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

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Abstract

This paper develops and empirically examines a model of relative productivity differences both within and across industries for small open economies. Residing in a relatively productive industry in a given country entails a key tension: any firm in the industry is likely to be relatively productive but so are its peer firms and domestic competitors in export markets. We decompose the effect of industry productivity on export performance into a positive direct effect of own firm productivity and an indirect effect of higher peer firm productivity and ask whether this indirect effect is negative, zero, or positive. In a sample of Chilean and Colombian plants, we find evidence of both a positive direct effect and a negative indirect effect. We also show both theoretically and empirically that industry level Ricardian predictions hold as the direct effect dominates the indirect effect. Empirical evidence suggests that industry-specific factors of production and asymmetric substitutability between domestic and foreign varieties drive this negative indirect effect.

JEL Codes: F10, F11, F12.

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1 Introduction

The positive correlation between productivity and exporting is among the most robust findings in empirical international trade. At the industry level, this provides the foundation for the Ricardian model in which relative productivity differences determine patterns of specialization. Empirical support for this model is plentiful and includes contributions by Macdougall (1951,1952), Stern (1962), Harrigan (1997), Eaton and Kortum (2002), Kerr (2009), and Costinot and Komunjer (2009). This model suggests that firms experience superior exporting outcomes because they can access relatively higher technology/productvity levels in certain industries. Simultaneously, another literature focuses on the firm as the unit of analysis and suggests that successful export performance is due to certain firms having high enough productivity to overcome the costs of exporting.[1] Neither literature takes a stand on how firm and industry productivity interact in determining exporting outcomes.[2]

This paper combines these two views by examining both empirically and theoretically how firm export performance depends not just on its own relative productivity but also on the relative productivity of the industry in which it resides. If a firm's own productivity is all that matters, the productivity level of the country-industry in which it resides should have no additional explanatory power for export performance after conditioning on firm productivity. We place this in the context of comparative advantage by asking whether residence in a country's Ricardian comparative advantage industry provides additional "indirect" benefits or hindrances, conditional on the "direct effect" of firm productivity.

We summarize the question and identification strategy with a simple thought experiment. Figure 1 displays firm productivity distributions for two countries (Chile and Colombia) in two industries (machinery and chemicals). Average productivity levels suggest that Chile possesses a Ricardian comparative advantage in machinery relative to chemicals. 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? We then compare any difference in machinery relative to chemicals, thereby ex-

[1] e.g. Bernard, Eaton, Jensen, and Kortum (2002), Melitz (2003), and Melitz & Ottaviano (2008).

[2] Trivially, representative firm models offer no variation between firm and industry productivity.

amining comparative and not absolute advantage and differencing out any country-specific effects.

Because of the nature of the question, we require detailed firm-level data across industries and countries. This requirement is satisfied by data for Chile and Colombia for 1990-1991 that has been used extensively in the international trade literature.[3] Employing this data, we find a positive direct effect of own firm productivity and a negative indirect effect of peer firms' productivity on a firm's export performance in an industry. Firms in comparative advantage industries possess higher productivity, on average, and this shows through as firm productivity has a positive direct effect on both the level of exports and the probability of exporting. However, *conditional on own productivity*, plants with relatively more productive domestic peer firms sell *less* abroad and have a *lower* propensity to export. In this sense, residence in a relatively productive industry in a given country entails a key tension: any firm in the industry is likely to be relatively productive but so are its peer firms and domestic competitors in export markets. We show both theoretically and empirically that the positive direct effect dominates the negative indirect effect; that is, industry-level Ricardian predictions hold in both the level of exports and the proportion of firms exporting. We also show that existing models of firm heterogeneity integrating comparative advantage predict that industry affiliation should have a positive or no impact on external performance after conditioning on own-firm characteristics when wages are set at the national level.

We model and empirically scrutinize two modifications to the canonical model to explain our results. Specifically, we focus on non-standard competition in product and factor markets.[4] We now define these non-standard forms of competition more precisely.

The mechanism that we term the "product market competition" channel argues that two varieties produced within the same national border are likely to be more substitutable than two varieties produced in different countries. If a country possesses relatively higher productivity in a given industry, this will correlate with more competitive economic conditions for all firms exporting

[3]We discuss our choice of years in section 4.

[4]Because we do not depart substantially from the canonical model, we do not invoke technology "spillovers" nor any technology transfer. See Keller (2002) for a summary of the technology transfer literature literature. This paper differs from much of that literature in that 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. 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.*

in the industry as measured by the position of the residual demand curve that they face. However, this effect will be stronger for firms producing relatively similar varieties. Across industries, this effect should be stronger for industries in which two domestic varieties face relatively more elastic demand than a domestic and a foreign variety. 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 are a more substitutable product with each other than with wines produced in other countries. Conversely, we posit that for 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).

We also explore what we call "factor market competition" through which higher relative productivity in an industry leads to a relatively higher wage of the specific factor associated with that industry. This increases the fixed costs of exporting leading to a lower probability of exporting and also lower exports for a firm of a given productivity level. In theory, industry-specific inputs can be thought of as factors of production that cannot easily be moved from industry to industry.[5] We find evidence of this channel in the data, as the industry wage correlates negatively with firm performance after having been purged of country- and industry-specific effects.

Examining and comparing productivity and export performance in Chile and Colombia is appropriate for four 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.[6] 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

[5] These can be industry-specific knowledge of workers or physical capital that diminishes in capacity if moved from one industry to another. 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 hiring and firing costs based on seniority.

[6] We have ensured that the plant-level measures of nominal 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 (2010).

similar competitive conditions in World markets based on their geographic location and level of development. Figure 2 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.

Third, for the time period we consider, 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.[7]

Fourth, analyzing relative productivity patterns between two countries of similar levels of development is well suited to the Ricardian framework as opposed to the Heckscher-Ohlin model. For the Heckscher-Ohlin model, if endowments are similar, it is not obvious how specialization should vary. However, when analyzing across-industry relative productivity patterns, it is not obvious why two countries of similar development levels should possess the same across-industry relative productivity patterns.

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 examining heterogeneous firms within an industry. While the Ricardian model has experienced a renaissance

[7] IMF Direction of Trade Statistics Database (2008). Moreover, both Chile and Columbia recognized this deficiency and entered into an economic complementation agreement in 1994 to reduce tariffs. More recently, Chile and Columbia entered into a free trade agreement in 2006. 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.

recently (as noted in the introduction), this literature has not asked how one can think about the interaction of heterogeneity both within and across industries. The literature on firm heterogeneity models heterogeneous firms in a given industry but does not ask how firms respond to residence in either a comparative advantage or disadvantage industry. Important exceptions include Demidova (2008) and Bernard, Redding, and Schott (2007) who focus on within and across industry heterogeneity in the context of large open economies.

Demidova (2008) presents a rich two-industry North-South model that predicts that own country-industry productivity should have a *positive* indirect effect on exporting probability conditional on the own firm productivity direct effect. In her model, high average firm productivity in a differentiated industry in the North discourages Southern entry in that industry. This causes the endogenous toughness of competition in the South to diminish further encouraging Northern exports to the South in that industry. Our work is complementary to Demidova (2008) in that we explore similar issues and how they might vary across large and small open economies. Bernard, Redding, and Schott (2007) present a two-industry, two-country model with Heckscher-Ohlin based comparative advantage and firm productive heterogeneity. Lower relative factor prices of the country's abundant factor lead to lower fixed costs of exporting in the industry that uses that factor relatively intensively, so that a firm of a given productivity in this industry is more likely to be able to export profitably.

Both models predict a positive indirect effect of residing in the comparative advantage industry, but this is due to their general equilibrium, large open economy structure (Demidova) or their emphasis on Heckscher-Ohlin forces (Bernard, Redding, and Schott). Our empirical finding of a negative indirect effect of industry productivity on a firm's exports and probability of exporting after conditioning on firm productivity motivates this investigation. We now show that the canonical model of firm heterogeneity for a small open economy with Ricardian foundations predicts no role for industry productivity in determining firm exporting outcomes.

Suppose that one of multiple small open economies exports to a large "World" market. By definition, assume that any economy examined is "small" enough that it takes the world equilibrium as given. The market structure is Dixit-Stiglitz with each firm producing a unique variety.[8] ϕ_{fic}

[8] Each firm produces a unique variety and the elasticity of substitution across varieties of $\sigma > 1$ regardless of the

represents productivity for firm f in industry i in country c; w_c is a country-specific wage. Firm exports to the World $[r_x(\phi)]$ are as follows where A_i is a demand shifter that each small open economy takes as given, τ represents iceberg transportation costs, and $\rho = (\sigma - 1)/\sigma$:[9]

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

Assuming that countries c and c' face the same τ, relative export revenue from the World market for two firms in different countries but the same industry is as follows,

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

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." [10]

In the next section, present our framework. Our model is consistent with the empirical evidence presented in Section 4 that industry productivity has a *negative* indirect effect on firm level export peformance in terms of both the probability of exporting and the levels of exports. This happens for two reasons. First, if varieties from the same source country are more substitutable, more productive firms shift in the residual demand curve for all other firms but more so for firms that produce relatively more substitutable varieties. Second, more productive peer firms bid up the wage of country-industry specific factors leading to greater difficulty in other firms covering the fixed costs of exporting.

3 Model

This section presents a simple model of multiple small open economies exporting to a large World market. This model motivates the empirical work in Section 4. We start by deriving the basic

country of origin.

