denote by $r_{d,ic}(\phi)$ the domestic revenues of a firm with productivity ϕ in industry i. If Y_c is aggregate income (which is equal to aggregate expenditure E_c) then $\alpha Y_c = M_i\overline{r}_{d,ic}$, where $\overline{r}_{d,ic}$ are average revenues in the domestic market. Since $\overline{r}_{d,ic}/r_{d,ic}(\phi_{d,ic}) = \left(\frac{\overline{\phi}_{d,ic}}{\phi_{d,ic}}\right)^{\sigma-1}$ and $r_{d,ic}(\phi_{d,ic}) = \sigma f s_{ic}^{\eta}$ then we can establish, using (17), the following condition:

$$\alpha Y_c = M_{ic}\frac{k\sigma f s_{ic}^{\eta}}{k+1-\sigma} \tag{21}$$

We now suppress the subscript c for clarity until we introduce the foreign analog expressions at which point the home country is indexed by c and the foreign country is indexed c'. We employ conditions (18), (20), (21), and the following three conditions: the definition of the CES export price index (equation 22), the zero-exporting profits condition for ϕ_{xi} (equation 23), and the fact that the mass of exporting firms is equal to the mass of firms times the probability of exporting (equation 24).

$$P_{x,i}^{1-\sigma} = \left(\frac{\tau s_i^{\eta}}{\rho\phi_{xi}}\right)^{1-\sigma}\frac{M_{i,x}k}{k+1-\sigma} \quad i \in 1,2 \tag{22}$$

$$\alpha Y^W \left(\frac{\tau s_i^\eta}{\rho \phi_{xi} P_{x,i}}\right)^{1-\sigma} \left(\frac{P_{x,i}}{P_i^W}\right)^{1-\epsilon} = \sigma f_x s_i^\eta \quad i \in 1,2 \tag{23}$$

$$M_{xi} = p_{i,x} M_i = \left(\frac{\phi_{di}}{\phi_{xi}}\right)^k M_i \quad i \in 1,2 \tag{24}$$

Substituting out the mass of firms (M_i), the mass of exporting firms (M_{ix}), and the CES export price index ($P_{x,i}$) to obtain the following three sets of equations:

$$\delta f_e \frac{k+1-\sigma}{\sigma-1} = \left(\frac{\phi_{m,i}}{\phi_{d,i}}\right)^k f + \left(\frac{\phi_{m,i}}{\phi_{x,i}}\right)^k f_x \quad i \in 1,2, \tag{25}$$

$$\left(\frac{\phi_{di}}{\phi_{xi}}\right)^k = \frac{f\left[k s_i K_i - \alpha\eta Y(k+1-\sigma)\right]}{\alpha\eta Y(k+1-\sigma)\left[\delta f_e \phi_{xi}^k + f_x \phi_{mi}^k\right]} \phi_{mi}^k \quad i \in 1,2, \tag{26}$$

$$\left[\frac{\tau s_i^\eta}{\rho \phi_{xi}}\right]^{1-\epsilon} \left[\frac{\phi_{xi}^k}{\phi_{di}^k}\right]^{\frac{\sigma-\epsilon}{\sigma-1}} \left[\frac{\alpha Y}{\sigma f s_i^\eta}\right]^{\frac{\epsilon-1}{\sigma-1}} \left(P_i^W\right)^{\epsilon-1} = \frac{f_x Y}{f Y^W} \quad i \in 1,2. \tag{27}$$

Solving equation (26) for ϕ_{id}, and substituting this into equations (25) and (27), We obtain the following

$$\delta f_e \frac{k+1-\sigma}{\sigma-1} = \frac{\delta f_e \alpha\eta Y(k+1-\sigma)\phi_{xi}^k + f_x k s_i K_i \phi_{mi}^k}{\left[k s_i K_i - \alpha\eta Y(k+1-\sigma)\right]\phi_{xi}^k} \quad i \in 1,2, \tag{28}$$

$$\left[\frac{\tau s_i^\eta}{\rho \phi_{xi}}\right]^{1-\epsilon} \left[\frac{f\left[s_i k K_i - \eta\alpha Y(k+1-\sigma)\right]\phi_{m,i}^k}{\eta\alpha Y(k+1\sigma)\left[\delta f_e \phi_{x,i}^k + f_x \phi_{x,i}^k\right]}\right]^{\frac{\sigma-\epsilon}{1-\sigma}} \left(P_i^W\right)^{\epsilon-1} = \frac{f_x Y}{f Y^W} \quad i \in 1,2. \tag{29}$$