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

[10] 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. Similar results hold using the framework of Melitz and Ottavaino (2008).

elements of the model and then a series of propositions that highlight the direct and indirect effects of industry productivity on firm export performance. The propositions that we derive and use are as follows. First, we show that countries with a comparative advantage in an industry will feature relatively higher specific factor wages and lower CES export price indexes in that industry. Second, we show that comparative advantage in an industry leads to larger export volumes and a larger proportion of exporting firms. Third, we show that firms face a higher minimum level of productivity necessary for exporting in a comparative advantage industry. Fourth, a firm *of a given productivity level* exports in lower volumes if it resides in a comparative advantage industry due to factor- and product-market competition. Fifth, we show that the observed average productivity in an industry can be used as a accurate proxy for underlying Ricardian productivity differences as defined in our model.

We now present the general structure of the model. There are three industries. Each small open economy produces, consumes and exports goods 1 and 2. Good 0 is imported from the rest of the World to balance trade in each country. In line with the empirical evidence presented in the introduction, we assume that the small open economies do not trade with each other. Due to our small open economy assumption, 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. We start by deriving the demand side of the model followed by the production side. We then present market clearing conditions that close the model and then discuss the characteristics of the equilibrium including the relevant propositions.

3.1 Demand

The preferences of the representative consumer in country c are defined by the following three-tier Cobb-Douglas utility function:

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

where Q_{ic} is a 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 producing country, i is the industry, and ω indexes varieties.[11] C is the set of all countries from which c consumes. The lowest tier aggregates within-industry varieties produced within a given country into a country-industry CES aggregator. The next tier aggregates these country-industry aggregators into a industry-level CES aggregate. The top tier is comprised of Cobb-Douglas preferences over industry aggregates. The elasticity of substitution between two varieties from the same country in a given industry is σ. The elasticity of substitution between industry country-level aggregates is ϵ. If $\sigma = \epsilon$, varieties in an industry are equally substitutable regardless or origin. In this case this three-tier stucture collapses down to a familiar two-tier structure (e.g. Romalis, 2004).

3.2 Production

The two factors of production are labor, which is freely mobile across industries earning a wage w_c, and a factor specific to industry i, that we denote by K_{ic} and that 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 aggregate endowment of (mobile) labor is L_c.

Within each industry i and country c, there is continuum of firms, each producing a different variety, and characterized by a productivity level ϕ as in Melitz (2003). A firm with productivity ϕ produces quantity q and possesses the following homothetic total cost function:

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

where $f w_c^{1-\eta} s_{ic}^{\eta}$ is a fixed cost of production 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

[11] As is common, we constain σ >1; the imposition of $\epsilon > 1$ is to maintain the fundamental Ricardian result that lower relative prices result in greater sales when comparing industries across countries.

to be the same across industries and countries.

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 a shape parameter k and minimum draw $\phi_{m,ic}$.[12] 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.

Upon entry, firms must pay a fixed cost $f_e w_c^{1-\eta} s_{ic}^{\eta}$ to draw a level of productivity in industry i. Upon drawing a productivity level ϕ, a firm makes two decisions. First, it decides whether to produce or not for the domestic market. Analogous to Melitz (2003), we indicate by $\phi_{d,ic}$ the productivity threshold for domestic production such that profits in the domestic market of a firm with that level of productivity, $\pi_{d,ic}\left(\phi_{d,ic}\right)$ are zero. Firms with productivity below $\phi_{d,ic}$ exit immediately. Firms with productivity above $\phi_{d,ic}$ continue to operate. Second, conditional on producing domestically, the firm decides whether to export or not. Firms that export incur an additional fixed cost $f_x w_c^{1-\eta} s_{ic}^{\eta}$ and a per-unit iceberg transport cost, $\tau > 1$. The exporting threshold $\phi_{x,ic}$ is such that profits in the World market for a firm with that level of productivity, $\pi_{x,ic}\left(\phi_{x,ic}\right)$, are zero. Firms with productivity below $\phi_{x,ic}$ do not export.

Revenue in the World market for an exporting firm with productivity ϕ in industry i is as follows:

$$r_{x,ic}\left(\phi\right) = E_i \left(\frac{\tau w_c^{1-\eta} s_{ic}^{\eta}}{\rho\phi}\right)^{1-\sigma} \left(P_{x,ic}\right)^{\sigma-1} \left(\frac{P_{x,ic}}{P_i^W}\right)^{1-\epsilon}. \tag{1}$$

where E_i is World expenditure in industry i, $P_{x,ic}$ is the price index associated with varieties supplied by country c in industry i on *World* markets, and P_i^W is the top-tier price index on the World market for industry i. All exporting countries face the same P_i^W. Absorbing the top-tier CES price index and industry expenditure into the industry constant A_i implies

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

[12]The cumulative density function of parameter ϕ is therefore: $G_{ic}\left(\phi\right) = 1 - \left(\frac{\phi_{m,ic}}{\phi}\right)^k$. We restrict $k > \sigma - 1$ to ensure that all integrals converge.

World market conditions, A_i, are not affected by firms' export decisions in country c, due to the small open economy assumption.[13] The importance of the relative magnitude of σ in relation to ϵ is clear here. Holding firm productivity and industry wages constant, if two domestic varieties are closer substitutes than a domestic and a foreign variety ($\sigma > \epsilon$), a lower export price index for country c in industry i will lower firm export revenue. The opposite will hold if two domestic varieties are more distant substitutes than a domestic and a foreign variety.

Exploiting the Pareto distribution, the observed probability of exporting is equal to the proportion of operational firms that export and is equal to $p_{x,ic} = \left(\frac{\phi_{d,ic}}{\phi_{x,ic}}\right)^k$. This expression is intuitive. For a given production cutoff, $\phi_{d,ic}$, the probability is declining in the exporting cutoff, $\phi_{x,ic}$, as exporting is relatively more difficult. For a given exporting cutoff, $\phi_{x,ic}$, the probability of exporting conditional on production is increasing in the production cutoff, $\phi_{d,ic}$, as there are fewer firms that are not exporting but still operating.

In Melitz (2003), the zero profit and free entry conditions for entry into domestic and foreign markets, $\phi_{x,ic}$ and $\phi_{d,ic}$, uniquely determine the equilibrium cutoffs.[14] The mass of firms, M_{ic} is determined residually in a two-step procedure.[15] Our model employs similar zero profit and free entry expressions that we display in the Appendix for brevity sake. Entry is free both within and across sectors. In our case, however, the cutoffs are determined simultaneously with the mass of firms as both are partially determined by the return to the specific factor. To derive properties of the equilibrium, we employ a industry-specific factor market clearing condition. Firms' revenues are split between the mobile factor and the specific factor such that a share η of total revenues in industry i are paid to K_{ic}:

$$\eta M_{ic}\overline{r}_{ic} = s_{ic}K_{ic} \tag{3}$$

where $\overline{r}_{ic}$ is the average revenue of a firm operating in industry i.

Consider now a second small open economy c' exporting to a large World market. We allow the two countries to differ in size, both in terms of population and specific factor endowments. We

[13] $A_i = E_i(P_i^W)^{1-\sigma}$.

[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 average absence of profits, total revenues are equal to total labor income.

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 minimum draws across countries and industries follow

$$\frac{\phi_{m,1c}}{\phi_{m,2c}} < \frac{\phi_{m,1c'}}{\phi_{m,2c'}}. \tag{4}$$

We start by asking whether the minimum productivity necessary for exporting will be relatively higher in a country's Ricardian comparative advantage industry by asking whether $\frac{\phi_{x,1c}}{\phi_{x,2c}} \gtreqless \frac{\phi_{x,1c'}}{\phi_{x,2c'}}$. Using the expression for export revenues in equation (2) and the expression $r_{x,ic}\left(\phi_{x,ic}\right) = \sigma f_x w_c^{1-\eta} s_{ic}^{\eta}$,[16] the relationship between the export cutoffs in the two countries in industry i is then: $\frac{\phi_{x,ic}}{\phi_{x,ic'}} = \left[\frac{P_{x,ic}}{P_{x,ic'}}\right]^{\frac{\epsilon-\sigma}{\sigma-1}} \left[\frac{w_c^{1-\eta} s_{ic}^{\eta}}{w_{c'}^{1-\eta} s_{ic'}^{\eta}}\right]^{\frac{\sigma}{\sigma-1}}$. We take the ratio of this expression across the two industries 1 and 2 and rearrange to obtain the following relationship between relative export cutoffs and relative specific factor returns,

$$\frac{\phi_{x,2c}/\phi_{x,2c'}}{\phi_{x,1c}/\phi_{x,1c'}} = \left[\frac{s_{2c}/s_{2c'}}{s_{1c}/s_{1c'}}\right]^{\frac{\eta\sigma}{\sigma-1}} \left[\frac{P_{x,1c}/P_{x,2c}}{P_{x,1c'}/P_{x,2c'}}\right]^{\frac{\sigma-\epsilon}{\sigma-1}}. \tag{5}$$

Although the price index depends on wages, equation (5) is useful for partially decomposing product- and factor-market competition. If $\sigma = \epsilon$, such that product market competition does not play a role, the larger the relative return to the specific factor in industry i-country c, the higher the relative exporting cutoff. If $\eta = 0$ such that factor specificity plays no role, 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.

We assume that $\sigma > \epsilon$ such that varieties produced in the same country are more substitutable than varieties produced in different countries. We do this for two reasons: first, it offers an alternative hypothesis to the specific factors model. Second, at this relatively high level of aggregation, baskets of goods are likely to be more comparable within borders than across borders.[17]

Assumption 1 Within each country c each industry i is endowed with the same amount of

[16]This latter derives from the fact that $\pi_{x,ic}\left(\phi_{x,ic}\right) = \frac{r_{x,ic}\left(\phi_{x,ic}\right)}{\sigma} - f_x w_c^{1-\eta} s_{ic}^{\eta}$.

[17]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.

specific factor: $K_{ic} = K_c \ \forall i, c$.

This assumption is made for analytical tractability. In the long run, as specific factors migrate to the industry with the highest return, there should be *no effect* of industry productivity on export-related performance via specific factors as the factor prices equate across industries. If endowments of specific factors are positively correlated with average productivity, this will lower the wage of the specific factor but will make our empirical result *less likely* to appear in the data. If allocations of the specific factors are negatively correlated with average productivity, this will amplify the results derived below due to wages of specific factors being pushed up by both higher relative demand and lower relative supply of the specific factor.

3.3 Propositions

We now derive five propositions that 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. It also states 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 industry* 2 *than in industry* 1 *, compared to* c'*, i.e.* $\frac{s_{1c}}{s_{1c'}} < \frac{s_{2c}}{s_{2c'}}$ *and the ratio of relative export price indexes will be less in country* c' *than in* c *such that* $\frac{P_{x,1c}}{P_{x,1c'}} > \frac{P_{x,2c}}{P_{x,2c'}}$ ***Proof.*** *See 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 higher demand for the specific factor which drives up its return. Second, more productive firms result in a lower CES price index as the cost of a unit of consumption will be lower in the industry in which firms are more productive. Based on these propositions, we can derive the following two propositions that show that common Ricardian predictions hold at the industry level in this setting such that if a country has a comparative advantage in a industry, then the total industry value of export shipments will be higher in that same industry. Also, it shows that the proportion of active firms that export will also be higher in that industry.

Proposition 2 *If* $\sigma > \epsilon$ *and* $\frac{\phi_{m,1c}}{\phi_{m,1c'}} < \frac{\phi_{m,2c}}{\phi_{m,2c'}}$ *then* $\frac{R_{1c}}{R_{1c'}} < \frac{R_{2c}}{R_{2c'}}$ *and* $\frac{p_{x,1c}}{p_{x,1c'}} < \frac{p_{x,2c}}{p_{x,2c'}}$ ***Proof.*** *See Appendix.* ■

We now show that the minimum level of productivity necessary to export will be relatively *higher* in a country's comparative advantage industry. This will lead to a firm *of a given productivity level* being less likely to export.

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 Proposition 1 and equation (5).* ■

Proposition 4 shows that a similar intuition holds for the level of exports. A firm of a given productivity level ϕ_0 will have a lower level of exports if it resides in a country's comparative advantage industry.

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:*

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

The result then follows from proposition (1). ■

In sum, propositions 3 and 4 and the structure of the model predict that own-firm productivity should have a positive direct effect on firm exporting but that industry productivity should have a negative indirect effect.

However, there is still a disconnect that we now resolve. Our theoretical model is based on Ricardian comparative advantage based on the minimum draw in a distribution. Unfortunately, this minimum draw is generally unobserved. This would be true even with a continuum of firms given that only firms with draws above $\phi_{d,ic}$ will appear in the data in equilibrium. Consequently the following proposition shows that average productivity in an industry will be positively and monotonically related to the minimum draw upon which the distributions are based. This allows us to use industry productivity as a theoretically consistent proxy for the underlying minimum draw.

Proposition 5 *If* $\frac{\phi_{m,1c}}{\phi_{m,1c'}} < \frac{\phi_{m,2c}}{\phi_{m,2c'}}$*, then* $\frac{\overline{\phi}_{d,1c}}{\overline{\phi}_{d,1c'}} < \frac{\overline{\phi}_{d,2c}}{\overline{\phi}_{d,2c'}}$ *where* $\left(\overline{\phi}_{d,ic}\right)^{\sigma-1} = \frac{1}{1-G\left(\phi_{d,ic}\right)} \int_{\phi_{d,ic}}^{\infty} \phi^{\sigma-1} g\left(\phi\right) d\phi$ *is the composite productivity of an "average" operating firm.* ***Proof.*** *See Appendix.* ■

The most transparent manner to assess product and factor market competition is to exploit the log-linear structure of the export revenue function of equation (2). Unfortunately, the underlying country-industry CES price indexes $P_{x,ic}$ are unobservable. For this reason, we derive a version of the export revenue function in which export revenues are a function of observed average country-industry productivity and observed wages which include payments to the specific factor:

$$r_{x,fic}(\phi) = A_c A_i'(\phi_{fic})^{\sigma-1} \left[\overline{\phi}_{d,ic}\right]^{\frac{k(1-\sigma)(\sigma-\epsilon)}{k(\sigma-\epsilon)+(1-\epsilon)(1-\sigma)}} \left[w_c^{1-\eta} s_{ic}^{\eta}\right]^{\frac{k\sigma(\sigma-\epsilon)}{k(\sigma-\epsilon)+(1-\epsilon)(1-\sigma)}+1-\sigma} \tag{6}$$

where the constants A_i' and A_c are industry- and country-specific terms that do not depend on country-industry nor firm terms. The derivation of this expression and the precise definitions of the constants A_c and A_i' is presented in the appendix. We now explore the empirical validity of the theory exposited above.

4 Empirical Results

This section explores the empirical predictions of Section 3 that, *conditional on the direct effect of own productivity*, a plant in a comparative advantage industry has a lower probability of exporting and exports lower volumes due to an indirect effect of industry productivity. 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 4.3 explores the factor market and product market competition channels between industry-level productivity and plant-level outcomes, conditional on own plant productivity. Section 4.4 discusses measurement error and Section 4.5 concludes by exploring the robustness of our results.

4.1 Data

Plant-level data come from the statistical agencies *Instituto Nacional de Estadistica* and *Administrativo Nacional de Estadistica* for Chile and Colombia, respectively. These data have been used extensively in the trade literature.[18] 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.[19] Due to the respective sizes of the countries, approximately 70% of the observations are for Colombian plants and the remainder are Chilean.[20]

The focus of this study is on plant- and industry-level productivity using value added per worker as our preferred measure.[21] Because of difficulties in comparing capital stocks across countries and time, our preferred specifications use value added per worker as a measure of productivity as opposed to total factor productivity.[22]

In order to compare productivity differences across countries, we ensure that the data are comparable. We want to remove non-productivity related relative price differences in value added. To do so we use 3-digit output deflators from the central bank of each country to put all value added data in 1980 constant country-specific pesos for each country. We then use the December exchange rate for 1980 in each country to transform value added in each industry into non-PPP adjusted 1980 U.S. dollars.[23] Finally, we use constructed disaggregated 1980 PPP price indexes

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

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

[20] This is roughly in proportion to their relative populations with the CIA factbook showing approximate populations for Colombia and Chile of 44 million and 16 million, respectively

[21] Although firm heterogeneity models with CES preferences predict that value added per worker is constant only if workers engaged in fixed costs are excluded, workers are pooled regardless of if they are engaged in coverage of fixed or variable costs in our data.

[22] We have examined capital stock data for these two countries and have decided they they are unusable in this context. Specifically, while flow variables such as value added and employment will not be affected by *past* inflation, measurement of stock variables such as capital can be affected by the high and variable inflation that affected both countries in the mid-1980s. We have examined measures of value added TFP with value added as a function of effective labor input and capital stock and compared both this and real value added per worker to Penn World Tables data on real GDP per worker. When aggregating to the national level, our measure of real value added per worker is very close to real GDP per worker from the Penn World Tables. However, our measure of TFP is an order of magnitude different even after using the Penn World Tables investment deflator and detailed central bank data on national investment deflators and checking the components of investment for comparability. As we will discuss in section 4.4, this is a first order concern for us as we examine the empirical content of our model.

[23] We put prices in PPP adjusted 1980 real dollars because this is the year for which the Penn World Tables provides

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. Because of our difference-in-difference strategy, all (multiplicative) country-specific and industry-specific terms in productivity (and in all outcome variables) will be differenced out. See the Data Appendix for more details.

To create measures of value added per worker, we also 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. Because we rely on measures of real value added per worker, any differences in the effectiveness of labor that are pervasive across industries will be absorbed into the country fixed effect used in the estimation.

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.[24] 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.[25] In addition, industry productivity is constructed excluding the plant in question. This is true for all regressions. 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.[26]

The following four sections proceed as follows: First, we present our baseline results that, conditional on the direct effect of own plant productivity, the indirect effect of higher industry

the finest level of disaggregation in terms of the number of goods. The exchange rate was relatively stable in 1980 leading to insensitivity to different months.

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

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

[26]The industry measures are then constructed from these instrumented values. We *do not* use industry productivity lagged one year as an instrument for itself.

productivity diminishes both the probability of exporting and the value of exports. Second, we discuss the roles played by both product market competition and factor market competition using equation (6). Third, we discuss the role of measurement error in our results. Fourth, we present robustness checks to our baseline results.

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. We start by estimating the probability of exporting as a function of plant- and industry-level productivity controlling for the relevant fixed effects.

$$Pr\left(EXP_{fic} > 0\right) = F\left(\beta_{plant}\phi_{fic} + \beta_{ind}\phi_{ic} + \beta_{chile}chile_c + \beta'_{ind}\Delta_i\right) + \nu_{fic}, \tag{7}$$

where $F(\bullet)$ is the logit operator, ϕ_{fic} and ϕ_{ic} are plant and industry level productivity, $chile_c$ 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 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 across plant within the industry.