Solving equation 28 for ϕ_{xi}^k, substituting into equation 29, and dividing the expression for $i = 1$ by $i = 2$ gives the following expression

$$\left[\frac{s_2 K_2 - \alpha\eta Y}{s_1 K_1 - \alpha\eta Y}\right]^{\frac{\sigma-\epsilon}{\sigma-1}} \left[\frac{s_1 K_1[s_2 K_2 - \alpha\eta Y]}{s_2 K_2[s_1 K_1 - \alpha\eta Y]}\right]^{\epsilon-1} \left(\frac{\phi_{m1}}{\phi_{m2}}\right)^{k(\epsilon-1)} \left(\frac{P_1^W}{P_2^W}\right)^{\epsilon-1} = \left(\frac{s_1}{s_2}\right)^{\frac{\eta\sigma(\epsilon-1)}{\sigma-1}}. \tag{30}$$

Dividing the expression for c by the analog for c' gives

$$\left[\frac{s_{2,c}K_{2,c} - \alpha\eta Y_c}{s_{1,c}K_{1,c} - \alpha\eta Y_c}\frac{s_{1,c'}K_{1,c'} - \alpha\eta Y_{c'}}{s_{2,c'}K_{2,c'} - \alpha\eta Y_{c'}}\right]^{\frac{\sigma-\epsilon}{\sigma-1}} \left[\frac{s_{2,c}K_{2,c} - \alpha\eta Y_c}{s_{1,c}K_{1,c} - \alpha\eta Y_c}\frac{s_{1,c'}K_{1,c'} - \alpha\eta Y_{c'}}{s_{2,c'}K_{2,c'} - \alpha\eta Y_{c'}}\right]^{\epsilon-1} \left(\frac{s_1}{s_2}\frac{s_{2,c'}}{s_{1,c'}}\right)^{\epsilon-1} \left(\frac{\phi_{m,1c}}{\phi_{m,2c}}\frac{\phi_{m,2c'}}{\phi_{m,1c'}}\right)^{k(\epsilon-1)} = \left(\frac{s_{1c}}{s_{2c}}\frac{s_{2c'}}{s_{1c'}}\right)^{\frac{\eta\sigma(\epsilon-1)}{\sigma-1}} \tag{31}$$

We now exploit the Cobb-Douglas nature of production and the definition of national income with the following two expressions keeping in mind our normalization of $w = 1$:

$$\frac{(1-\eta)s_{ic}K_{ic}}{\eta} = L_{ic} \quad \frac{(1-\eta)s_{ic'}K_{ic'}}{\eta} = w_{c'}L_{ic'} \tag{32}$$

$$Y_c = (L_{1c} + L_{2c}) + s_{1c}K_{1c} + s_{2c}K_{2c} \quad Y_{c'} = w_{c'}(L_{1c'} + L_{2c'}) + s_{1c'}K_{1c'} + s_{2c'}K_{2c'} \tag{33}$$

Substituting these two expressions into equation 31 gives the following equation

$$\left[\frac{1-\alpha\left[1+\frac{s_{1c}}{s_{2c}}\right]}{1-\alpha\left[1+\frac{s_{2c}}{s_{1c}}\right]}\frac{1-\alpha\left[1+\frac{s_{2c'}}{s_{1c'}}\right]}{1-\alpha\left[1+\frac{s_{1c'}}{s_{2c'}}\right]}\right]^{\frac{\sigma-\epsilon}{\sigma-1}+\epsilon-1}\left(\frac{\phi_{m,1c}\phi_{m,2c'}}{\phi_{m,2c}\phi_{m,1c'}}\right)^{k(\epsilon-1)}=\left(\frac{s_{1c}s_{2c'}}{s_{2c}s_{1c'}}\right)^{\frac{\eta\sigma(\epsilon-1)}{\sigma-1}+\frac{\sigma-\epsilon}{\sigma-1}} \tag{34}$$

We can then proceed with a proof by contradiction. Suppose that $\frac{\phi_{m,1c}}{\phi_{m,2c}} < \frac{\phi_{m,1c'}}{\phi_{m,2c'}}$ so that the home country has a comparative advantage in industry 2. Suppose that there are no relative factor price differences such that $\frac{s_{1c}}{s_{2c}} = \frac{s_{1c'}}{s_{2c'}}$. The first set of terms in brackets on the left equals unity as does the term on the right of the equality. Therefore the left hand side is greater than the right hand side, a contradiction. Now suppose that $\frac{s_{1c}}{s_{2c}} > \frac{s_{1c'}}{s_{2c'}}$. In this case, the right hand side is greater than one. However both terms on the left hand side are less than one, a contradiction. Therefore $\frac{s_{1c}}{s_{2c}} < \frac{s_{1c'}}{s_{2c'}}$.