Logit results are presented in Table 2. We also estimate linear probability of exporting models for ease of interpretation. Own-plant productivity has a positive direct effect on the probability of exporting while industry productivity has a negative indirect 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]

[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

Proposition (2) implies an extremely important linear restriction on the coefficients ϕ_{fic} and ϕ_{ic}. Because the country possessing a Ricardian comparative advantage in an industry will export with a higher probability, we should observe $\beta_{plant} + \beta_{ind} > 0$. This restriction is a direct implication of Ricardian comparative advantage holding at the industry level. The p-values for this restriction are presented in the final row of this table.

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% to 19% 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 8.6% to 14% 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 7.4% to 5% for 1990 and 1991, respectively.[28] For reference, the unconditional probability of exporting in this sample for 1990-1991 is 22% for Colombia and 20% for Chile.

In the second specification, we analyze the value of exports as a function of own-plant productivity and industry productivity using the expression derived in equation (6).[29]

$$r_{x,fic} = \beta_{plant}\phi_{fic} + \beta_{ind}\phi_{ic} + \beta_{chile}chile_c + \beta'_{ind}\Delta_i + \nu_{fic}, \tag{8}$$

The country- and industry-specific constants, as well as the national wage w_c, will be absorbed by country- and industry-specific fixed effects. We start by presenting results that present the direct effect of own plant productivity and the indirect effect of industry productivity on export performance in our sample. We then exploit the structure of equation (6) to show that both product and factor market competition play a role in our results and to assess the relative values of σ and ϵ. Equation (6) along with the assumption of the Pareto distribution also allows us to derive values of σ and ϵ.

a similar point.

[28]The final two magnitudes are simply the sum of the positive direct effect and the negative indirect effect.

[29]We explicitly choose to make export revenue a function of average productivity and not average exporter productivity. Because the number of exporters in many industries is relatively small, this would require attaching a great deal of importance to very few observations and enhance collinearity problems. Because of the structure of the model, we can avoid this problem by deriving a theoretically correct export revenue function in terms of plant productivity, industry wages, and industry productivity, the last of which which we believe is a better proxy for the productivity of peer firms than measured productivity of other exporters.

Tables 3 shows that the qualitative results from Table 2 continue to hold. Own plant productivity increases sales while the indirect effect of the productivity of other plants in the industry diminishes sales 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. However, these results become much stronger and uniform when we explicitly examine the product and factor market competition channels in section 4.3.

Figures 3-4 present this information graphically. In each graph, we purge the left-hand side variable from Tables 2 and 3 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.[30] Visual inspection suggests that no single industry or small group of industries is responsible for the patterns in the regressions results although we explore this econometrically in the robustness section.

We are naturally concerned with the endogenous simultaneity of exporting and productivity. Although the mechanisms exposited in the firm heterogeneity literature take a strong stand that productivity causes exporting, the empirical literature is more nuanced.[31] We stress that the variable we are most interested in these estimations is *industry-level* and not plant-level productivity. Although if plant productivity suffers from endogeneity due to reverse causation, the impact on the industry coefficient is not obvious. To partially address these concerns, industry productivity is constructed excluding the plant in question. In these specifications, arguments about the endogeneity of productivity in the cross section are less relevant 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.[32]

[30] 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.

[31] 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 following the Canada-U.S. Free Trade Agreement.

[32] 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

4.3 Decomposing Product and Factor Market Competition

The results above suggest that plants *of a given productivity level* attain superior economic outcomes abroad when they reside in less economically competitive industries. However, the transmission mechanisms are unclear given that industry productivity can operate either through product- or factor-maket competition in our model. In this section, we explore the roles that factor and product market competition might play in generating these results by using the theoretically derived export revenue function, equation (6), whose log-linear structure provides a direct mapping from reduced form coefficients to structural parameters. As specified in the theory section, if two domestic varieties are more substitutable than a domestic and a foreign variety, high industry level productivity in a country will contract the residual demand curve 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. If factors are industry-specific, a superior distribution of productivity in an industry bids up the wages of the specific factor leading to a lower probability of exporting and a lower level of exports conditioning on plant productivity.

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. For homogenous goods it is more likely that there is no national differentiation such that $\sigma = \epsilon$. 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 ($\epsilon < \sigma$). For example, Chilean wines constitute a distinguishable type of wine compared to wines from other countries.[33] 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

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.

[33] An example of this is Chilean Carménère wine which is found widely within Chile but rarely outside.

classifications of Rauch (1999). These classifications indicate if an industry is "homogeneous" (h), "reference priced" (r), or "differentiated" (d).[34] Table 6 presents shares that reflect the degree to which an industry is composed of goods classified as differentiated.

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.[35] This can also be seen as the structural coefficient on industry productivity in equation (6) goes to zero when $\epsilon = \sigma$; this will be most likely when $(\%diff)_i$=0.

Following equation (6), we control for factor market competition by explicitly introducing industry average wages as our measure of $w_c^{1-\eta} s_{ic}^{\eta}$ where the country-specific mobile wage will be absorbed into the country-specific fixed effect where industry average wages are measured by total salaries and benefits in the industry-country-year divided by total employment in the same dimension excluding the plant in question. Equation (6) also predicts that more differentiated industries lessen the negative effect of s_{ic} leading us to interact it with $(\%diff)_i$ for consistency with the theoretical framework.[36] The baseline equation of interest becomes:

$$\begin{aligned} ln(r_{fict}) &= \beta_{plant} ln(\phi_{fict}) + \beta_{ind}^{'} \ln(\phi_{ict}) + \beta_{ind} (\%diff)_i \times \ln(\phi_{ict}) \\ &\quad + \beta_{ind\_wage}^{\prime} ln(s_{ict}) + \beta_{ind\_wage} (\%diff)_i \times ln(s_{ict}) \\ &\quad + \beta_{chile} chile_{ct} + \beta_{ind}^{\prime} \Delta_{it}^{\prime} + \eta_{fict}, \end{aligned}$$

where we include the time subscript due to the pooled nature of the results we present. To summarize, theory predicts that, because of product market competition, $\beta_{ind} < 0$ and that, because

[34] "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*.

[35] 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.

[36] In accordance with equation (6), this will lead to the coefficient on wages being premultiplied by the share of the specific factor in total wages (η).

of factor market competition, $\beta'_{ind\_wage} < 0$ and $\beta_{ind\_wage} > 0$.

Table 5 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 greater in absolute magnitude in industries with higher shares of differentiated exports. However, equation (6) suggests that industry wages should be included as an additional control. Column (2) includes factor market competition and finds that higher industry wages lead to lower export levels as predicted. This suggests that both factor market and product market competition are at work in this sample. However because wages are not a pure cost shifter in the data but just a proxy, we do not attach a value to the structural parameter η. Column (3) shows that the coefficient on industry wages differs across Rauch classifications as predicted by theory as it is less negative for more differentiated industries. Evaluating the coefficient on industry productivity from column (3) at the average value of $\%diff_i$ delivers a value of -0.40 whose absolute value is less than the absolute value of the coefficient on plant productivity (0.80).[37] We now exploit the fact that, given this structure, the standard deviation of log domestic sales should be equal to $1/(k+1-\sigma)$. In the sample, we measure this standard deviation to be 1.47.[38] Using this standard deviation with our estimate of σ in table 5 delivers a value of k=1.48. We can then use our estimates of σ, k, and equation (6) to calculate ϵ=1.58. It is worth noting that while the reduced form coefficients in table 3 are somewhat variable, this variability is not reflected in the coefficients for σ and ϵ suggesting that year to year variable industry composition in aggregate exports is being sufficiently controlled for by inclusion of the interaction terms.

Table 6 presents these same regressions by year. Although the point estimates are less precise, similar results with the pooled sample hold with 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 3. This suggests that, as predicted by theory, the effect varies for homogenous and differentiated industries. Second, the coefficients on industry productivity and industry productivity interacted

[37] The average value of $\%diff_i$ from table 4 is 0.74.

[38] This is remarkably stable. We calculate the statistic within industry, year, and country and then average it across industries for each country and year. For Colombia, the average standard deviation of log sales is 1.47 in 1990 and 1.48 in 1991. For Chile, it was 1.43 and 1.44 for 1990 and 1991, respectively. Their average informs our use of 1.47.

with the differentiated share are *jointly* significant at the 10% level for column (4). Third, the coefficient on industry wage interacted with the differentiated goods is positive as predicted by theory. Estimates of epsilon are similar to those reported in table 5.