6.2 Proof of Proposition 2

As with the proof of Proposition (1), start with equations (18) through (24) and substitute out the mass of firms (M_i) and the mass of exporting firms (M_{ix}) to obtain the following equations:

$$\delta f_e\frac{k+1-\sigma}{\sigma-1}=\left(\frac{\phi_{m,i}}{\phi_{d,i}}\right)^k f+\left(\frac{\phi_{m,i}}{\phi_{x,i}}\right)^k f_x \quad i\in 1,2 \tag{35}$$

$$\frac{\alpha\eta Y(k+1-\sigma)}{kf}\left[\delta f_e\left(\frac{\phi_{di}}{\phi_{mi}}\right)^k+f+f_x\left(\frac{\phi_{di}}{\phi_{xi}}\right)^k\right]=s_iK_i \quad i\in 1,2 \tag{36}$$

$$P_{x,i}^{1-\sigma}=\left(\frac{\tau s_i^\eta}{\rho\phi_{xi}}\right)^{1-\sigma}\left(\frac{\phi_{di}}{\phi_{xi}}\right)^k\frac{\alpha Y}{s_i^\eta\sigma f} \quad i\in 1,2 \tag{37}$$

$$\alpha Y^W\left(\frac{\tau s_i^\eta}{\rho\phi_{xi}P_{x,i}}\right)^{1-\sigma}\left(\frac{P_{x,i}}{P_i^W}\right)^{1-\epsilon}=\sigma f_x s_i^\eta \quad i\in 1,2 \tag{38}$$

We now substitute out ϕ_{id}^k from equation (36), and substituting into equations (35) and (37), we obtain

$$\phi_{x,i}^k=\frac{(\sigma-1)f_x s_iK_i\phi_{mi}^k}{\delta f_e(k+1-\sigma)\left[s_iK_i-\alpha\eta Y\right]} \quad \in 1,2, \tag{39}$$

$$P_{x,i}^{1-\sigma}=\left(\frac{\tau s_i^\eta}{\rho\phi_{xi}}\right)^{1-\sigma}\frac{1}{\sigma s_i^\eta}\frac{[ks_iK_i-\alpha\eta Y](k+1-\sigma)}{\eta(k+1-\sigma)(\delta f_e\phi_{xi}^k+f_x\phi_{mi}^k)}\phi_{mi}^k \quad \in 1,2, \tag{40}$$

Substituting equation 39 into equation 40 gives:

$$P_{x,i}^{1-\sigma}=\left(\frac{\tau s_i^\eta}{\rho\phi_{xi}}\right)^{1-\sigma}\frac{s_iK_i-\alpha\eta Y}{\eta f_x\sigma s_i^\eta} \quad i\in 1,2, \tag{41}$$

Dividing equation 38 by equation 41 and then dividing the equation for $i=1$ by $i=2$ delivers

$$\left(\frac{P_{x,2}}{P_{x,1}}\right)^{\epsilon-1}=\left(\frac{P_1^W}{P_2^W}\right)^{1-\epsilon}\frac{s_1K_1-\alpha\eta Y}{s_2K_2-\alpha\eta Y} \tag{42}$$

Dividing this by its foreign analog, substituting in total factor payments for Y_c, and simplifying delivers

$$\left(\frac{P_{x,2c}P_{x,1c'}}{P_{x,1c}P_{x,2c'}}\right)^{\epsilon-1} = \frac{s_{1,c}s_{2,c'}}{s_{2,c}s_{1,c'}}\frac{1-\alpha\left(1+\frac{s_{2,c}}{s_{1,c}}\right)}{1-\alpha\left(1+\frac{s_{1,c}}{s_{2,c}}\right)}\frac{1-\alpha\left(1+\frac{s_{1,c'}}{s_{2,c}}\right)}{1-\alpha\left(1+\frac{s_{2,c'}}{s_{1,c'}}\right)}. \tag{43}$$

This can be rearranged slightly to obtain

$$\left(\frac{P_{x,2c}P_{x,1c'}}{P_{x,1c}P_{x,2c'}}\right)^{\epsilon-1} = \frac{s_{1,c}s_{2,c'}}{s_{2,c}s_{1,c'}}\frac{1-\alpha\left(1+\frac{s_{2,c}}{s_{1,c}}\right)}{1-\alpha\left(1+\frac{s_{2,c'}}{s_{1,c'}}\right)}\frac{1-\alpha\left(1+\frac{s_{1,c'}}{s_{2,c}}\right)}{1-\alpha\left(1+\frac{s_{1,c}}{s_{2,c}}\right)} \tag{44}$$

Because (without loss of generality) $\frac{s_{1,c}}{s_{2,c}} < \frac{s_{1,c'}}{s_{2,c'}}$, each of the three fractions on the right hand side are less than one. Therefore $\frac{P_{x,1c}}{P_{x,2c}} > \frac{P_{x,1c'}}{P_{x,2c'}}$.

7 Data Appendix

The key to plotting the above figures involves making the Chilean and Colombian firms as comparable as possible. This involves making output, labor input, capital input, and materials input comparable. We explain these in turn. In addition to the measures below, we have verified that the plant level data aggregates to values nearly identical to those reported in the World Bank Trade and Production data set that is based on UNIDO 3-digit ISIC data. We thank Veronique Pavenka for clarifying issues associated with UNIDO data collection. In addition, we only consider plants with at least 10 employees in each data set because this is the minimum plant size in the Chilean data set.

7.1 Labor Input

Labor is broken down into skilled and unskilled in each data set. Units of labor are measured in the number of workers in each data set. In addition, we can allow for the effectiveness of labor to vary across countries as in Caselli (2005) and as used by Morrow (2008). Using this procedure, labor is transformed into effective labor using data on educational attainment and assumptions about the returns to schooling. Labor input is assumed to be EL where L is the physical quantity of labor employed and E is the effectiveness of labor. The effectiveness of labor without any schooling is normalized to $E = 1$. Labor is assumed to become 13% more productive per year of schooling for years one through four of educational attainment, 10% more productive per year for years four through eight, and 7% per year for subsequent years. Based on these measures one unit of physical labor is assumed to be 2.04 units of effective labor for Chile and 1.65 for Colombia.

7.2 Capital Input

Capital was constructed using the perpetual inventory method in which capital stock is available for a single year and then subsequent capital stock is calculated by adding observed investment and subtracting assumed depreciation. Capital and investment are measured in thousands of the nominal domestic currency in each data set. For both countries, the depreciation rate is imposed to be 5% per year for buildings, 10% for machinery, and 20% for vehicles.

Colombian plant level investment is the sum of (1) building investment, (2) machinery investment, (3) transportation investment, and (4) office investment. More detailed composition is available from the authors upon request. Chilean plant level investment is the sum of (1) building investment, (2) machinery investment, and (3) vehicles investment. Results are invariant to dropping office investment from Colombian investment data,

Because of the unavailability of deflators by type of investment, we use the same deflator on all types of investment in Colombia. Two dimensions need to be taken into consideration when deflating the measures of investment. First, the domestic investment price deflator must be used to make the investment numbers comparable over time within the country. This is common to nearly all firm level studies. However, because we are trying to make two firm level data sets comparable, we also translate these variables into a common real currency. We do this by first transforming all investment numbers into real 1980 non-PPP adjusted Colombian Pesos using the domestic capital formation deflator available from the file *i_srea_015.xls.* from *http://www.banrep.gov.co/statistics/sta_prices.htm..* All annual values use the June value of the Capital Formation variable where values are indexed so that June, 1980 is the base period. We then use the nominal exchange rate for 1980 to trans! form these numbers into 1980 non-PPP adjusted U.S. Dollars. The nominal exchange rate for 1980 is taken to be 50.92 which is the December average Peso-Dollar exchange rate as in IMF international Financial statistics. We then use the Penn World Tables PPP price index for investment to transform these into real 1980 PPP-adjusted U.S. dollars. PI is taken from Penn World Tables Edition 6.1.

Buildings investment is deflated using the implicit price deflator for construction. Machinery and vehicles investment are deflated using the implicit price deflator for machinery. These deflators were graciously provided with the plant level data by James Levinsohn. Nominal Pesos are transformed into real PPP adjusted U.S. dollars using a the Penn World Tables 6.1 PPP Investment deflator for Chile. The exchange rate is the December 1980 value of 39.00.