Are these calculated values of σ and ϵ consistent with coefficients estimated in past industry-level estimations of the Ricardian model?[39] We can answer this by asking what the implied industry level elasticity of exports with respect to industry productivity is based on our model. This can be done by solving for the theoretically appropriate $P_{x,ic}$ in terms of observed industry average productivity, exploiting the second tier CES relationshis $\frac{R_{ic}}{R_{ic'}} = \left(\frac{P_{x,ic}}{P_{x,ic'}}\right)^{1-\epsilon}$, and predicting a reduced form coefficient based on the values of σ, ϵ, and k from table 5.[40] Our estimates of these structural variables from column (1) of table 5 imply an industry level elasticity of 0.40. This is between the industry Ricardian coefficients of 0.31 and 0.30 by Kerr (2009) and Morrow (2010), respectively, and coefficients in the neighborhood of unity estimated by Costinot and Komunjer (2009) although Kerr (2009) and Costinot and Komunjer (2009) use bilateral trade data and Morrow uses production data.[41]

4.4 Discussion of Measurement Error

Estimation of exports as a function of own-plant and country-industry productivity is equivalent to estimation of equation (9) below 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

$$r_x(\phi_{fic}) = \beta_{dev}(\phi_{fic} - \phi_{ic}) + \beta_{ind'}\phi_{ic} + \beta_{chile}chile_c + \beta'_{ind}\Delta i + \epsilon_{fic}. \tag{9}$$

Comparing this to estimation of the equation

$$r_x(\phi_{fic}) = \beta_{plant}\phi_{fic} + \beta_{ind}\phi_{ic} + \beta_{chile}chile_c + \beta'_{ind}\Delta i + \epsilon_{fic},$$

[39] We note that while these estimates are similar to macroeconomic estimates of the elasticity of substitution, they are less than those based on import data at highly disaggregated levels. See Imbs and Mejean (2009) for a thorough discussion of these differences.

[40] This is done by taking the value of $\phi_{d,ic}$ and solving for $\phi_{x,ic}$ in terms of it and then using equation (40) in the Appendix

[41] We use the implied valued of σ and ϵ from column (1) because these map most closely against the Ricardian models mentioned above where exports are the left hand side variable and no attention is paid to specific factors.

it is clear that the coefficient on own-plant productivity, β_{plant}, is equivalent to β_{dev} and the coefficient on industry productivity, β_{ind}, is equal to $\beta'_{ind} - \beta_{dev}$. If there is pervasive measurement error in industry productivity but not in plant (relative to country-industry mean) productivity, this will bias $\beta_{ind'}$ to zero and will bias β_{ind} to $-\beta_{dev} = -\beta_{plant}$.

We examine this by dividing possible measurement error into two types. First, measurment error in which accounting differences lead to differences in physical quantities counted or measurement error in capital stock. If this type of measurement error is driving our results, we should find it uniformly across industries.

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 economy. Because section 4.3 finds that this effect is more common in differentiated industries, we do not believe that measurement error of the first type is driving our results.

4.5 Robustness

This section explores the robustness of our results in two ways. First, we ensure that our results are not due to a specific industry. Towards that goal, we perform the exercise of table 5 dropping one industry at a time. Second, we examine the possibility that industry productivity is merely picking up higher order terms for plant productivity. We show that our baseline results as well as our results using the Rauch classification are robust to that possibility.

Due to the relatively small number of industries upon which our analysis is based, we are concerned about the stability of our results. Table 7 replicates table 5 except that industries are dropped one by one to show that the results involving the Rauch classifications are not overly sensitive to a single industries. Each row reports the relevant column coefficients from table 5 dropping the industry indicated in the far left hand column. For all specifications, the coefficient on industry productivity interacted with % differentiated is negative as indicated by theory. In addition the coefficients on industry wage and industry wage interacted with % differentiated are negative and positive as indicated by theory. Implied values of σ and ϵ are included for completeness.

Table 8a presents baseline 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 and 3. Table 8b shows that the results involving Rauch classifications are robust to these higher order terms as well.

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 for a given firm 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. Using plant-level data for Chile and Colombia for 1990 and 1991, we find the common result that own firm productivity enhances exporting outcomes but we also identify a negative indirect effect of higher peer firm productivity that diminishes exporting outcomes for firms of a given productivity level. We model and empirically scrutinize two channels for these results.

First, we introduce imperfect relative substitutability using a nested-CES approach in which two varieties produced within the same border are better substitutes on international markets than 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 more for firms producing more substitutable varieties than for varieties that are less substitutable.

Second, we then introduce factor market competition involving 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 find evidence for each of these mechanisms in our data set. 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. For factor market competition, we find that, conditional on own-plant wage, higher industry wages lead to lower exports. As predicted by the model, this is partially mitigated in more differentiated industries.

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 Free Entry, Zero Profit, and Market Clearing Conditions

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 stream of profits is equal to the entry cost:

$$\left[1 - G\left(\phi_{d,ic}\right)\right] \frac{\overline{\pi}_{ic}}{\delta} = f_e w_c^{1-\eta} s_{ic}^{\eta}, \tag{10}$$

where $\frac{\overline{\pi}_{ic}}{\delta}$ is the discounted constant expected profit and δ is an exogenous per period probability of "death." 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:

$$\overline{\pi}_{ic} = \overline{\pi}_{d,ic} + \underbrace{\frac{1 - G\left(\phi_{ix}\right)}{1 - G\left(\phi_{id}\right)}}_{p_{x,ic}} \overline{\pi}_{x,ic} \tag{11}$$

where $p_{x,ic}$ represents the probability of exporting conditional on successful entry.

Expected domestic profits in each market coincide with the profits of a firm characterized by composite productivity level defined as $\left(\overline{\phi}_{d,ic}\right)^{\sigma-1} = \frac{1}{1-G\left(\phi_{d,ic}\right)} \int_{\phi_{d,ic}}^{\infty} \phi^{\sigma-1} g\left(\phi\right) d\phi$. Expected profits from exporting are based on an analogous composite productivity of exporting firms, $\left(\overline{\phi}_{x,ic}\right)^{\sigma-1} = \frac{1}{1-G\left(\phi_{x,ic}\right)} \int_{\phi_{x,ic}}^{\infty} \phi^{\sigma-1} g\left(\phi\right) d\phi$. The zero profit cutoff conditions $\pi_{d,ic}\left(\phi_{d,ic}\right) = 0$ and $\pi_{x,ic}\left(\phi_{x,ic}\right) = 0$, yield the following relationships between the cutoffs, industry specific wages, and average profits in the domestic and foreign markets,respectively:

$$\overline{\pi}_{d,ic} = w_c^{1-\eta} s_{ic}^{\eta} f \left[\left(\frac{\overline{\phi}_{d,ic}}{\phi_{d,ic}} \right)^{\sigma-1} - 1 \right], \tag{12}$$

$$\overline{\pi}_{x,ic} = w_c^{1-\eta} s_{ic}^{\eta} f_x \left[\left(\frac{\overline{\phi}_{x,ic}}{\phi_{x,ic}} \right)^{\sigma-1} - 1 \right]. \tag{13}$$

6.2 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:

$$\left(\frac{\overline{\phi}_{d,ic}}{\phi_{d,ic}} \right)^{\sigma-1} = \left(\frac{\overline{\phi}_{x,ic}}{\phi_{x,ic}} \right)^{\sigma-1} = \frac{k}{k+1-\sigma}. \tag{14}$$

We substitute (11) in (10) and replace $\overline{\pi}_{d,ic}$ and $\overline{\pi}_{x,ic}$ with their expressions in (12) and (13). Substituting (14) and the Pareto cumulative density function (**??**) in the resulting expression, yields the following condition:

$$\delta f_e \frac{k+1-\sigma}{\sigma-1} = f \left(\frac{\phi_{m,ic}}{\phi_{d,ic}} \right)^{k} + f_x \left(\frac{\phi_{m,ic}}{\phi_{x,ic}} \right)^{k}. \tag{15}$$

Average firm revenues $\overline{r}_{ic}$ can be rewritten as $\frac{\overline{r}_{ic}}{\sigma} = \overline{\pi}_{ic} + w_c^{1-\eta} s_{ic}^{\eta} f + \frac{1-G(\phi_{x,ic})}{1-G(\phi_{d,ic})} w_c^{1-\eta} s_{ic}^{\eta} f_x$. Using the free-entry condition (10) to substitute $\overline{\pi}_{ic}$ and the Pareto cdf, average firm revenues can be expressed as:

$$\frac{\overline{r}_{ic}}{\sigma} = w_c^{1-\eta} s_{ic}^{\eta} \delta f_e \left(\frac{\phi_{d,ic}}{\phi_{m,ic}}\right)^k + w_c^{1-\eta} s_{ic}^{\eta} f + \left(\frac{\phi_{d,ic}}{\phi_{x,ic}}\right)^k w_c^{1-\eta} s_{ic}^{\eta} f_x. \tag{16}$$

By replacing (16) in (3) we obtain the following equation:

$$\eta M_{ic} \sigma w_c^{1-\eta} s_{ic}^{\eta} \left(\delta f_e \left(\frac{\phi_{d,ic}}{\phi_{m,ic}}\right)^k + f + \left(\frac{\phi_{d,ic}}{\phi_{x,ic}}\right)^k f_x\right) = s_{ic} K_{ic}. \tag{17}$$

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 $r_{d,ic}(\phi_{d,ic}) = \sigma f w_c^{1-\eta} s_{ic}^{\eta}$ then we can establish, using (14), the following condition:

$$\alpha Y_c = M_{ic} \frac{k \sigma f w_c^{1-\eta} s_{ic}^{\eta}}{k+1-\sigma} \tag{18}$$

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 (15), (17), (18), and the following three conditions: the definition of the CES export price index (equation 19), the zero-exporting profits condition for ϕ_{xi} (equation 20), and the fact that the mass of exporting firms is equal to the mass of firms times the probability of exporting (equation 21).