7.3 Output

The gross production variable in the Colombian data set included: the value of all goods and by-products sold, revenue from work done for third parties, value of electricity sold, value of operational income (value of installation, repair, and maintenance), change in Business inventories, and tax certificate revenue.

Revenue is reported in thousands of nominal Colombian Pesos. They are transformed into thousands of non-PPP adjusted 1980 Colombian Pesos using the 3-digit ISIC producer price index which is available at: *http://www.banrep.gov.co/statistics/sta_prices.htm.* The specific spreadsheet is provided in link containing the spreadsheet *i_srea_015.xls.* All variables are the June values with all observations indexed so that the value for 1980=1.00.

There are two measures of output for the Chilean Data. There is income which includes sales of goods produced, sales shipped to other establishments, resales, work done for third parties and repairs done for third parties. Then there is gross output which includes income, electricity sold, buildings produced for own use, machinery produced for own use, vehicles produced for own use and final inventory of goods in process. We use gross output. Industry level output deflators are available from the Instituto Nacional de Estadisticas and was graciously provided by David Greenstreet.

To make output comparable across countries in a given industry we constructed country-industry level output deflators from the *disaggregated* PPP benchmark data that is available from the Penn World Tables and was used in Morrow (2009). Unfortunately, the benchmark data are

only available at five year intervals. In addition, the level of disaggregation changes from year to year. We choose to use the values from 1980 because Chile and Colombia are not covered in the 1985 survey. One fortuitous aspect of the 1980 benchmark is that it is available at the greatest level of disaggregation. The 1980 benchmark covers 155 industrial groupings, the 1985 benchmark covers 135 industrial groupings, and the 1996 benchmark only covers 31 industrial groupings. Consequently, we choose to use the 1980 data. This means that we are making the implicit assumption that all changes in the PPP deflator after 1980 can sufficiently be accounted for by a country fixed effect in which all industry level PPP deflators grow at the same rate. The mean (across industries) relative PPP deflator for Chile relative to Colombia is 1.747 and the median is 1.440. These can be compared to relative values of the PPP GDP deflator of 1.409, and 1.061 for investment goods. This suggests that PPP adjusted prices were higher in Chile than in Colombia.

Table 1
Data Summary

	1990			1991		
ISIC	#Chile	# Colombia	Total	# Chile	# Colombia	Total
311	657	761	1,418	642	710	1,352
312	34	154	188	34	148	182
321	210	380	590	210	361	571
322	153	717	870	142	654	796
323	31	86	117	30	83	113
324	66	201	267	66	195	261
331	131	136	267	124	118	242
332	52	171	223	52	159	211
341	33	137	170	35	127	162
342	83	296	379	88	282	370
351	27	125	152	27	120	147
352	107	271	378	107	262	369
355	32	61	93	32	59	91
356	92	293	385	90	288	378
369	60	246	306	60	231	291
381	211	462	673	204	431	635
382	85	287	372	81	272	353
383	28	188	216	29	170	199
384	54	201	255	52	185	237
390	35	139	174	33	122	155
Total	2,181	5,312	7,493	2,138	4,977	7,115

Table 2
Value Added

	1990		1991	
VA per Worker$_{fic}$	1.422***	1.477***	1.469***	1.555***
	(0.058)	(0.06)	(0.053)	(0.05)
VA per worker$_{ic}$		−0.512*		−0.87***
		(0.289)		(0.282)
Observations	7493	7493	7115	7115
Industries	20	20	20	20
Industry FE	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Restriction p-val		0		0.01

Std. errors in parenthese and clustered by country-industry level (e.g. Chile ISIC 311). ***=1% level, **=5% level, *=10% level

Table 3
Propensity to Export

	1990		1991		1990		1991	
	Logit		Logit		OLS		OLS	
VA per Worker$_{fic}$	1.204***	1.287***	1.287***	1.415***	0.148***	0.157***	0.181***	0.195***
	(0.08)	(0.089)	(0.105)	(0.107)	(0.012)	(0.014)	(0.016)	(0.018)
VA per Worker$_{ic}$		−0.649**		−1.018***		−0.085*		−0.143***
		(0.332)		(0.264)		(0.047)		(0.042)
Obs.	7493	7493	7115	7115	7493	7493	7115	7115
Industries	20	20	20	20	20	20	20	20
Industry FE	yes	yes	yes	yes	yes	yes	yes	yes
Country FE	yes	yes	yes	yes	yes	yes	yes	yes
Restriction p-val		0.027		0.107		0.099		0.195

The dependent variable is equal to 1 if there are positive levels of exports, zero otherwise. Standard errors in parentheses. ***=1% level, **=5% level, *=10% level. Standard errors clustered by country-industry level (e.g. Chile ISIC 311)

Table 4
Domestic Revenue

	1990		1991	
VA per Worker$_{fic}$	1.336***	1.392***	1.372***	1.456***
	(0.053)	(0.053)	(0.053)	(0.047)
VA per Worker$_{ic}$		−0.48*		−0.85***
		(0.283)		(0.28)
Obs.	7472	7472	7102	7102
Industries	20	20	20	20
Industry FE	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Restriction p-val		0.001		0.027

"Domestic Revenue" is the value of production - value of exports
Standard errors in parentheses. ***=1% level, **=5% level, *=10% level.
Standard errors clustered by country-industry level (e.g. Chile ISIC 311)

Table 5
Export Revenue

	1990		1991	
VA per Worker$_{fic}$	0.755***	0.773***	0.809***	0.879***
	(0.108)	(0.112)	(0.097)	(0.112)
VA per Worker$_{ic}$		−0.127		−0.51*
		(0.276)		(0.283)
Obs.	1251	1251	1491	1491
Industries	20	20	20	20
Industry FE	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Restriction p-val		0.022		0.146

"Domestic Revenue" is the value of production - value of exports
Standard errors in parentheses. ***=1% level, **=5% level, *=10% level.
Standard errors clustered by country-industry level (e.g. Chile ISIC 311)

Table 6
Rauch Classification Data

ISIC	Name	Share Diff	ISIC	Name	Share Diff
311	Food products	0.0695	351	Industrial chemicals	0.1455
312	Misc Food Products	0.6375	352	Other chemicals	0.8025
321	Textiles	0.1875	355	Rubber products	1.0
322	Wearing apparel	0.988	356	Plastic products	1.0
323	Leather products	0.945	369	Other non-metallic mineral products	0.3035
324	Footwear	1.0	381	Fabricated metal products	1.0
331	Wood products, except furniture	0.763	382	Machinery, except electrical	1.0
332	Furniture, except metal	1.0	383	Machinery, electric	1.0
341	Paper and products	0.1875	384	Transport equipment	1.0
342	Printing and publishing	1.0	390	Other manufactured products	0.92

Table 7
Identification through Rauch Classifications (pooled)

	Export Levels			
	(1)	(2)	(3)	(4)
VA per worker$_{fict}$	0.822***	0.603***	0.706***	0.603***
	(0.078)	(0.072)	(0.178)	(0.072)
VA per worker$_{fict}$ x (% diff)$_i$			0.186	
			(0.223)	
VA per worker$_{ict}$	0.106	0.544*	0.199	0.546**
	(0.28)	(0.299)	(0.291)	(0.303)
VA per worker$_{ict}$ x (% diff)$_i$	−0.812**	−1.156**	−0.986**	−1.158***
	(0.392)	(0.442)	(0.403)	(0.437)
wage per worker$_{fic}$		0.0004***		0.0004***
		(0.0001)		(0.0001)
wage per worker $_{ic}$		−1.735**		−1.768
		(0.791)		(1.073)
wage per worker$_{ic}$ x(% diff)$_i$				0.039
				(1.155)
Obs.	2742	2742	2742	2742
Industries	20	20	20	20
Industry-Year FE	yes	yes	yes	yes
Country-Year FE	yes	yes	yes	yes

Standard errors presented in parentheses. ***=1% level, **=5% level, *=10% level. Robust standard errors by country-industry-year level (e.g. Chile ISIC 311, 1990)

Table 8
Identification through Rauch Classifications (annual)