$$P_{x,i}^{1-\sigma} = \left(\frac{\tau w_c^{1-\eta} s_{ic}^{\eta}}{\rho \phi_{xi}}\right)^{1-\sigma} \frac{M_{i,x} k}{k+1-\sigma} \quad i \in 1,2 \tag{19}$$

$$\alpha Y^W \left(\frac{\tau w_c^{1-\eta} s_{ic}^{\eta}}{\rho \phi_{xi} P_{x,i}}\right)^{1-\sigma} \left(\frac{P_{x,i}}{P_i^W}\right)^{1-\epsilon} = \sigma f_x w_c^{1-\eta} s_{ic}^{\eta} \quad i \in 1,2 \tag{20}$$

$$M_{xi} = p_{i,x} M_i = \left(\frac{\phi_{di}}{\phi_{xi}}\right)^k M_i \quad i \in 1,2 \tag{21}$$

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:

$$\delta f_e \frac{k+1-\sigma}{\sigma-1} = \left(\frac{\phi_{m,i}}{\phi_{d,i}}\right)^k f + \left(\frac{\phi_{m,i}}{\phi_{x,i}}\right)^k f_x \quad i \in 1,2, \tag{22}$$

$$\left(\frac{\phi_{di}}{\phi_{xi}}\right)^k = \frac{f\left[k s_i K_i - \alpha \eta Y (k+1-\sigma)\right]}{\alpha \eta Y (k+1-\sigma)\left[\delta f_e \phi_{xi}^k + f_x \phi_{mi}^k\right]} \phi_{mi}^k \quad i \in 1,2, \tag{23}$$

$$\left[\frac{\tau s_i^\eta}{\rho\phi_{xi}}\right]^{1-\epsilon}\left[\frac{\phi_{xi}^k}{\phi_{di}^k}\right]^{\frac{\sigma-\epsilon}{\sigma-1}}\left[\frac{\alpha Y}{\sigma f s_i^\eta}\right]^{\frac{\epsilon-1}{\sigma-1}}\left(P_i^W\right)^{\epsilon-1}=\frac{f_x Y}{f Y^W}\quad i\in 1,2. \tag{24}$$

Solving equation (23) for ϕ_{id}, and substituting this into equations (22) and (24), We obtain the following

$$\delta f_e\frac{k+1-\sigma}{\sigma-1}=\frac{\delta f_e\alpha\eta Y(k+1-\sigma)\phi_{xi}^k+f_x k s_i K_i\phi_{mi}^k}{\left[k s_i K_i-\alpha\eta Y(k+1-\sigma)\right]\phi_{xi}^k}\quad i\in 1,2, \tag{25}$$

$$\left[\frac{\tau w_c^{1-\eta}s_i^\eta}{\rho\phi_{xi}}\right]^{1-\epsilon}\left[\frac{f\left[s_i k K_i-\eta\alpha Y(k+1-\sigma)\right]\phi_{m,i}^k}{\eta\alpha Y(k+1\sigma)\left[\delta f_e\phi_{x,i}^k+f_x\phi_{x,i}^k\right]}\right]^{\frac{\sigma-\epsilon}{1-\sigma}}\left(P_i^W\right)^{\epsilon-1}=\frac{f_x Y}{f Y^W}\quad i\in 1,2. \tag{26}$$

Solving equation 25 for ϕ_{xi}^k, substituting into equation 26, and dividing the expression for $i=1$ by $i=2$ gives the following expression

$$\left[\frac{s_2K_2-\alpha\eta Y}{s_1K_1-\alpha\eta Y}\right]^{\frac{\sigma-\epsilon}{\sigma-1}}\left[\frac{s_1K_1[s_2K_2-\alpha\eta Y]}{s_2K_2[s_1K_1-\alpha\eta Y]}\right]^{\epsilon-1}\left(\frac{\phi_{m1}}{\phi_{m2}}\right)^{k(\epsilon-1)}\left(\frac{P_1^W}{P_2^W}\right)^{\epsilon-1}=\left(\frac{s_1}{s_2}\right)^{\frac{\eta\sigma(\epsilon-1)}{\sigma-1}}. \tag{27}$$

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

$$\left[\frac{s_{2,c}K_{2,c}-\alpha\eta Y_c}{s_{1,c}K_{1,c}-\alpha\eta Y_c}\frac{s_{1,c'}K_{1,c'}-\alpha\eta Y_{c'}}{s_{2,c'}K_{2,c'}-\alpha\eta Y_{c'}}\right]^{\frac{\sigma-\epsilon}{\sigma-1}}\left[\frac{s_{2,c}K_{2,c}-\alpha\eta Y_c}{s_{1,c}K_{1,c}-\alpha\eta Y_c}\frac{s_{1,c'}K_{1,c'}-\alpha\eta Y_{c'}}{s_{2,c'}K_{2,c'}-\alpha\eta Y_{c'}}\right]^{\epsilon-1}\left(\frac{s_1}{s_2}\frac{s_{2,c'}}{s_{1,c'}}\right)^{\epsilon-1}\left(\frac{\phi_{m,1c}}{\phi_{m,2c}}\frac{\phi_{m,2c'}}{\phi_{m,1c'}}\right)^{k(\epsilon-1)}=\left(\frac{s_{1c}}{s_{2c}}\frac{s_{2c'}}{s_{1c'}}\right)^{\frac{\eta\sigma(\epsilon-1)}{\sigma-1}} \tag{28}$$

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 $w=1$:

$$\frac{(1-\eta)s_{ic}K_{ic}}{\eta}=w_cL_{ic}\qquad\frac{(1-\eta)s_{ic'}K_{ic'}}{\eta}=w_{c'}L_{ic'} \tag{29}$$

$$Y_c=w_c(L_{1c}+L_{2c})+s_{1c}K_{1c}+s_{2c}K_{2c}\quad Y_{c'}=w_{c'}(L_{1c'}+L_{2c'})+s_{1c'}K_{1c'}+s_{2c'}K_{2c'} \tag{30}$$

Substituting these two expressions into equation 28 gives the following equation

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

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

To prove that the relative price indexes follow the postulated pattern, combine equations (15), (17), and (18) to yield

$$\phi_{x,i}^k=\frac{(\sigma-1)f_x s_i K_i\phi_{mi}^k}{\delta f_e(k+1-\sigma)\left[s_iK_i-\alpha\eta Y\right]}\quad\in 1,2, \tag{32}$$

and equations (17), (18), (19), and (21) to yield

$$P_{x,i}^{1-\sigma} = \left(\frac{\tau s_i^\eta}{\rho\phi_{xi}}\right)^{1-\sigma} \frac{1}{\sigma s_i^\eta} \frac{[ks_iK_i - \alpha\eta Y](k+1-\sigma)}{\eta(k+1-\sigma)(\delta f_e\phi_{xi}^k + f_x\phi_{mi}^k)}\phi_{mi}^k \quad \in 1,2, \tag{33}$$

Substituting equation 32 into equation 33 gives:

$$P_{x,i}^{1-\sigma} = \left(\frac{\tau s_i^\eta}{\rho\phi_{xi}}\right)^{1-\sigma} \frac{s_iK_i - \alpha\eta Y}{\eta f_x\sigma s_i^\eta} \quad i \in 1,2, \tag{34}$$

Dividing equation (20) by equation (34) and then dividing the equation for $i = 1$ by $i = 2$ delivers

$$\left(\frac{P_{x,2}}{P_{x,1}}\right)^{\epsilon-1} = \left(\frac{P_1^W}{P_2^W}\right)^{1-\epsilon} \frac{s_1K_1 - \alpha\eta Y}{s_2K_2 - \alpha\eta Y} \tag{35}$$

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

$$\left(\frac{P_{x,2c}P_{x,1c'}}{P_{x,1c}P_{x,2c'}}\right)^{\epsilon-1} = \frac{s_{1,c}s_{2,c'}}{s_{2,c}s_{1,c'}} \frac{1-\alpha\left(1+\frac{s_{2,c}}{s_{1,c}}\right)}{1-\alpha\left(1+\frac{s_{2,c'}}{s_{1,c'}}\right)} \frac{1-\alpha\left(1+\frac{s_{1,c'}}{s_{2,c}}\right)}{1-\alpha\left(1+\frac{s_{1,c}}{s_{2,c}}\right)} \tag{36}$$

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

6.3 Proof of Proposition 2

With CES preferences, the ratio of exporting sales accruing to country c to country c' in industry i will be $\frac{R_{ic}}{R_{ic'}} = \left(\frac{P_{x,ic}}{P_{x,ic'}}\right)^{1-\epsilon}$. Based on Propostition (1), the first result follows trivially. For the second result use equations (18), (19), (20), and (21) to obtain

$$\left(\frac{P_{x,ic}}{P_i^W}\right)^{1-\epsilon} = \frac{f_x}{f}\left(\frac{\phi_{d,ic}}{\phi_{x,ic}}\right)^k \frac{Y}{Y^W}. \tag{37}$$

Taking differences in differences gives the desired result based on Propostition (1)

$$\left(\frac{P_{x,1c}}{P_{x,1c'}}\frac{P_{x,2c'}}{P_{x,2c}}\right)^{1-\epsilon} = \frac{p_{x,1c}\ p_{x,2c'}}{p_{x,1c'}\ p_{x,2c}}. \tag{38}$$

6.4 Proof of Proposition 5

Combining equations equations (15), (17), and (18) gives the following expressions

$$\alpha k\eta\delta f_e(k+1-\sigma)Y_c\phi_{d,ic}^k = kf(\sigma-1)s_{ic}K_{ic}\phi_{m,ic}^k$$

Taking differences-in-differences gives the following expression

$$\left(\frac{\phi_{d,1c}}{\phi_{d,2c}}\frac{\phi_{d,1c'}}{\phi_{d,2c'}}\right)^k = \frac{s_{1c}s_{1c'}}{s_{2c}s_{2c'}}\left(\frac{\phi_{m,1c}}{\phi_{m,2c}}\frac{\phi_{m,1c'}}{\phi_{m,2c'}}\right)^k. \tag{39}$$

The desired result then comes from a direct application of Proposition (1).