	Export Levels (1990)				Export Levels (1991)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VA per worker$_{fic}$	0.773***	0.533***	0.736***	0.533***	0.876***	0.662***	0.691***	0.662***
	(0.112)	(0.092)	(0.252)	(0.092)	(0.112)	(0.112)	(0.267)	(0.112)
VA per worker$_{fic}$ (% diff)$_{ic}$			0.061				0.289	
			(0.316)				(0.322)	
VA per worker$_{ic}$	0.351	0.76	0.377	0.727	−0.214	0.273	−0.046	0.315
	(0.346)	(0.491)	(0.349)	(0.498)	(0.448)	(0.368)	(0.479)	(0.371)
VA per worker$_{ic}$ (% diff)$_{i}$	−1.004**	−1.257*	−1.056**	−1.219	−0.573	−1.003*	−0.868	−1.05**
	(0.484)	(0.74)	(0.479)	(0.742)	(0.642)	(0.538)	(0.671)	(0.517)
wage per worker$_{fic}$		0.0005***		0.0005***		0.0004***		0.0004***
		(0.0002)		(0.0002)		(0.0001)		(0.0001)
wage per worker$_{ic}$		−1.86		−1.348		−1.719*		−2.653**
		(1.34)		(1.85)		(1.0)		(1.144)
wage per worker$_{ic}$ (% diff)$_{i}$				−0.616				1.091
				(1.816)				(1.279)
Obs.	1251	1251	1251	1251	1491	1491	1491	1491
Industries	20	20	20	20	20	20	20	20
Industry FE	yes	yes	yes	yes	yes	yes	yes	yes
Country FE	yes	yes	yes	yes	yes	yes	yes	yes

Standard errors presented in parentheses. ***=1% level **=5% level, *=10% level. Standard errors clustered by country-industry level (e.g. Chile ISIC 311)

Table 9
Value Added TFP

	1990			1991		
	Value Added	Exports	Pr(exp>0)	Value Added	Exports	Pr(exp>0)
VA per worker$_{fic}$	1.507***	0.964***	1.347***	1.648***	1.101***	1.575***
	(0.093)	(0.132)	(0.127)	(0.067)	(0.139)	(0.132)
VA per worker$_{ic}$	−0.963***	−0.607***	−0.913***	−1.2***	−0.788***	−1.192***
	(0.167)	(0.164)	(0.205)	(0.107)	(0.139)	(0.139)
Obs.	7493	1266	7493	7115	1497	7115
Industries	20	20	20	20	20	20
Industry FE	yes	yes	yes	yes	yes	yes
Country FE	yes	yes	yes	yes	yes	yes
Restriction p-val	0	0	0	0	0	0

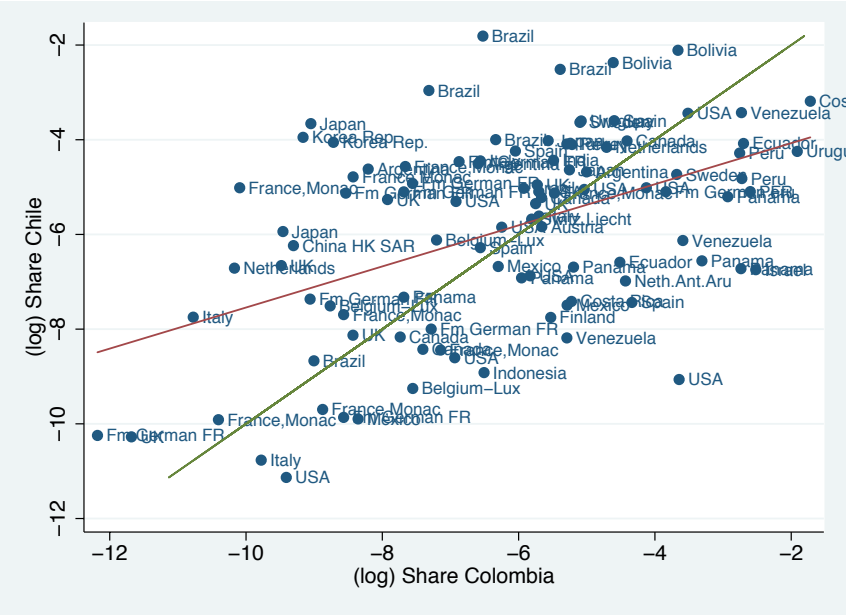
Standard errors presented in parentheses. ***=1% level **=5% level, *=10% level. Standard errors clustered by country-industry level (e.g. Chile ISIC 311)