6.5 Construction of Equation (6) and

Start with equations (2), (20), and (37). Substitute out $P_{x,ic}$ and $\phi_{x,ic}$. The desired result follows. The explicit meaning of the constants A_i' and A_c is as follows:

$$A_i' = A_i \left(\frac{k}{k+1-\sigma}\right)^{\frac{k(1-\sigma)(\sigma-\epsilon)}{k(\sigma-\epsilon)+(1-\epsilon)(1-\sigma)}} \left(\frac{\tau}{\rho}\right)^{1-\sigma} \left[\frac{\alpha}{\sigma f Y^W}\left(\frac{\tau}{\rho}\right)^{\frac{k(\sigma-1)}{k+1-\sigma}}\right]^{\frac{(\sigma-\epsilon)(k+1-\sigma)}{k(\sigma-1)+(1-\epsilon)(k+1-\sigma)}} \left(P^W\right)^{\frac{(1-\epsilon)(k+1-\sigma)(\sigma-\epsilon)}{k(\sigma-1)+(1-\epsilon)(k+1-\sigma)}}$$

and

$$A_c = Y_c^{\frac{2k(1-\sigma)(\sigma-\epsilon)}{k(\sigma-\epsilon)+(1-\epsilon)(1-\sigma)}}.$$

7 Data Appendix

The key to making international comparisons of productivity involves making the Chilean and Colombian plants as similar as possible. This involves making value added labor input, and capital input 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 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
Propensity to Export
[Dependent variable =1 if the plant exports and =0 otherwise]

	1990				1991			
	Logit		OLS		Logit		OLS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(log) VA per Worker$_{fic}$	1.20***	1.28***	0.15***	0.16***	1.29***	1.40***	0.18***	0.19***
	(0.08)	(0.09)	(0.01)	(0.01)	(0.10)	(0.11)	(0.02)	(0.02)
(log) VA per Worker$_{ic}$		-0.64**		-0.086*		-0.99***		-0.14***
		(0.33)		(0.05)		(0.26)		(0.04)
Observations	7493	7493	7493	7493	7115	7115	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		0.025		0.11		0.086		0.18

Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry panel (e.g. Chile 311). *** p<0.01, ** p<0.05, * p<0.1

Table 3
Export Revenue
[Dep. variable=(log) export value]

	1990		1991	
	(1)	(2)	(3)	(4)
(log) VA per Worker$_{fic}$	0.75***	0.78***	0.81***	0.87***
	(0.11)	(0.11)	(0.10)	(0.11)
(log) VA per Worker$_{ic}$		-0.19		-0.55**
		(0.26)		(0.27)
Observations	1251	1251	1491	1491
Industries	20	20	20	20
Industry FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Restriction p-val		0.033		0.19

Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry panel (e.g. Chile 311).
***p<0.01, ** p<0.05, * p<0.1.

Table 4
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 5
Identification through Rauch Classification (Pooled)
[Dep. variable=(log) export value]

	(1)	(2)	(3)
(log) VA per Worker$_{fict}$	0.82***	0.80***	0.80***
	(0.08)	(0.08)	(0.07)
(log) VA per Worker$_{ict}$	0.0059	0.44*	0.69**
	(0.23)	(0.25)	(0.33)
(log) VA per Worker$_{ict}$ x (% diff)$_i$	-0.69**	-1.19***	-1.38***
	(0.27)	(0.34)	(0.37)
(log) Wage per Worker$_{fict}$		-1.89**	-5.42***
		(0.83)	(2.04)
(log) Wage per Worker$_{fict}$ x (% diff)$_i$			3.75*
			(2.15)
Implied σ	1.82	1.80	1.80
Implied ϵ	1.45	1.48	1.58
Observations	2742	2742	2742
Industries	20	20	20
Industry-Year FE	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes

Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry-year panel (e.g. Chile 311, 1990). ***p<0.01, ** p<0.05, * p<0.1.

Table 6
Identification through Rauch Classification (Annual)
[Dep. variable=(log) export value]

		1990			1991	
	(1)	(2)	(3)	(4)	(5)	(6)
(log) VA per Worker$_{fict}$	0.77***	0.77***	0.77***	0.87***	0.87***	0.87***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
(log) VA per Worker$_{ict}$	0.21	0.34	0.45	-0.25	-0.044	0.17
	(0.30)	(0.39)	(0.44)	(0.34)	(0.25)	(0.31)
(log) VA per Worker$_{ict}$ x (% diff)$_i$	-0.79**	-0.95*	-1.04*	-0.56	-0.81**	-0.95**
	(0.34)	(0.55)	(0.55)	(0.43)	(0.37)	(0.35)
(log) Wage per Worker$_{fict}$		-0.57	-1.87		-0.94	-5.04
		(1.28)	(2.77)		(1.12)	(3.26)
(log) Wage per Worker$_{fict}$ x (% diff)$_i$			1.34			4.40
			(2.96)			(3.33)
Implied σ	1.77	1.77	1.77	1.87	1.87	1.87
Implied ϵ	1.51	1.52	1.56	1.31	1.34	1.46
Observations	1251	1251	1251	1491	1491	1491
Industries	20	20	20	20	20	20
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry panel e.g. Chile 311). ***p<0.01, ** p<0.05, * p<0.1.

Table 7
Sensitivity to Specific Industries (pooled)
[Dep. variable=(log) export value]

Excluded Industry	(log) VA per Worker_{fic}	(log) VA per Worker_{ic}	(log) VA per Worker_{ic} x(% diff)$_i$	(log) wage per worker $_{ic}$	(log) wage per worker_{ic} x(% diff)$_i$	Implied σ	Implied ϵ
311	0.89***	0.70*	-1.65***	-3.80***	2.81**	1.89	1.48
312	0.80***	0.74**	-1.38***	-4.14***	2.20**	1.80	1.62
321	0.86***	0.23	-1.44***	-4.76***	1.72	1.86	1.04
322	0.81***	0.61**	-1.27***	-4.48***	2.67**	1.81	1.59
323	0.80***	0.68**	-1.33***	-5.21***	3.62***	1.80	1.60
324	0.79***	0.56*	-1.26***	-4.23***	2.69**	1.79	1.53
331	0.82***	0.41*	-0.95***	-3.74***	2.68**	1.82	1.62
332	0.79***	0.62**	-1.37***	-4.47***	2.66**	1.79	1.51
341	0.77***	0.50*	-1.23***	-4.19***	2.78**	1.77	1.48
342	0.78***	0.69**	-1.41***	-4.72***	2.72**	1.78	1.54
351	0.76***	1.18**	-1.98***	-5.47***	3.25***	1.76	1.58
352	0.82***	0.63**	-0.94**	-4.95***	2.49**	1.82	1.78
355	0.77***	0.60**	-1.27***	-4.33***	2.87***	1.77	1.54
356	0.81***	0.75**	-1.36***	-5.00***	3.08***	1.81	1.64
369	0.77***	0.70**	-1.43***	-5.16***	3.27**	1.77	1.53
381	0.79***	0.61**	-1.28***	-4.43***	2.85**	1.79	1.56
382	0.80***	0.62**	-1.31***	-4.44***	2.89**	1.80	1.56
383	0.80***	0.61**	-1.32***	-4.44***	2.77**	1.80	1.55
384	0.77***	0.62**	-1.31***	-4.41***	2.76**	1.77	1.54
390	0.80***	0.70**	-1.53***	-4.37***	2.15	1.80	1.49

Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry-year panel (e.g. Chile 311, 1990). ***p<0.01, ** p<0.05, * p<0.1.

Table 8a
Non-Linear Plant Productivity
[Dep. variable=(log) export value]

	1990		1991	
	Exports	Pr(exp>0)	Exports	Pr(exp>0)
(log) VA per Worker$_{fic}$	0.37	1.49***	0.73*	1.86***
	(0.25)	(0.47)	(0.37)	(0.38)
(log) VA per Worker$^2_{fic}$	0.069	-0.038	0.022	-0.077
	(0.04)	(0.08)	(0.05)	(0.06)
(log) VA per Worker$_{ic}$	-0.25	-0.62*	-0.56**	-0.96***
	(0.29)	(0.32)	(0.28)	(0.26)
Observations	1251	7478	1491	7109
Industries	20	20	20	20
Industry FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

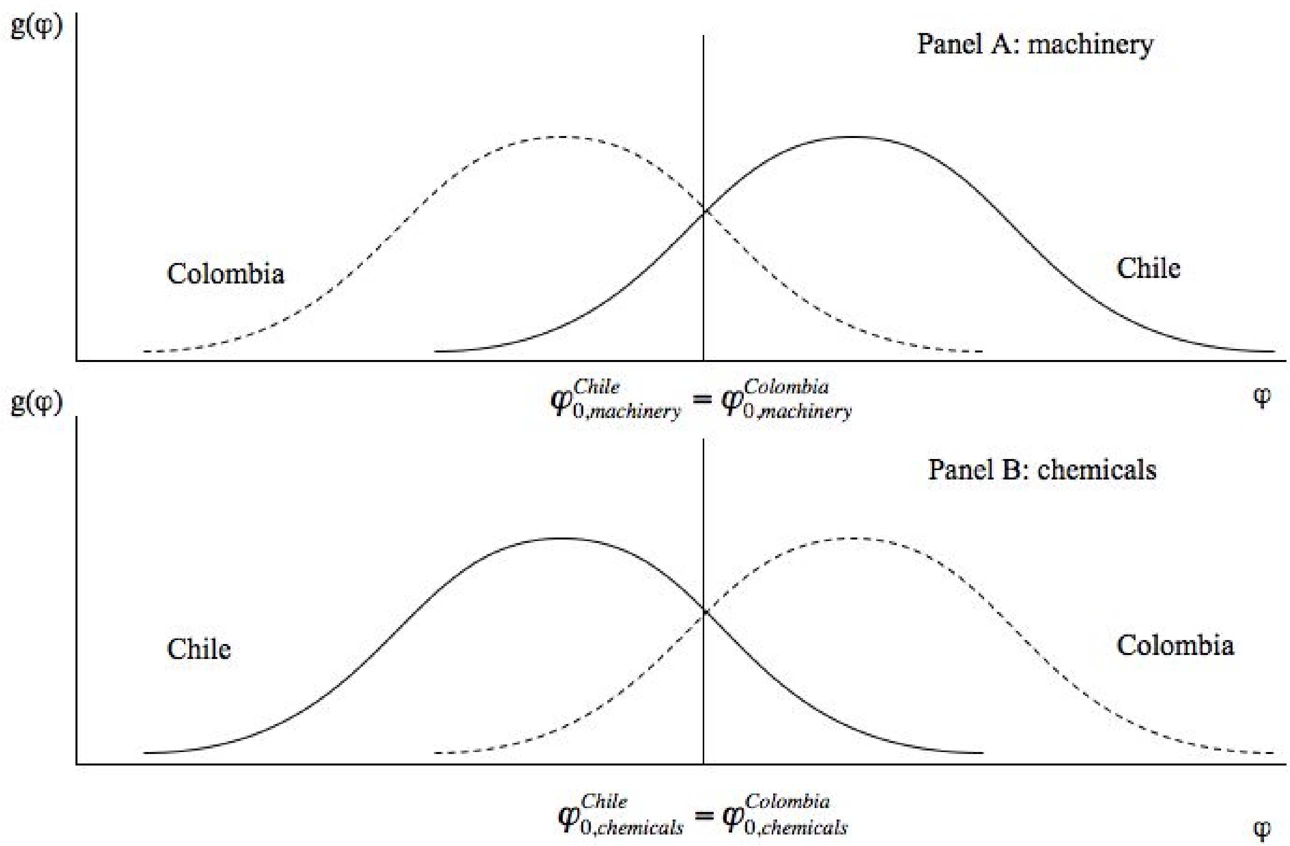
Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry panel (e.g. Chile 311).
***p<0.01, ** p<0.05, * p<0.1.

Table 8b
Non-Linear Plant Productivity With Rauch
[Dep. variable=(log) export value]

	(1)	(2)	(3)
(log) VA per Worker$_{fict}$	0.52**	0.55**	0.55**
	(0.23)	(0.24)	(0.24)
(log) VA per Worker$^2_{fict}$	0.048	0.042	0.040
	(0.04)	(0.04)	(0.04)
(log) VA per Worker$_{ict}$	-0.072	0.31	0.49
	(0.26)	(0.28)	(0.30)
(log) VA per Worker$_{ict}$	-0.61**	-1.05***	-1.24***
x (% diff)$_i$	(0.28)	(0.36)	(0.37)
(log) Wage per Worker$_{fict}$		-1.67**	-3.33***
		(0.82)	(0.99)
(log) Wage per Worker$_{fict}$			1.61***
x (% diff)$_i$			(0.56)
Observations	2742	2742	2742
Industries	20	20	20
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes

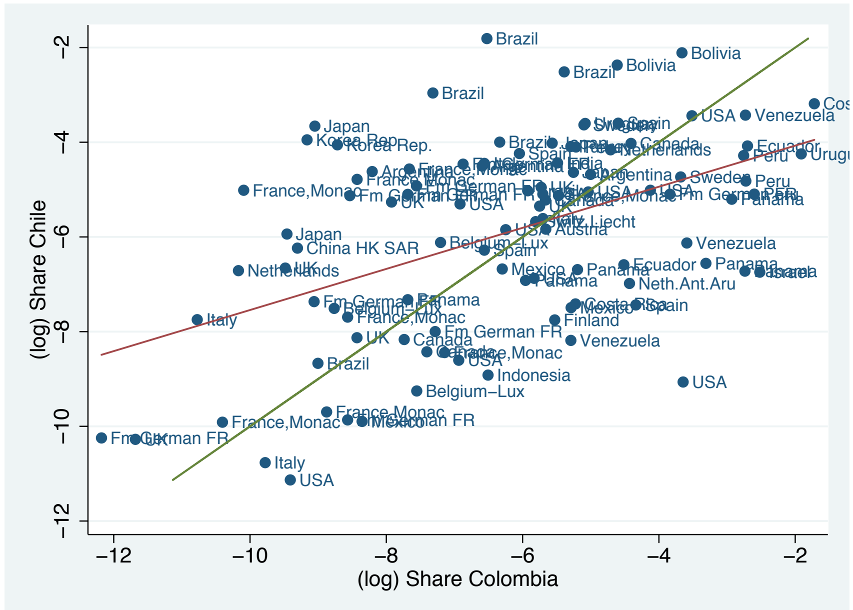
Robust and clustered standard errors in parentheses. Clustered standard errors by country-industry panel (e.g. Chile 311).
***p<0.01, ** p<0.05, * p<0.1.

Figure 1:



g(φ)
Panel A: machinery
Colombia
Chile
$\varphi_{0,machinery}^{Chile} = \varphi_{0,machinery}^{Colombia}$
φ
g(φ)
Panel B: chemicals
Chile
Colombia
$\varphi_{0,chemicals}^{Chile} = \varphi_{0,chemicals}^{Colombia}$
φ

Figure 2:



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

Figure 3:

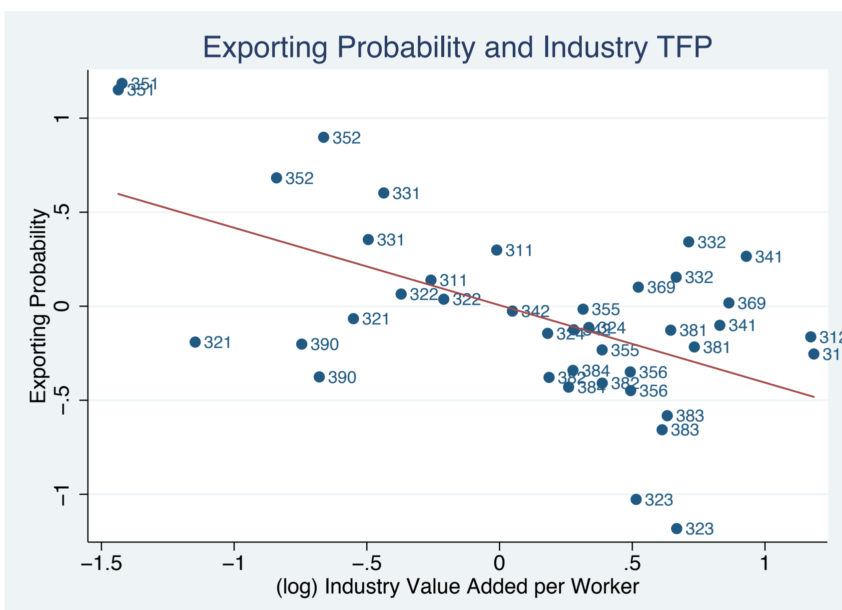
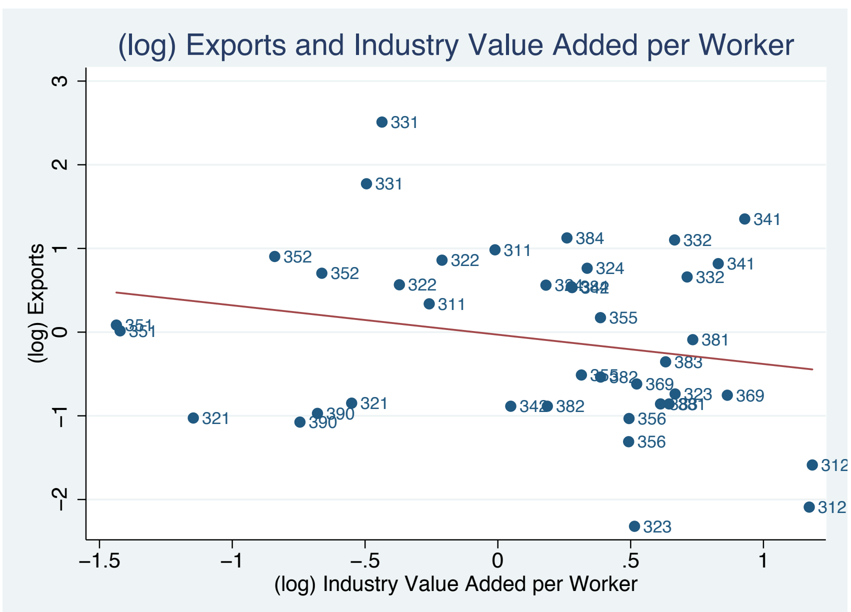


Figure 4:



(log) Exports and Industry Value Added per Worker
(log) Exports
(log) Industry Value Added per Worker