Table 10
Non-Linear Plant Productivity

	1990			1991		
	Value Added	Exports	Pr(exp>0)	Value Added	Exports	Pr(exp>0)
VA per worker$_{fic}$	1.174***	0.372	1.451***	1.346***	0.746**	1.848***
	(0.119)	(0.253)	(0.506)	(0.169)	(0.369)	(0.374)
VA per worker$^2_{fic}$	0.059***	0.071	−0.027	0.039	0.022	−0.072
	(0.019)	(0.044)	(0.085)	(0.03)	(0.055)	(0.058)
$VAperworker_{ic}$	−0.538*	−0.207	−0.642*	−0.895***	−0.532*	−0.991***
	(0.297)	(0.3)	(0.332)	(0.284)	(0.292)	(0.263)
Obs.	7493	1266	7493	7115	1497	7115
Industries	20	20	20	20	20	20
Industry FE	yes	yes	yes	yes	yes	yes
Country FE	yes	yes	yes	yes	yes	yes

The dependent variable in the logit =1 if there are positive levels of exports, zero otherwise. Standard errors presented in parentheses. ***=1% level,**=5% level, *=10% level. Standard errors clustered by country-industry level (e.g. Chile ISIC 311)

Figure 1:



We also include a 45 degree line for ease of visual inspection.

Figure 2:

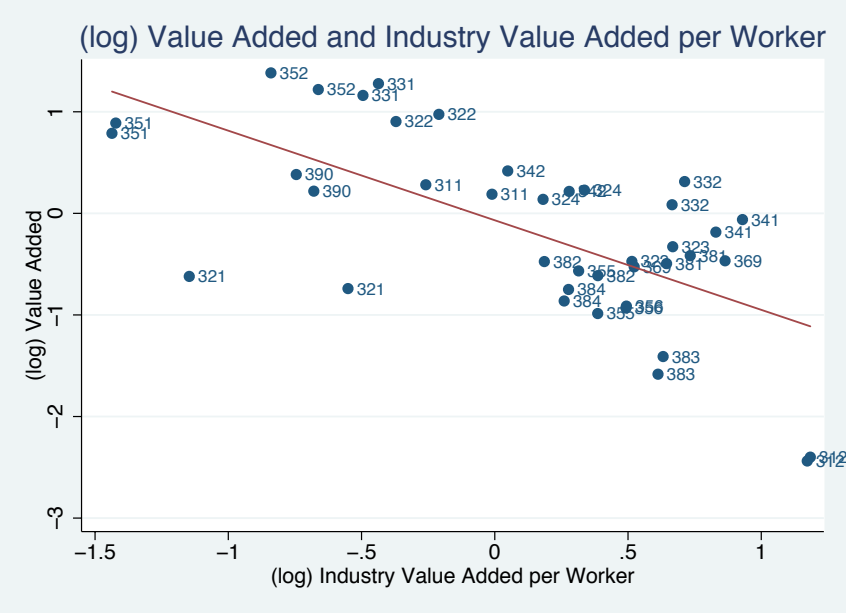


Figure 3:

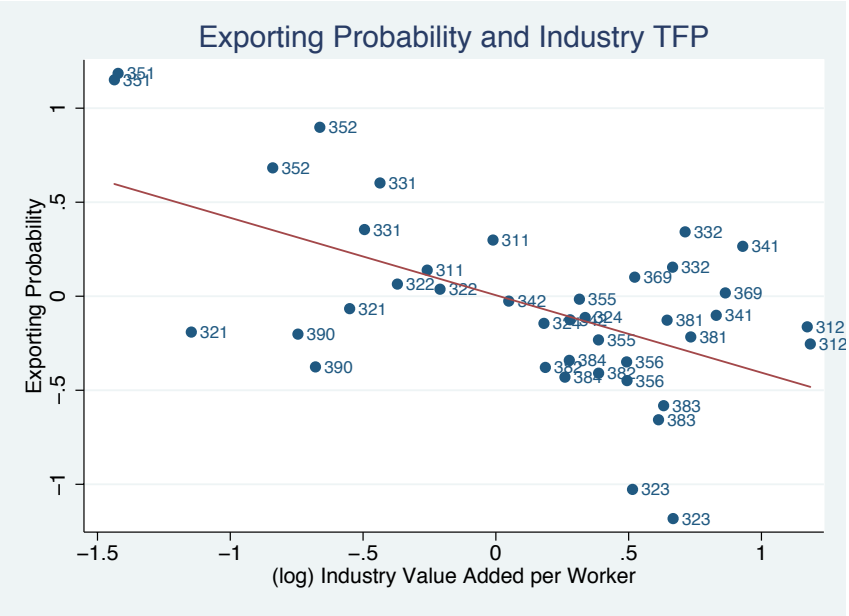


Figure 4: