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Miguel Cardoso
Brock University, mcardoso@brocku.ca

Ananth Ramanarayanan
University of Western Ontario, aramanar@uwo.ca

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by

Miguel Cardoso and Ananth Ramanaryanan

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Immigrants and Exports: Firm-level Evidence from Canada *

Miguel Cardoso — Brock University

Ananth Ramanarayanan — University of Western Ontario

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Abstract

We examine how immigrant employment enhances trade at the firm level using unique administrative matched employer-employee data from Canada. We augment a standard model of firms' export market entry and sales decisions with trade costs that depend on destination-specific immigrant employment at the firm level. We estimate simple structural equations derived from the model that relate destination-specific exporting decisions to immigrant employment. We develop a method to deal with the potential endogeneity of immigrant employment that exploits the optimality conditions associated with the firm's employment decision. We find positive and statistically significant effects of firm level immigrant employment on exporting. These effects vary with product type and immigrant employee characteristics in ways consistent with the idea that immigrant employees alleviate information barriers to trade.

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Cardoso: mcardoso@brocku.ca; Ramanarayanan: ananth.ramanarayanan@gmail.com

1 Introduction

Firms face considerable barriers to engaging in international trade. A large literature has documented the importance of trade barriers and trade costs implied by aggregate data (e.g., Anderson and van Wincoop, 2004) and by firm-level exporting behavior (e.g., Das, Roberts and Tybout, 2007). In addition to overcoming physical and policy-related barriers, firms spend resources to acquire information about destination markets.[1] Immigrants may play a key role in overcoming information barriers by sharing knowledge about their home country or acting as intermediaries between firms, as argued, for example, in Rauch (2001). Since Gould's (1994) pioneering study with US aggregate data, a *trade-creation effect of immigrants*—immigration from a particular country increases trade with that country—has been documented extensively using aggregate or regional trade data and immigrant stocks in different countries.[2]

In this paper, we use Canadian employer-employee matched data to analyze the trade-creation effect of immigration at the firm level, i.e., immigrants from a particular country employed by a Canadian firm increase *that firm's* exports to the country. We use firm-level data in order to complement the aggregate evidence on the trade-creation effect of immigrants and shed light on the mechanisms behind this effect. If immigrant workers provide the kind of information on their home countries suggested in the literature, then they should be reducing trade barriers more for their employers than they do nationwide. While the aggregate or regional immigrant stocks used in previous studies are useful proxies for the information that immigrant networks provide to firms, the impacts of immigrants on trade volumes should be observable in individual firms' trade with their

[1] Information frictions are highlighted in, for example, Allen, 2014, Head and Mayer, 2013, and Steinwender, 2018

[2] Examples include Head and Ries (1998) for Canada, Combes, Lafourcade and Mayer (2005) for France, Girma and Yu (2002) for the UK, and Peri and Requena-Silvente (2010) for Spain. Felbermayr, Grossmann and Kohler (2015) provide a survey of the literature.

own immigrant employees' home countries.

We use a unique administrative dataset compiled from tax, customs, and immigration records by Statistics Canada (the national statistical agency) that matches all Canadian workers to their firms. This dataset links firms to their export transactions by destination and product, and links immigrant workers to their country of origin and other demographic characteristics. These data give us a comprehensive view of the immigrant composition of employees in Canadian firms and these firms' exporting decisions by destination. This is the first paper to use these data, which provide an ideal setting to study the trade-creation effect of immigrants at the firm level.

We guide our empirical analysis of the trade-creation effect of immigrants with a standard model of export entry and sales decisions by firms, augmented to include a role for immigrant employment in these decisions. In our model, firms face idiosyncratic demand and fixed costs of exporting to each destination, as well as a variable trade cost that depends on the firm's number of immigrant employees from that destination. The model yields simple structural equations relating a firm's export sales and entry decisions by destination to its domestic sales, its immigrant employment, and observable destination-specific characteristics. We estimate versions of these equations by sector (homogeneous and differentiated) and including different characteristics of immigrant employees (education, earnings, age at arrival, and immigration entry category—i.e., skilled worker, family, business, or refugee).

We find that, across Canadian firms and export destinations, firms with more immigrant employees from a country are more likely to export to that country, and have higher sales there conditional on exporting, even after controlling for firm size and a set of standard gravity-type destination characteristics. For example, a firm that employs one immigrant from a country has a 4 percent higher probability of exporting to that country and 26 percent higher export sales conditional on exporting there than a firm with the same domestic sales but zero immigrants from that country.

We use two dimensions of the data – product type and immigrant employee characteristics – to provide evidence for the idea that immigrants play a role in alleviating information frictions in trade. When restricted to homogeneous goods (those traded on exchanges or at reference prices) as opposed to differentiated goods, the effects of immigrant employment on export entry and sales are much smaller (and insignificant for sales conditional on entry). This finding is consistent with the idea, suggested by Rauch (2001) and Rauch and Trindade (2002), that information barriers are less important for homogeneous goods than for differentiated goods. Moreover, the relationship between immigrant employment and exporting is accounted for primarily by immigrants who are highly educated; are above median earnings within their firm; arrived to Canada as adults rather than as children; and arrived in any immigration entry category other than refugee status. These findings support the idea that skilled / recent immigrants (who are not fleeing persecution) are more likely to have useful connections to, and knowledge of, their home country.

In estimating the firm-level entry and sales equations derived from our model, an endogeneity issue arises if firms know their destination-specific idiosyncratic demand before making employment decisions. Knowing that immigrants from a certain country reduce trade costs to sell there, a firm might hire more immigrants from a destination to which it is more profitable to export because of higher demand, and sell more exports there for the same reason. To the extent that this is true, direct estimates of the model's entry and sales equations are biased upward.

We develop a novel approach to address this endogeneity issue by exploiting additional implications of the model derived from firms' optimal employment decisions. We adapt an approach from the literature on estimating production functions that yields a relationship between the share of revenues paid to immigrant employees from each country and the marginal product of labor plus the elasticity of the variable trade cost for exporting to that country.[3] This method addresses the endogeneity issue through the additional restrictions implied by the optimality of firm's employment choices. Using this method, we find effects of immigrant employment on export sales that are smaller in magnitude than, but qualitatively similar to, those derived from estimates of the export sales equation.

We also consider an alternative instrumental variable (IV) approach, instrumenting for immigrant employment at the firm level with lags of itself. Lagged employment is a valid instrument if previous immigrant employment is correlated with current immigrant employment, but not with innovations to demand that drive current export status and export sales.[4] We find IV estimates of the sales and entry equations using lagged employment to be very similar to the OLS estimates.

This paper is related to a growing recent literature contributing to understanding the links between migrant networks and international trade flows. Since the work of Gould (1994) augmenting gravity equations with immigrant stocks using aggregate US data, researchers have taken several approaches to overcome identification and endogeneity issues with aggregate data. Most closely related to our paper are studies using matched worker-firm datasets from different countries: Hiller (2013), Hatzigeorgiou and Lodefalk (2016), Andrews, Schank and Upward (2017), and Marchal and Nedoncelle (2017). The first three of these (using Danish, Swedish, and German data, respectively) use IV methods and Marchal and Nedoncelle (2017) (with French data) uses propensity score matching methods. Relative to these papers, we introduce a novel method based on previously unexplored implications of firms' immigrant employment decisions, we provide evidence that the trade-creation effect varies with immigrant characteristics in ways consistent with

[3]Essentially, we use an index number method, versions of which date back to Solow's (1957) use of input cost shares to identify production function elasticities. Recent generalizations and applications of this method include Gandhi, Navarro and Rivers (2018), De Loecker and Warzynski (2012), De Loecker et al. (2016), and Blum et al. (2018).

[4]Lagged immigrant employment is among the set of instruments used in previous studies on immigration and trade using matched employer-employee data, including Hiller (2013), Hatzigeorgiou and Lodefalk (2016), and Andrews, Schank and Upward (2017).

the idea that immigrants reduce information barriers, and we analyze newly created data for Canada.

Another set of papers uses aggregate or regional data and draws on specific events that resulted in exogenous variation of immigrant locations. These include refugee resettlement (Parsons and Vézina, 2018 and Steingress, 2018), the location of Japanese internment camps in the US in the 1940s (Cohen, Gurun and Malloy, 2017), and the timing of the opening of the Swiss labor market to the rest of Europe (Ariu, 2019). In another vein, Peri and Requena-Silvente (2010), Bastos and Silva (2012), and Burchardi, Chaney and Hassan (2017) rely on the exogeneity of historically determined migrant stocks with respect to current international transactions (exports in the first two studies and foreign investment in the last). Relative to these papers, we use immigrant employment at the firm level rather than regional or national immigrant stocks to isolate the trade-creating effects that immigrants provide directly to firms.

Understanding the role of immigration in facilitating trade has important policy implications. A key aspect of a developed countries' immigration policy is to use immigration to assist firms in overcoming their labor and skill shortages.[5] Policymakers also expend effort on encouraging domestic firms' exports.[6] Our analysis of the firm-level effects of immigrant employment on exporting behavior show that these goals are interdependent, and the effects of immigration policies or export-promotion policies should take into account the dependence between the two.

The rest of the paper is structured as follows. In Section 2, we describe the data sources and document some patterns in immigrant employment and firm exporting in Canada. In Section 3, we lay out the theoretical framework and derive equations relating export

[5]For example, the Temporary Foreign Worker Program in Canada and the H-1B Program in the United States enable employers to hire foreign workers to fill labor and skill shortages.

[6]For example, Export Development Canada and the United States Commercial Service are government agencies that exist to promote international trade.

market entry and sales to immigrant employment, as well as the optimality condition from the firm's input choice decision. The estimation results are in Section 4, and Section 5 concludes.

2 Data

We use a unique matched employer-employee dataset for Canada that links firms to export transactions and links immigrant employees to their immigration records, to quantify the trade-creation effects of immigrant employment at the firm level. In this section, we describe the data sources and provide some summary statistics on the relationship between immigrant employment and exporting.

2.1 Data Sources

Our dataset is compiled from four Canadian administrative data sources: the National Accounts Longitudinal Microdata File (NALMF), Trade by Exporter Characteristics (TEC), personal tax files (T1), and the Longitudinal Immigration Database (IMDB). The first two (NALMF and TEC) cover all incorporated Canadian firms, the T1 data cover all individual tax-filers in Canada, and the IMDB includes all temporary and permanent residents who immigrated to and filed taxes in Canada. The linkage environment that matches workers and firms across these datasets is collectively referred to as the Canadian Employer-Employee Dynamics Database (CEEDD).[7]

The NALMF provides information on payroll, revenues, employment, and NAICS industry classification at the firm level. The TEC is compiled from customs transaction-level data, and provides annual firm-level export sales by destination country and product

[7] The data are accessed at the Canadian Centre for Data Development and Economic Research (CDER) within Statistics Canada in Ottawa.

category at the 8-digit Harmonized System (HS8) classification. We concord the HS8 classification with 4-digit SITC codes so that we can quantify the the trade-creation effect of immigrant employment across differentiated and homogeneous products according to the Rauch (1999) classification.[8]

For all individual tax-filers in Canada, the T1 tax returns provide information on employment income and allow us to link employees to firms. In addition, the IMDB provides additional information for all immigrants to Canada since 1980 and filed at least one tax return since 1982. The IMDB includes information on country of birth, last country of residence, level of education, and entry class (family, business, refugee, etc.). Our linked dataset constructed from these administrative sources provides a comprehensive account of Canadian firms' immigrant employment by source country and their export market entry and sales by destination country.

2.2 Sample of Interest

We restrict our analysis to an unbalanced panel of manufacturing firms that operated between 2010 to 2013, which are all the years for which export data are available.[9] The data contains 52,421 unique firms of which 18,151 have positive export sales to at least one of the 226 countries in our sample during the four year period.

We restrict our sample to firms in the manufacturing industry for three reasons. The first reason is to connect to previous literature on the trade-creation effect of immigrants, which has focused on manufacturing exports. Second, manufacturing exports account for over 50 percent of Canada's exports for the period 2010-2013. Finally, the number

[8] Our trade data includes exports but not imports for each firm. An additional channel by which immigrant employment could increase trade at the firm-level is by increasing imports of intermediate inputs (see Ariu, 2019).

[9] For one result below, we use multi-year lags of immigrant employment at each firm, for which we link employee data to firms going back to 2007.

of firm-country pairs beyond manufacturing becomes computationally unmanageable. Even restricting the sample to manufacturing firms, the data contain over 30 million firm-destination-year observations.

We define an exporting firm as a firm that exported to at least one country during the four year period 2010-2013. Exporting firms are on average larger than non-exporting firms: average employment in exporting firms is 104 workers whereas in non-exporting firms it is only 14. This employment disparity also exists for immigrant employment: on average exporting firms employ 24 foreign-born workers whereas non-exporting firms only employ 3. The most likely export destination for a Canadian manufacturing firm is, unsurprisingly, the United States, with over 30% of exporting firms exporting to the U.S.

Table 1 shows the top 15 source countries for immigrant employment during the 2010-2013 time period. India, the Philippines and China make up the top three source countries for employment in the manufacturing industry. These countries also top the list of source countries of recent immigrants.[10]

2.3 Patterns in immigrant employment and exporting

Here we provide a first look at the degree to which employment of immigrants from a country is associated with exporting to that country across Canadian manufacturing firms. Figure 1 plots the percentage of firms with positive immigrant employment that export (vertical axis) against the percentage of all firms that export, by immigrant source / export destination country. For example, about 17 percent of manufacturing firms that employ German immigrants export to Germany, while 3.5 percent of all manufacturing firms export to Germany (the point labelled "DE" in the figure). The entire mass in the figure is above the 45-degree line, meaning that for every country in the world, Canadian

[10]Statistics Canada, Immigrant population in Canada, 2016 Census of Population.

firms that employ immigrants from that country are more likely than average to export there.

In Figure 2, we look at the analogous relationship between immigrant employment and a measure of export sales conditional on exporting, comparing the average *export ratio* (export sales relative to domestic sales) for firms employing immigrants and for all firms, by country. The figure shows that firms with immigrant employees export a higher than average proportion of their sales to the immigrant employees' home countries. For example, across all firms that export to China, the average export ratio is 1.3 percent, while the average export ratio among firms exporting to China that also employ Chinese immigrants is about 4 percent.

From Table 2 we see that the relationship between immigrant employment and exporting holds across the firm-size distribution, with the relative magnitude larger for small firms. For example, across all countries, a firm in the 1^{st} (bottom) revenue quartile with positive immigrant employment from a particular country is about 14 times more likely to export to that country than a firm that does not employ immigrants from that country (0.57% ÷ 0.04%). For the 4^{th} (top) revenue quartile, there is still a pronounced difference, but the ratio falls to a factor of 6 (8.61% ÷ 1.45%).

Taken together, these findings suggest that there is a strong relationship between firm-level employment of immigrants from a particular destination country and exports to that country, both through the extensive margin of entry into the destination as well as the intensive margin of the volume of export sales there conditional on entry. In addition, this positive relationship between immigrant employment and exporting holds across the size distribution of firms. In Section 3 we outline a theoretical framework that specifies a firm's trade costs as a function of its immigrant employment, and yields structural equations that we use to estimate the trade-creation effect of immigrant employment at the firm level.

3 Theoretical framework

In this section, we lay out a model that specifies how firm-level immigrant employment affects trade costs, and thereby firms' export entry and sales decisions across destinations. We then derive equations that we use to estimate the effect of immigrant employment on exporting.

3.1 Technology, Demand, and Trade Costs

A continuum of monopolistically competitive firms, indexed by i, each produce a unique good using labor. Firm i's labor productivity is ϕ_i. Countries are indexed by $k = 1, \ldots, K$. We label Canada as country 1, and given our data, we consider the decisions of Canadian firms only. Firms decide on whether to export to each country, and conditional on exporting, how much to sell.

There is a representative consumer in each country k that consumes a CES bundle,

$$Q_k = \left(\int_{\Omega_k} \alpha_{ik}^{\frac{1}{\sigma}} q_{ik}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where Ω_k is the set of goods available in country k, q_{ik} is the quantity of good i consumed in country k, the elasticity of substitution is $\sigma > 1$, and α_{ik} is a firm- and country-specific demand shock that is i.i.d. across firms and countries. Following standard steps, demand for good i in country k is given by:

$$q_{ik} = \alpha_{ik} Q_k \left(\frac{p_{ik}}{P_k} \right)^{-\sigma} \tag{2}$$

where the price index P_k is given by $P_k = \left(\int_{\Omega_k} p_{ik}^{1-\sigma} \alpha_{ik} di \right)^{1/(1-\sigma)}$. In terms of expenditures

$x_{ik} = p_{ik}q_{ik}$,

$$x_{ik} = p_{ik}^{1-\sigma}\alpha_{ik}E_k \quad (3)$$

where $E_k = \frac{Q_k}{P_k^{-\sigma}}$ is an index of market demand in country k.

In order to sell to each foreign destination, a firm faces fixed and variable trade costs. A firm's variable cost of exporting to destination k depends on the number of immigrants from k employed at the firm. Fixed costs f_{ik} are idiosyncratic across firms. Letting N_{ik} denote the number of immigrants from country k employed at firm i, firm i has to pay an iceberg cost $\tau_k(N_{ik})$ per unit of goods shipped to country k. We let $N_i = \sum_k N_{ik}$ denote firm i's total employment.

We assume that variable costs, but not fixed costs, depend on firms' immigrant employment, because our empirical approaches would only identify the sum of the effects of immigrants on the two costs. The summary statistics in Section 2 strongly suggest that both the intensive margin (sales conditional on exporting) and the extensive margin (positive or zero exports) depend on a firms' immigrant employment by destination. For this reason, we put the dependence on immigrant employment in the variable cost, since this accounts for both observations. By contrast, if only fixed costs, and not variable costs, depend on immigrant employment, then export entry decisions would be correlated with immigrant employment, but export sales conditional on entry would not.

3.2 Export sales and export entry

With the model outlined above, we first derive implications for export sales and export entry decisions when firms take as given the source-country composition of their employees. This approach provides a useful benchmark because it yields firm-level analogues of the immigrant-augmented aggregate gravity equations used in, e.g., Gould (1994), Head and Ries (1998), and Peri and Requena-Silvente (2010). Taking into account firm-level employment decisions, however, leads to an endogeneity problem not present with aggregate data, which we address in section 3.3.

Firms take as given the wage, w, and choose their prices to maximize profits taking as given the demand function (2). This leads to the standard constant markup over marginal cost,

$$p_{ik} = \frac{\sigma}{\sigma - 1} \frac{w\tau_k(N_{ik})}{\phi_i}$$

Conditional on exporting to country k, firm i's export sales there are given by

$$x_{ik} = \left(\frac{\sigma}{\sigma - 1} \frac{w\tau_k(N_{ik})}{\phi_i} \right)^{1-\sigma} \alpha_{ik} E_k$$

Using the analogous expression for domestic sales, $x_{i1} = \left(\frac{\sigma}{\sigma-1} \frac{w}{\phi_i} \right)^{1-\sigma} \alpha_{i1} E_1$, we can write firm i's sales to country k, x_{ik}, as:

$$x_{ik} = x_{i1} \tau_k(N_{ik})^{1-\sigma} \tilde{\alpha}_{ik} \tilde{E}_k \tag{4}$$

where $\tilde{\alpha}_{ik} = \alpha_{ik}/\alpha_{i1}$ and $\tilde{E}_k = E_k/E_1$.

In logs, equation (4) is:

$$\log x_{ik} = \log x_{i1} + (1 - \sigma) \log \tau_k(N_{ik}) + \log \tilde{E}_k + \log \tilde{\alpha}_{ik} \tag{5}$$

Firm i exports to country k if the variable profits from doing so exceed the fixed cost f_{ik}. Profits from exporting to k are $\pi_{ik} = x_{ik}/\sigma$, so firm i exports to k if $x_{ik} \geq \sigma f_{ik}$. Using the indicator Ξ_{ik} to denote if firm i exports to k,

$$\Xi_{ik} = \begin{cases} 1 & \text{if } x_{i1} \tau_k(N_{ik})^{1-\sigma} \tilde{\alpha}_{ik} \tilde{E}_k \geq \sigma f_{ik} \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

As a probabilistic statement, equation (6) can be written:

$$\Pr(\Xi_{ik} = 1) = \Pr\left(\log x_{i1} + (1-\sigma)\log \tau_k(N_{ik}) + \log \tilde{E}_k + \log \tilde{\alpha}_{ik} - \log(\sigma f_{ik}) \geq 0\right) \quad (7)$$

Equations (5) and (7) provide two implications on the effects of immigrant employment on trade costs, through the intensive and extensive margins of exports. If the trade cost for exporting to country k as a function of immigrants employed from k, τ_k, is decreasing, equation (5) shows that firm i's export sales to k increase with its employment of immigrants from k, controlling for size through its domestic sales x_{i1}. Similarly, equation (7) shows that the probability of firm i exporting to k increases with its employment of immigrants from k.

3.3 Endogeneity of Immigrant Employment

In our data, we observe firm-level market entry decisions (Ξ_{ik} for $k = 2, \ldots, K$), sales by destination conditional on entry, including domestic sales (x_{ik} for $k = 1, \ldots, K$), and immigrant employment by source country (N_{ik} for $k = 2, \ldots, K$). Using destination country-level proxies for $\tilde{E}_k$ and a given functional form for the trade cost τ_k, the only unobserved variables in equations (5) and (7) are $\tilde{\alpha}_{ik}$ and f_{ik}.

If N_{ik} were exogenous, i.e. orthogonal to $\tilde{\alpha}_{ik}$, then we could estimate the effect of N_{ik} on τ_k (and thereby on export entry and sales decisions) by OLS on equation (5), or by using a Probit or linear probability model (LPM) on equation (7). However, if firms observe (at least part of) α_{ik} before making their hiring decisions, we would expect that N_{ik} is correlated with $\tilde{\alpha}_{ik}$ across firms for a given destination, and across destinations for a given firm. For example, if firm i observes a particularly high realization of α_{ik}, then it is particularly profitable for that firm to export to k. If the firm knows that employing immigrants from k lowers the costs of exporting to k (i.e. $\frac{\partial \tau_k}{\partial N_{ik}} < 0$), then it will increase N_{ik}, so that N_{ik} and $\tilde{\alpha}_{ik}$ would be positively correlated. In this case, OLS estimation of equation (5) and Probit or LPM estimation of equation (7) yield upward-biased estimates of the effects of immigrant employment on both the intensive and extensive margins of exports.

Here we describe a novel approach to dealing with this endogeneity issue, motivated by methods prevalent in the literature on estimating production functions. This approach makes explicit use of firms' optimal immigrant hiring decisions and the additional restrictions these decisions impose on the relationship between export sales and immigrant employment. We also discuss an alternative instrumental variable (IV) approach using lagged immigrant employment at the firm-level. In section 4, we compare estimates of equations (5) and (7) that assume exogeneity of immigrant employment with these two alternative methods.

3.3.1 Exploiting firms' optimal employment decisions

Our approach for addressing the endogeneity of immigrant employment is to exploit additional restrictions implied by firms' optimal employment decisions. We derive an equation from the firm's first-order conditions that relates immigrant workers' wage payments to the elasticity of the variable trade cost with respect to immigrant employment, by destination. The restrictions implied by optimal behavior yield an estimating equation free from the endogeneity issue associated with equations (5) and (7), allowing us to replace the unobserved α_{ik} with observables. This approach is similar to index number methods in the estimation of production functions, as in Caves, Christensen and Diewert (1982). Recent papers that use variants of index methods to estimate either production functions or markups include Gandhi, Navarro and Rivers (2018), De Loecker and Warzynski (2012), De Loecker et al. (2016), and Blum et al. (2018).

We write the firm's problem in terms of labor input choices, by first inverting country

k's demand for firm i's output from equation (2):

$$q_{ik}^{-1/\sigma}(\alpha_{ik}E_k)^{1/\sigma} = p_{ik} \tag{8}$$

Letting $y_{ik} = \tau_k(N_{ik})q_{ik}$ denote the quantity that firm i has to produce in order to sell q_{ik} to country k, Firm i's sales to country k are $x_{ik} = p_{ik}q_{ik}$, or:

$$x_{ik} = \left(\frac{y_{ik}}{\tau_k(N_{ik})}\right)^{\frac{\sigma-1}{\sigma}} (\alpha_{ik}E_k)^{1/\sigma} \tag{9}$$

We can view firm i's profit maximization problem in two stages: given total output y_i, choose outputs $\{y_{ik}\}_{k=1,\ldots,K}$ and entry decisions $\{\Xi_{ik}\}_{k=1,\ldots,K}$ to maximize total revenues X_i. Then, choose labor inputs $\{N_{ik}\}_{k=1,\ldots,K}$ to maximize profit given how total revenues vary with input choices. With sales to each country given by equation (9), total revenues X_i given total output y_i is:

$$\begin{aligned} X_i = &\max_{\{y_{ik}\}} \sum_k \Xi_{ik} y_{ik}^{\frac{\sigma-1}{\sigma}} \tau_k(N_{ik})^{\frac{1-\sigma}{\sigma}} (\alpha_{ik}E_k)^{1/\sigma} \\ &\text{s.t. } \sum_k \Xi_{ik} y_{ik} \leq y_i \end{aligned}$$

As shown in the appendix, the maximized value of total revenues is

$$X_i = y_i^{\frac{\sigma-1}{\sigma}} \left(\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k(N_{ik})^{1-\sigma}\right)^{1/\sigma} \tag{10}$$

To write the profit maximization problem, we assume that firm i's production technology is[11]:

$$y_i = \phi_i \sum_k N_{ik} \tag{11}$$

so with total revenues given by (10), the profit maximization problem is:

$$\max_{\{N_{ik},\Xi_{ik}\}_k} \left(\phi_i \sum_k N_{ik}\right)^{\frac{\sigma-1}{\sigma}} \left(\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k(N_{ik})^{1-\sigma}\right)^{1/\sigma} - w\sum_k N_{ik} - \sum_k \Xi_{ik}f_{ik}$$

Conditional on $\Xi_{ik} = 1$, the first-order condition for N_{ik} is:

$$\begin{aligned} w = &\frac{\sigma-1}{\sigma} y_i^{-\frac{1}{\sigma}} \phi_i \left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}} \\ &+ y_i^{\frac{\sigma-1}{\sigma}} \frac{1}{\sigma} \left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}-1} \alpha_{ik}E_k\left(1-\sigma\right)\tau_k\left(N_{ik}\right)^{-\sigma}\frac{\partial\tau_k\left(N_{ik}\right)}{\partial N_{ik}} \end{aligned} \tag{12}$$

As shown in the appendix, firm i's sales to country as a fraction of total revenues, $\frac{x_{ik}}{X_i}$, can be written:

$$\frac{x_{ik}}{X_i} = \frac{\tau_k\left(N_{ik}\right)^{1-\sigma}\alpha_{ik}E_k}{\sum_j \Xi_{ij}\tau_j\left(N_{ij}\right)^{1-\sigma}\alpha_{ij}E_j} \tag{13}$$

so that the first-order condition for N_{ik} can be written:

$$wN_{ik} = \frac{\sigma-1}{\sigma}X_i\frac{N_{ik}}{N_i} + x_{ik}\frac{1-\sigma}{\sigma}\frac{\partial\log\tau_k\left(N_{ik}\right)}{\partial\log N_{ik}} \tag{14}$$

Equation (14) shows how we can infer the effects of immigrants on trade costs from observed employment and sales. In the absence of an effect of immigrants on τ, (i.e. if $\frac{\partial\tau_k(N_{ik})}{\partial N_{ik}} = 0$), equation (14) states that payments to workers from country k as a fraction of

[11] Our derivations are the same if we generalize the technology to $y_i = \phi_i(\sum_k N_{ik})^{\theta} m_i^{1-\theta}$, where m_i consists of other inputs used by firm i and $\theta \in (0,1)$ has constant returns to scale. In Appendix 6.2, we also consider a version of the model in which immigrants' labor productivity differs by source country. The estimates of the elasticity $\frac{\partial\log\tau_k(N_{ik})}{\partial\log N_{ik}}$ from this version are similar to our findings below.

firm i's revenues would equal the product of labor compensation's total share of revenues, $\frac{\sigma-1}{\sigma}$, times the fraction of employees from country k, $\frac{N_{ik}}{N_i}$. This is the familiar condition that, with perfect competition for inputs, the share of revenue paid to an input equals the elasticity of revenue with respect to that input.

With trade costs that depend on the number of immigrant employees (i.e. $\frac{\partial \tau_k(N_{ik})}{\partial N_{ik}} < 0$), the revenue elasticity of immigrant employees from each country now consists of the part directly due to the production of output as well as the effects of increasing revenues through reducing trade costs. The wage payments firm i makes to immigrants from country k above $\frac{\sigma-1}{\sigma} \frac{N_{ik}}{\sum_j N_{ij}}$ are compensation for the marginal increase in revenues associated with reduced trade costs for exporting to country k, $\frac{\partial \log \tau_k(N_{ik})}{\partial \log N_{ik}}$. This reduction increases payments to workers from k in a way proportional to firm i's sales to country k, x_{ik}, since the variable trade cost reduction applies to each unit of sales.

Equation (14) does not suffer from the same endogeneity issues as equations (5) and (7). This is because equation (13) allows us to replace the unobserved residual α_{ik} in the original first order condition (12) with the observed share of sales to country k, $\frac{x_{ik}}{X_i}$.

3.3.2 An instrumental variables approach

An alternative approach to addressing the endogeneity issue present in estimating equations (5) and (7) is to use instruments for country-specific immigrant employment at the firm level. To implement this approach, we use as instruments three years of lags of N_{ik}, with the logic that past immigrant employment is correlated with current immigrant employment by country, but uncorrelated with current country-specific shocks to demand.[12]

[12] An additional instrument used in firm-level studies such as Hiller (2013), Hatzigeorgiou and Lodefalk (2016), and Andrews, Schank and Upward (2017) is the stock of immigrants from a country employed by all other firms in a firm's region or industry. This instrument is meant to proxy for an exogenous supply of immigrant workers from a certain country that varies across firms only through the exclusion of that firms' immigrant employment. Here, we use only the lagged instrument, which generates firm-level variation directly through firms' own past decisions.

A potential shortcoming of using lagged employment as an instrument is that firms may make employment decisions several years in advance to prepare for exporting, as argued, for example, in Molina and Muendler (2013). We include results from instrumental variables estimation of the sales and entry equations (5) and (7) in section 4 below.

4 Empirical Findings

In this section, we use the firm-level data described in Section 2 to estimate the effect of immigrant employment on firm exporting behavior. We report estimates based on equations (5) and (7) without and with the instruments described in section 3.3.2, and estimates of the first-order condition, equation (14). Throughout, we assume that the variable and fixed trade cost take the forms:

$$\tau_k(N_{ik}) = \exp(\kappa_\tau' D_k) \times g_\tau(N_{ik}) \tag{15}$$

$$f_{ik} = \exp(\kappa_f' D_k) \times \eta_{ik} \tag{16}$$

where η_{ik} is i.i.d. across firms and countries, and $\beta_\tau' D_k$ and $\beta_f' D_k$ are linear combinations of a vector of country k's characteristics, D_k, that proxy for distance from Canada. We include observables in D_k drawn from the gravity literature: geodesic distance between country k's most populous city and Canada's (Toronto), and dummy variables that specify whether country k is landlocked, has English as an official language, and shares a Free Trade Agreement (FTA) with Canada. The function g_τ is common across countries, and is given by:

$$g_\tau(N_{ik}) = (1 + N_{ik})^{-\varepsilon_\tau} \tag{17}$$

This assumption on the shape of g_τ has two convenient properties. First, $g_\tau(0) = 1$, so a firm that hires zero immigrants from a particular country faces a finite destination-specific fixed and variable export cost for exporting to that country.[13] Second, the percentage reduction in the variable trade costs from adding an additional immigrant worker declines as the number of immigrant workers increases, which is intuitive: hiring one more immigrant worker from country k at a firm with 20 employees from k should have a smaller effect on its costs of exporting to country k than at a firm with only two immigrant employees from k, all else equal. In particular, the semi-elasticity of the variable trade cost with respect to N_{ik} is $\frac{\partial \log \tau_k(N_{ik})}{\partial N_{ik}} = \frac{-\varepsilon_\tau}{1+N_{ik}}$, which is decreasing in absolute value in N_{ik}.

With these assumptions on τ_k, equation (5) can be written:

$$\log x_{ik} = \beta_0 + \beta_1 \log x_{i1} + \beta_2 \log(1 + N_{ik}) + \beta_D' D_k + \log \tilde{E}_k + v_{ik} \tag{18}$$

where $\beta_2 = (\sigma - 1)\varepsilon_\tau$, $\beta_D = (\sigma - 1)\kappa_\tau$, and $v_{ik} = \log \tilde{\alpha}_{ik}$. We add the constant β_0 so that v_{ik} has mean zero, and we allow the coefficient on domestic sales, β_1 to differ from 1.

Similarly, the version of equation (7) for the entry decision that we estimate is:

$$\Pr(\Xi_{ik} = 1) = \Pr\Big(\gamma_0 + \gamma_1 \log x_{i1} + \gamma_2 \log(1 + N_{ik}) + \gamma_D' D_k + \log \tilde{E}_k + u_{ik} > 0\Big) \tag{19}$$

where $\gamma_2 = (\sigma - 1)\varepsilon_\tau$, $\gamma_D = (\sigma - 1)\kappa_\tau - \kappa_f$, and $u_{ik} = \log \tilde{\alpha}_{ik} - \log \eta_{ik}$.

Finally, we divide the first order condition (14) by total revenues and add a constant and an error term to write it as:

$$\frac{wN_{ik}}{X_i} = \delta_0 + \delta_1 \frac{N_{ik}}{N_i} + \delta_2 \frac{x_{ik}}{X_i} \frac{N_{ik}}{1 + N_{ik}} + \zeta_{ik} \tag{20}$$

where $\delta_1 = \frac{\sigma-1}{\sigma}$ and $\delta_2 = \frac{\sigma-1}{\sigma}\varepsilon_\tau$. In estimating equations (18) and (22), we use destination GDP and GDP per capita as proxies for $\tilde{E}_k$. We estimate all three equations with year,

[13] This would not be the case if, for example, $g_\tau(N_{ik}) = N_{ik}^{-\varepsilon_\tau}$, in which a large number of firms would face infinite costs to export to a large number of countries, since most firms have zero immigrant employees from most countries.

province, and industry fixed effects.

4.1 Benchmark estimates of the export sales and entry equations

In the first column of Table 3, we report OLS estimates of equation (18). The table shows a significant relationship between employment of immigrants from country k and export sales to country k. Conditional on a firm exporting to country k, the percentage change in export sales to k from hiring one more immigrant worker from there, $\frac{\partial \log x_{ik}}{\partial N_{ik}}$, is equal to $\frac{\beta_2}{1+N_{ik}}$. Therefore, the first column of the table shows that, for example, for a firm exporting to k with no employees from k, adding one employee from k is associated with an increase in export sales to k by 26%, while the increase for a firm with 10 employees going to 11 employees from k is 2.6%.[14]

The first column of Table 4 contains estimates of the effect of immigrant employment on firms' export market entry decisions, from linear probability estimation of equation (22). The coefficient of immigrant employment on the probability of exporting is positive and significant at the 1% level. Hiring one immigrant from country k at a firm that employs zero raises the probability of exporting to country k by 3.9%.

In both Tables 3 and 4, the coefficients on domestic sales are of the expected sign: larger domestic sales are associated with a higher probability of exporting to each destination and higher sales conditional on exporting. The coefficients on the gravity variables are also of the expected signs: distance reduces the probability of exporting and export sales while shared language, free trade agreements, and larger destination market raise entry probability and export sales.

[14] For comparison, Hatzigeorgiou and Lodefalk (2016), using a specification with a constant semi-elasticity of export sales to immigrant employment, finds that an additional immigrant from country k is associated with 3.6% higher export sales to country k.

4.1.1 Differences across homogeneous and differentiated goods

As argued by Rauch (1999) and Rauch and Trindade (2002), information barriers are likely to be more important for differentiated goods than for homogeneous goods, since the latter are sold on organized exchanges or at reference prices. If immigrants reduce the information barriers to export to their home countries, we should see a distinction in the effects of immigrant employment on homogeneous and differentiated export sales.

To evaluate this difference in our data, we estimate sector-specific version of equations (18) and (22). Letting $s = (h, d)$ denote a sector (homogeneous, differentiated), we allow the demand elasticity, σ^s, the destination demand shocks α^s_{ik}, the trade cost function parameter, ε^s_τ, and the fixed cost f^s_{ik} to vary by sector. The sector-specific version of equations (18) and (22) are:

$$\log x^s_{ik} = \beta^s_0 + \beta^s_1 \log x^s_{i1} + \beta^s_2 \log(1 + N_{ik}) + \beta^{s\prime}_D D_k + \log \tilde{E}_k + v^s_{ik} \tag{21}$$

$$\Pr(\Xi^s_{ik} = 1) = \Pr\Big(\gamma^s_0 + \gamma^s_1 \log x^s_{i1} + \gamma^s_2 \log(1 + N_{ik}) + \gamma^{s\prime}_D D_k + \log \tilde{E}_k + u^s_{ik} > 0\Big) \tag{22}$$

where Ξ^s_{ik} and x^s_{ik} are the firm i's exporting decision for sector-s goods and sales of sector-s goods conditional on entry in country k. Given that we do not observe sector-specific proxies for market demand, we assume that market demand for each sector is proportional to total market demand, so that total destination GDP and GDP per capita proxy for market demand in each sector, $\tilde{E}^s_k$.

We define homogeneous and differentiated categories according to the Rauch (1999) classification: homogeneous goods are those traded on organized exchanges or at a standardized reference price, and differentiated goods are all others.[15]

The second and third columns of Table 3 report estimates of equation (21) for ho-

[15] We use the UN concordance to map the HS8 product categories in the data to the 4-digit SITC classification upon which Rauch (1999)'s classification is based, and we use the "conservative" version of the classification, which minimizes the number of SITC product categories classified as homogeneous.

mogeneous and differentiated goods separately. The estimates show that immigrant employment has a positive, significant effect on export sales of differentiated goods. For a firm exporting to k with no employees from k, adding one employee from k raises export sales of differentiated goods to k by 28%. The effect for homogeneous goods' export sales is much smaller, and is not statistically significant. The second and third columns of Table 4 shows that a similar pattern holds for entry decisions. Hiring one immigrant from country k at a firm that employs zero is associated with an increased probability of exporting differentiated goods to country k by more than three times the amount of exporting homogeneous goods, 3.5% to 1% respectively.

The differences that we find in the effects of immigrant employment on exports of differentiated and homogeneous goods support the idea that immigrants play a role for their employers in alleviating information frictions associated with international trade.

4.2 First-order-condition and IV estimates

Given the potential endogeneity concerns outlined in section 3.3, in this section we present results from our two alternative methods that address the endogeneity of immigrant employment. Table 5 contains estimates of equation (20), derived from the first order condition of the firms' optimization problems, and Table 6 contains instrumental variables estimates of the sales and exporting equations (18) and (22).

The first column of Table 5 shows the estimates of the first order condition, and the second and third column contain the estimates for homogeneous and differentiated goods separately. The estimated coefficient on the interacted term $\frac{x_{ik}}{X_i}\frac{N_{ik}}{1+N_{ik}}$ is positive and significant, at about 0.009. From equation (20), this coefficient corresponds to $\frac{\sigma-1}{\sigma}\varepsilon_\tau$ in the model, while the estimates on $\log(1+N_{ik})$ in Table 3 correspond to $(\sigma-1)\varepsilon_\tau$, so comparing the two requires a value for σ. We consider a range of values for σ motivated by empirical findings in the literature. For example, Broda and Weinstein (2006) estimate elasticities of substitution for 10-digit HS product categories, finding a mean elasticity of 12 and a median elasticity of 3. For σ in the range [3,12], the estimate of 0.009 would yield a range of $\sigma \times .009 = [0.027, 0.107]$ for the value of the coefficient β_2 in the export sales equation (18). These results indicate that, for example, for $\sigma = 12$, at a firm that exports to country k but has zero immigrant employees from k, hiring one employee from k raises export sales there by 10.7%. Therefore, the effect of immigrant employment on exports estimated from the first order condition method is smaller than that from OLS estimation of the exprot sales equation, but is still positive and significant. The second and third columns of Table 5 contain estimates of equation (20) for homogeneous and differentiated goods. As with the OLS estimates of the sales equation in Table 3, the implied effect of immigrant employment is stronger for differentiated goods than for homogeneous goods.

Our second approach to deal with the endogeneity issue is to estimate the sales and entry equations instrumenting for immigrant employment with its lags. Table 6 contains the results. Using three years of lags of firm-level immigrant employment as instruments, we find a positive and significant effect of immigrant employment on firm export sales for all goods, and for both homogeneous goods and differentiated goods separately. Moreover, the point estimates are very close to the OLS estimates from Table 3. From the results in Tables 5 and 6, we conclude that addressing the endogeneity of immigrant employment in firms' exporting decisions both with our new approach based on optimality of immigrant employment decisions and a conventional IV method yield positive and significant estimates of the trade-creation effect of immigrant employment at the firm level. In addition, all our estimates show a pronounced difference between exporting behavior for homogeneous and differentiated goods, lending support to the idea that immigrant employment alleviates information barriers that are more prevalent in the trade of differentiated goods.

4.3 Heterogeneity in immigrant characteristics

In this section, we use the detailed data on immigrants' characteristics to shed additional light on the mechanisms by which immigrant employment affects firms' exporting behavior. We evaluate whether the strength of the trade-creation effect of immigrant employment varies with observable immigrant characteristics which are likely to proxy for differences in immigrant employees' connections to their home countries and positions within their employers in Canada. For example, high-skilled, highly paid immigrants may contribute more to reducing trade barriers for their employers than low-skilled, low paid immigrants. In addition, recent immigrants or those who immigrated as adults may have stronger ties to their home country than those who arrived as children or in the distant past. We also compare immigrants based on their immigration entry class. For example, due to persecution in their home country, refugees are less likely to maintain contacts useful to their Canadian employer compared to skilled workers or family-based immigrants.

We incorporate immigrants' characteristics by assuming that the trade cost function for exporting to country k, τ_k, depends on the composition of immigrant employees, along different decompositions. Let $\mathcal{G} = \{1, \ldots, G\}$ denote a partition of immigrants along a single attribute (e.g. $\mathcal{G}$ ={High skill, Low skill} or $\mathcal{G}$ ={Arrived as child, Arrived as adult}) and let N_{ik}^{g} denote the number of immigrants from country k within group $g = 1, \ldots, G$ employed by firm i. Firm i's variable cost of exporting to country k is then $\tau_k(N_{ik}^1, \ldots, N_{ik}^G)$. Instead of the functional form (17), we assume the part of trade costs that depends on immigrant employment is given by $g(N_{ik}^1, \ldots, N_{ik}^G) = \prod_g (1 + N_{ik}^g)^{-\varepsilon_\tau^g}$, so that the analogues of equations (5) and (7) are

$$\log x_{ik} = \log x_{i1} + (1-\sigma)\beta_\tau' D_k + (\sigma - 1)\sum_g \varepsilon_\tau^g \log(1 + N_{ik}^g) + \log \tilde{\alpha}_{ik} + \log \tilde{E}_k \quad (23)$$

$$\Pr(\Xi_{ik} = 1) = \Pr\Big(\log x_{i1} + ((1-\sigma)\beta_\tau - \beta_f)' D_k + (\sigma - 1)\sum_g \varepsilon_\tau^g \log(1 + N_{ik}^g) \quad (24)$$
$$+ \log \tilde{E}_k + \log \tilde{\alpha}_{ik} > 0\Big)$$

We consider different partitions $\mathcal{G}$ based on characteristics that reflect how much influence an immigrant employee is likely to have within their firm and how connected an immigrant is likely to be to their home country. These attributes are: (1) earnings (above or below median earnings within the firm); (2) education at time of arrival (college or no college); (3) age at arrival (adult or youth, i.e. above or below 18); (4) time since arrival (less than or greater than 10 years); and (5) immigration entry category (skilled worker, family, investor, refugee, or other).[16]

In Table 7 we report OLS estimates of equation (23) for the first four immigrant group partitions described above. The table shows that the effect on export sales conditional on entry is more strongly associated with the number of immigrants employees who are in the top half their firm's earnings distribution (N_{ik}^{AM}), have attended college (N_{ik}^{HS}), arrived as adults to Canada (N_{ik}^{A}), and arrived more recently ($N_{ik}^{<10}$). These findings are consistent with the idea that immigrants decrease information frictions to export their home country. For example, age at arrival is particularly important: for a firm exporting to country k with no employees from k, adding one employee who emigrated from k as an adult raises export sales to k by about 24%, while hiring an employee who arrived as a youth is insignificant. Presumably, an immigrant arriving in Canada as an adult has had the time to acquire the

[16] Relative earnings within the firm serves as a proxy for occupation, which we do not observe. The rationale for using this proxy is that employees who affect production and sales decisions are likely higher up in a firm's earnings distribution.

knowledge and contacts in their home country that would make them valuable in reducing trade barriers for their employer in Canada.

In Table 8 we explore the importance of immigrant entry class on the strength of the trade creation effect for export sales. As expected, since refugees have weak links to their home country, we find that employment of refugees does not increase exports to their home country. On the other hand, family, investment, and skilled worker class immigrants all increase export sales to their home country. Our finding that employment of refugees is negatively associated with exports to their home country is consistent with the aggregate evidence for Canada in Head and Ries (1998).

Table 9 reports the effects of employment of different immigrant groups on firms' export entry decisions, from LPM estimation of equation (24). Similar to the results on export sales in Table 7, we find that firms' employment of immigrants who: are high skilled; arrived to Canada as adults; are in the top half of a firm's earnings distribution; or arrived more recently, is more strongly associated with entry. For example, hiring one high skilled employee who emigrated from country k at a firm with no high skilled employees from country k raises the probability of exporting to k by 6.25%, compared to only 1.07% for a low skilled employee.

In Table 10 we report the effects of employment of different immigrant entry categories on export market entry. Employment of investor class immigrants leads to the highest increase in export participation for a firm, followed by the skilled class and family class immigrants. Hiring one immigrant from country k at a firm that employs zero, raises the probability of exporting to country k by 7.8%, 5.9%, or 2.3%, for investment, skilled, or family class immigrants respectively. Employment of refugees is associated with a small negative effect on firm export entry to the refugees' home country.

5 Conclusion

In this study, we have added to the literature on the relationship between immigrant employment and exporting behavior at the firm-level using a novel administrative matched dataset of Canadian manufacturing firms and immigrant employees. Our results suggest that there is a positive, significant effect of immigrant employment on firms' export market entry and sales decisions. To address a potential endogeneity issue, we adapt an approach from the literature on production function estimation, based on the first-order condition of the firms' optimal immigrant employment decisions.

We exploit detailed data on product categories and individual immigrant characteristics in our linked employer-employee data to evaluate the heterogeneity of the trade-creation effect across immigrants. For example, highly educated, highly paid immigrants have a larger impact on increasing firm export sales relative to low skilled immigrants. Canada's immigration policy, one that encourages and emphasizes skilled and entrepreneurial immigrants, has therefore presumably contributed to the trade-creation effect at the aggregate level. Both skilled and investment class immigrants have strong positive effects on expanding existing export sales and increasing export participation to country k for firms that hire them. Our results provide a better understanding of how firms utilize their immigrant workforce to facilitate international trade, and could be useful in better measuring the overall impact of migration on the welfare of native-born workers. A fruitful extension along these lines would be to embed our model into a more general framework that jointly accounts for the various effects of immigrants on native-born workers through the labor market. In addition, given that firms are likely making hiring decisions with future export decisions in mind (as argued in, for example, Molina and Muendler, 2013), a future theoretical contribution would be extending our framework to a dynamic setting.

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Figures and Tables

Figure 1: Firm Exporting and Immigrant Composition

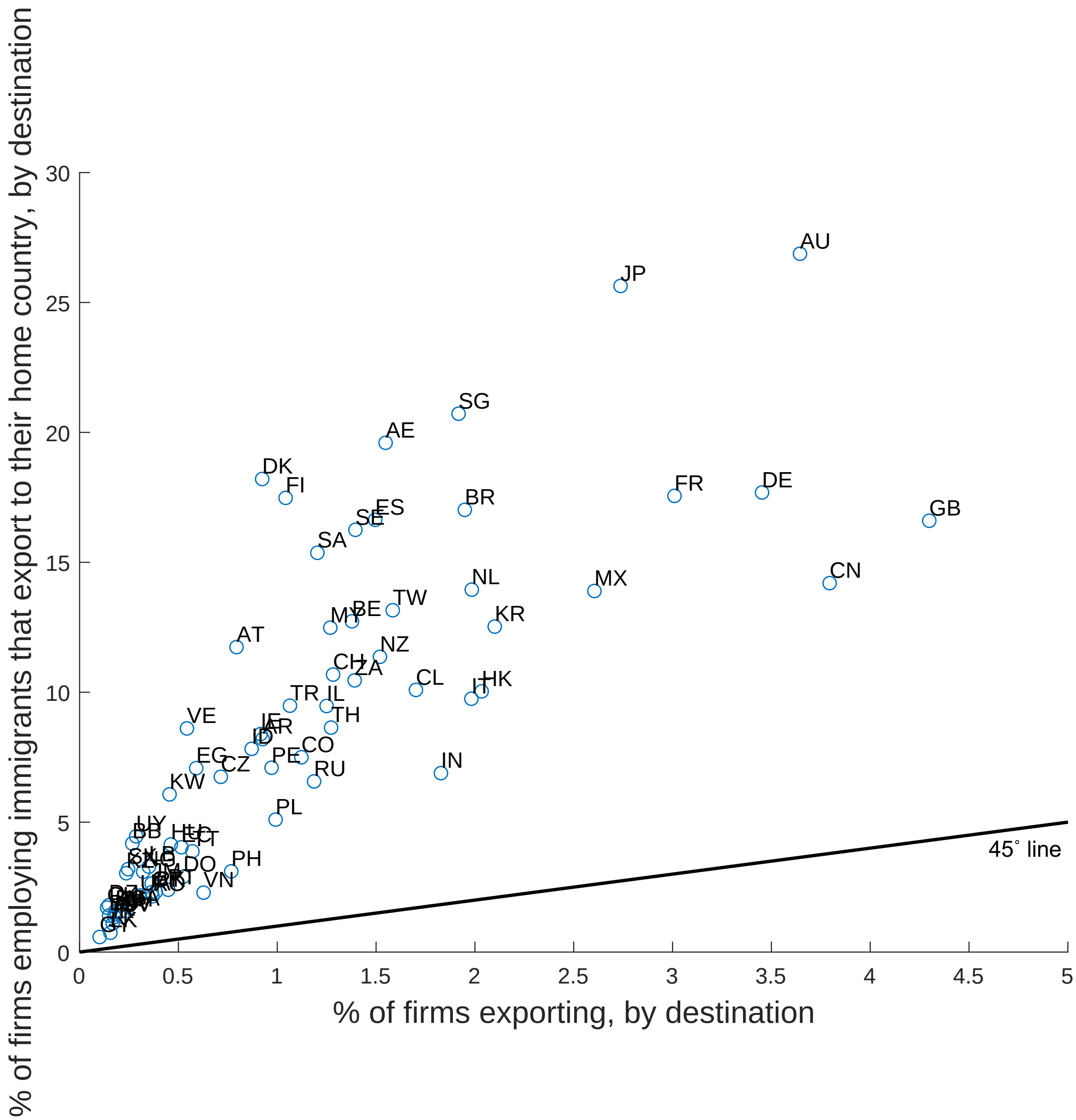

Figure 2: Average Export Sales and Immigrant Composition

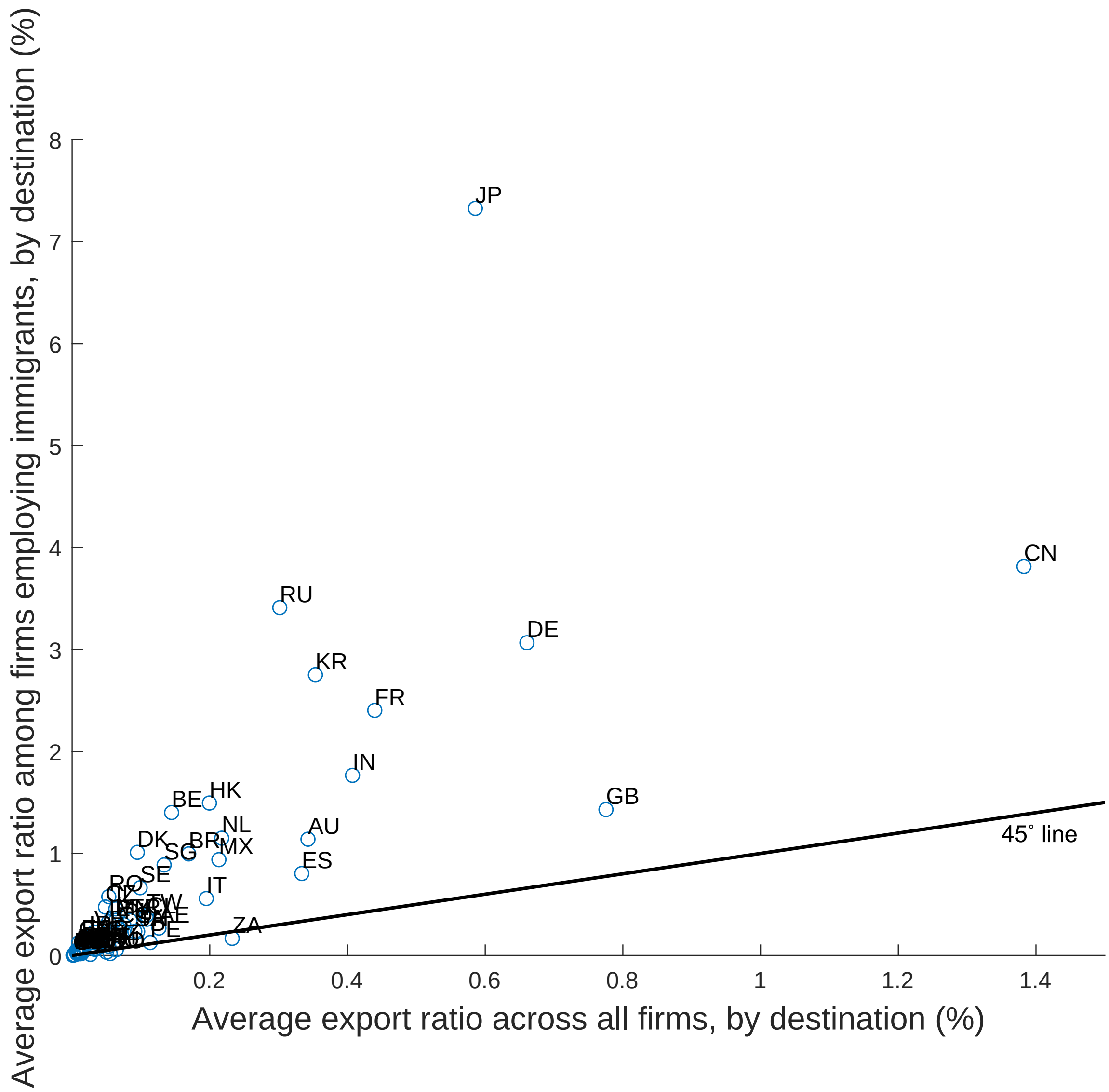

Table 1: Top Immigrant Source Countries

Country	Immigrants Employed
India	194,328
Philippines	174,688
China	135,669
Vietnam	105,657
Sri Lanka	52,330
Poland	51,396
Romania	34,714
Guyana	34,359
Hong Kong	33,280
United Kingdom	32,684
Pakistan	26,648
Jamaica	26,181
El Salvador	22,037
Russia	19,352
Haiti	19,219

Notes: Employment numbers for manufacturing firms using the sample pooled from 2010-2013

Table 2: Firm Exports by Revenue Quartile

	With Immigrant Employment	Without Immigrant Employment
Revenue Quartile	Positive Exports Flows	Positive Exports Flows
1	0.57%	0.04%
2	1.01%	0.14%
3	2.26%	0.38%
4	8.61%	1.45%

An observation is a firm-country pair pooled over the time period 2010-2013. The *with* immigrant employment column shows the percentage of exporting firms that export to country k conditional on having immigrant employment from country k.

Table 3: OLS estimates of export sales equation

Dependent variable: Log exports of:	All goods	Homogeneous goods	Differentiated goods
$\log(x_{i1})$	0.359***	0.313***	0.335***
	(0.004)	(0.012)	(0.005)
$\log(1+N_{ik})$	0.262***	0.0425	0.285***
	(0.017)	(0.039)	(0.018)
log distance	-0.393***	-0.343***	-0.367***
	(0.011)	(0.038)	(0.012)
English	0.224***	0.086	0.218***
	(0.016)	(0.057)	(0.018)
Landlocked	-0.062*	-0.621***	-0.008***
	(0.032)	(0.129)	(0.034)
FTA	0.193***	0.306***	0.179***
	(0.025)	(0.087)	(0.026)
log GDP	0.251***	0.245***	0.239***
	(0.005)	(0.015)	(0.005)
log GDP per capita	-0.004	-0.201***	0.009***
	(0.007)	(0.043)	(0.008)
Firm-destination obs.	190,155	33,011	171,741
Adjusted R^2	0.262	0.333	0.227

Notes: The table contains estimates of equation (18) in the text, from data pooled for all firms, destination countries, and years. All regressions include a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik} is firm-level immigrant employment by destination. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 4: LPM estimates of export participation equation

Dependent variable: Indicator of positive exports of:			
	All goods	Homogeneous goods	Differentiated goods
$\log(x_{i1})$	0.0034***	0.0008***	0.0029***
	(0.0000)	(0.0000)	(0.0000)
$\log(1 + N_{ik})$	0.0390***	0.0101***	0.0347***
	(0.0006)	(0.0003)	(0.0006)
log distance	-0.0149***	-0.0038***	-0.0390***
	(0.0001)	(0.0001)	(0.0001)
English	0.0131***	0.0029***	0.0121***
	(0.0000)	(0.0000)	(0.0001)
Landlocked	0.0019**	0.0006***	0.0019**
	(0.0000)	(0.0000)	(0.0000)
FTA	0.0193***	0.0043***	0.0180***
	(0.0002)	(0.0001)	(0.0002)
log GDP	0.0045***	0.0009***	0.0041***
	(0.0000)	(0.0000)	(0.0000)
log GDP per capita	-0.0009***	-0.0003***	-0.0008***
	(0.0000)	(0.0000)	(0.0000)
Firm-destination obs.	30,089,6945	30,089,694	30,089,694
Adjusted R^2	0.051	0.015	0.047

Notes: The table contains estimates of equation (22) in the text, from data pooled for all firms, destination countries, and years. All regressions include a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik} is firm-level immigrant employment by destination. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 5: OLS estimates of the employment first order condition

Dependent variable: $\frac{wN_{ik}}{X_i}$, wage share of immigrants by destination	All goods	Homogeneous goods	Differentiated goods
Coefficient on $\frac{N_{ik}}{N_i}$	0.228***	0.230***	0.228***
	(0.0104)	(0.0103)	(0.0104)
Coefficient on $\frac{x_{ik}}{X_i}\frac{N_{ik}}{1+N_{ik}}$	0.0089***	-0.0086	0.0123***
	(0.0012)	(0.0055)	(0.0024)
Firm-destination obs.	192,018	192,018	192,018
Adjusted R^2	0.554	0.553	0.554

Notes: The table contains estimates of equation (20) in the text, from data pooled for all firms, destination countries, and years. All regressions include a constant and year, province, and industry fixed effects. x_{ik} is firm-level export sales, X_i is total firm revenues, N_{ik} is firm-level immigrant employment by destination, and N_i is firm-level total employment. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 6: IV estimates of export sales equation

Dependent variable: Log exports of:			
	All goods	Homogeneous goods	Differentiated goods
$\log(x_{i1})$	0.3452***	0.2919***	0.3263***
	(0.0046)	(0.0831)	(0.0049)
$\log(1 + N_{ik})$	0.2775***	0.0854**	0.2954***
	(0.0184)	(0.0238)	(0.0198)
log distance	-0.4088***	-0.3618***	-0.3843***
	(0.0116)	(0.0398)	(0.0123)
English	0.2342***	0.1380***	0.2210***
	(0.0169)	(0.0360)	(0.0180)
Landlocked	-0.0393	-0.5148***	0.0072
	(0.0333)	(0.0542)	(0.0349)
FTA	0.1944***	0.3140***	0.1791***
	(0.0249)	(0.1257)	(0.0265)
log GDP	0.2491***	0.2278***	0.2406***
	(0.0046)	(0.0123)	(0.0049)
log GDP per capita	0.0051	-0.1424***	0.0158**
	(0.0074)	(0.0148)	(0.0079)
Firm-destination obs.	181,082	31,314	163,796
Adjusted R^2	0.272	0.398	0.237

Notes: The table contains instrumental variables estimates of equation (18) in the text, from data pooled for all firms, destination countries, and years. All regressions include a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik} is firm-level immigrant employment by destination. Instruments for $\log(1 + N_{ik})$ are 3 lags of itself. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 7: OLS estimates of export sales equation of immigrant groups

Dependent variable: Log exports				
	(1)	(2)	(3)	(4)
$\log(1+N_{ik}^{AM})$	0.272***			
	(0.028)			
$\log(1+N_{ik}^{BM})$	0.042			
	(0.027)			
$\log(1+N_{ik}^{HS})$		0.228***		
		(0.028)		
$\log(1+N_{ik}^{LS})$		0.111***		
		(0.026)		
$\log(1+N_{ik}^{A})$			0.241***	
			(0.021)	
$\log(1+N_{ik}^{Y})$			0.063	
			(0.042)	
$\log(1+N_{ik}^{<10})$				0.221***
				(0.028)
$\log(1+N_{ik}^{>10})$				0.136***
				(0.024)
$\log(x_{i1})$	0.363***	0.363***	0.361***	0.362***
	(0.004)	(0.004)	(0.004)	(0.004)
log distance	0.393***	0.394***	0.393***	0.393***
	(0.011)	(0.011)	(0.011)	(0.011)
English	0.227***	0.229***	0.226***	0.228***
	(0.017)	(0.017)	(0.017)	(0.017)
Landlocked	-0.065***	-0.064***	-0.063***	-0.063***
	(0.032)	(0.032)	(0.032)	(0.032)
FTA	0.192***	0.188***	0.190***	0.188***
	(0.025)	(0.025)	(0.025)	(0.025)
log GDP	0.254***	0.252***	0.253***	0.252***
	(0.005)	(0.005)	(0.005)	(0.005)
log GDP per capita	-0.011	-0.007	-0.006	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)
Firm-destination observations	190,155	190,155	190,155	190,155
Adjusted R^2	0.262	0.262	0.262	0.262

Notes: The table contains estimates of equation (23), from data pooled for all firms, destination countries, and years, for different partitions of immigrant employees. All regressions include a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik}^{g} is firm-level employment of immigrants from a particular destination in group g. Immigrant groups for each regression are: (Column 1) AM=Above Median Earnings, BM=Below Median Earnings; (2) HS=College Educated, LS=Non College Educated; (3) A=18 years of age or older at arrival, Y=below 18 years of age at arrival; (4) <10 = Less than 10 years since arrival, >10 = Greater than 10 years since arrival. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 8: OLS estimates of export sales equation with immigrant entry class

Dependent variable: Log exports	
$\log(1 + N_{ik}^{Skilled})$	0.083***
	(0.029)
$\log(1 + N_{ik}^{Family})$	0.315***
	(0.035)
$\log(1 + N_{ik}^{Investment})$	0.214***
	(0.069)
$\log(1 + N_{ik}^{Refugee})$	-0.213***
	(0.048)
$\log(1 + N_{ik}^{Other})$	0.086
	(0.065)
$\log(x_{i1})$	0.364***
	(0.0044)
log distance	-0.394***
	(0.011)
English	0.210***
	(0.017)
Landlocked	-0.056*
	(0.033)
FTA	0.189***
	(0.025)
$\log GDP$	0.255***
	(0.005)
$\log GDP$ per capita	-0.016**
	(0.007)
Firm-destination observations	190,155
Adjusted R^2	0.262

Notes: The table contains estimates of equation (23), from data pooled for all firms, destination countries, and years, for the entry class partition of immigrant employees. The regression includes a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik}^{c} is firm-level employment of immigrants from a particular destination in entry class c. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 9: LPM estimates of export participation by immigrant groups

Dependent variable: Indicator of positive export sales				
	(1)	(2)	(3)	(4)
$\log(1+N_{ik}^{AM})$	0.0376***			
	(0.0009)			
$\log(1+N_{ik}^{BM})$	0.0185***			
	(0.0008)			
$\log(1+N_{ik}^{HS})$		0.0625***		
		(0.0012)		
$\log(1+N_{ik}^{LS})$		0.0107***		
		(0.0006)		
$\log(1+N_{ik}^{A})$			0.0327***	
			(0.0006)	
$\log(1+N_{ik}^{Y})$			0.0326***	
			(0.0016)	
$\log(1+N_{ik}^{<10Years})$				0.0306***
				(0.0009)
$\log(1+N_{ik}^{>10Years})$				0.0304***
				(0.0008)
$\log(x_{i1})$	0.0034***	0.0035***	0.0034***	0.0035***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
log distance	-0.0149***	-0.0150***	-0.0149***	-0.0149***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
English	0.0131***	0.0131***	0.0131***	0.0131***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Landlocked	0.0019***	0.0019***	0.0019***	0.0019***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
FTA	0.0192***	0.0192***	0.0192***	0.0192***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
log GDP	0.0046***	0.0045***	0.0046***	0.0045***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
log GDP per capita	-0.0009***	-0.0009***	-0.0009***	-0.0009***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Firm-destination observations	30,089,694	30,089,694	30,089,694	30,089,694
Adjusted R^2	0.050	0.052	0.050	0.050

Notes: The table contains estimates of equation (24), from data pooled for all firms, destination countries, and years, for different partitions of immigrant employees. All regressions include a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik}^{g} is firm-level employment of immigrants from a particular destination in group g. Immigrant groups for each regression are: (Column 1) AM=Above Median Earnings, BM=Below Median Earnings; (2) HS=College Educated, LS=Non College Educated; (3) A=18 years of age or older at arrival, Y=below 18 years of age at arrival; (4) <10 = Less than 10 years since arrival, >10 = Greater than 10 years since arrival. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

Table 10: LPM estimates of export entry equation with immigrant entry class

Dependent variable: Indicator of positive export sales	
$\log(1+N_{ik}^{Skilled})$	0.0588***
	(0.0013)
$\log(1+N_{ik}^{Family})$	0.0228***
	(0.0009)
$\log(1+N_{ik}^{Investment})$	0.0784***
	(0.0052)
$\log(1+N_{ik}^{Refugee})$	-0.0090***
	(0.0009)
$\log(1+N_{ik}^{Other})$	-0.0167***
	(0.0019)
$\log(x_{i1})$	0.0035***
	(0.0000)
log distance to k	-0.0150***
	(0.0001)
English in k dummy	0.0130***
	(0.0001)
k Landlocked dummy	0.0019***
	(0.0000)
FTA with k dummy	0.0194***
	(0.0002)
log GDP in k	0.0045***
	(0.0000)
log GDP per capita in k	-0.0009***
	(0.0000)
Firm-destination observations	30,089,694
Adjusted R^2	0.052

Notes: The table contains estimates of equation (24), from data pooled for all firms, destination countries, and years, for the entry class partition of immigrant employees. The regression includes a constant and year, province, and industry fixed effects. x_{i1} is firm-level domestic sales. N_{ik}^{c} is firm-level employment of immigrants from a particular destination in entry class c. Distance measures geodesic distance to destination country's most populous city. English equals 1 if destination has English as an official language and 0 otherwise. Landlocked equals 1 if destination is landlocked and 0 otherwise. FTA equals 1 if destination has a free trade agreement with Canada and 0 otherwise. GDP and GDP per capita are for the destination. Robust standard errors clustered by firm-country are in parentheses. Significance denoted by * (10%), ** (5%), and *** (1%).

6 Appendix

6.1 Firms' hiring decisions

To write the firm's problem in terms of labor input choices, we start from output: for each destination k to which firm i sells, to satisfy demand it must produce $q_{ik} = \tau_k (N_{ik}) p_{ik}^{-\sigma} \alpha_{ik} E_k$, which can be inverted to:

$$\left(\frac{q_{ik}}{\tau_k (N_{ik})}\right)^{-1/\sigma} (\alpha_{ik} E_k)^{1/\sigma} = p_{ik}$$

So revenues for firm i from selling to k are:

$$\begin{aligned} x_{ik} &= p_{ik} \frac{q_{ik}}{\tau_k (N_{ik})} \\ &= \left(\frac{q_{ik}}{\tau_k (N_{ik})}\right)^{\frac{\sigma-1}{\sigma}} (\alpha_{ik} E_k)^{\frac{1}{\sigma}} \end{aligned}$$

To write the profit maximization problem in terms of labor inputs $\{N_{ik}\}_{k=1,\dots,K}$, first take as given firm i's total output y_i, and solve for the quantities exported to each country k, q_{ik}. Firm i allocates its sales to maximize revenues, taking as given the α_{ik}'s:

$$\begin{aligned} &\max_{\{q_{ik}\}} \sum_k \Xi_{ik} q_{ik}^{\frac{\sigma-1}{\sigma}} (\tau_k (N_{ik}))^{\frac{1-\sigma}{\sigma}} (\alpha_{ik} E_k)^{\frac{1}{\sigma}} \\ &\text{s.t. } \sum_k \Xi_{ik} q_{ik} \leq y_i \end{aligned}$$

The first order conditions for output produced for sale to k, q_{ik}, and output produced for domestic sale, q_{i1}, conditional on $\Xi_{ik} = 1$, yield:

$$\frac{\sigma-1}{\sigma}q_{ik}^{\frac{-1}{\sigma}}\left(\tau_k\left(N_{ik}\right)\right)^{\frac{1-\sigma}{\sigma}}\left(\alpha_{ik}E_k\right)^{\frac{1}{\sigma}}=\lambda_i$$

and for domestic output:

$$\frac{\sigma-1}{\sigma}q_{i1}^{\frac{-1}{\sigma}}\left(\alpha_{i1}E_1\right)^{\frac{1}{\sigma}}=\lambda_i$$

So taking the ratio of these two,

$$q_{i1}\frac{\alpha_{ik}E_k}{\alpha_{i1}E_1}\tau_k\left(N_{ik}\right)^{1-\sigma}=q_{ik} \tag{25}$$

Summing equation (25) across k and rearranging gives:

$$\frac{q_{i1}}{\alpha_{i1}E_1}=\frac{y_i}{\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}} \tag{26}$$

Using (25) and (26), we can write total revenues as:

$$\begin{aligned}\sum_k \Xi_{ik}q_{ik}^{\frac{\sigma-1}{\sigma}}\left(\tau_k\left(N_{ik}\right)\right)^{\frac{1-\sigma}{\sigma}}\left(\alpha_{ik}E_k\right)^{\frac{1}{\sigma}} &=\sum_k \Xi_{ik}q_{i1}^{\frac{\sigma-1}{\sigma}}\left(\frac{\alpha_{ik}E_k}{\alpha_{i1}E_1}\tau_k\left(N_{ik}\right)^{1-\sigma}\right)^{\frac{\sigma-1}{\sigma}}\left(\tau_k\left(N_{ik}\right)\right)^{\frac{1-\sigma}{\sigma}}\left(\alpha_{ik}E_k\right)^{\frac{1}{\sigma}}\\ &=\left(\frac{q_{i1}}{\alpha_{i1}E_1}\right)^{\frac{\sigma-1}{\sigma}}\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}\\ &=y_i^{\frac{\sigma-1}{\sigma}}\left(\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}\right)^{\frac{1-\sigma}{\sigma}}\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}\\ &=y_i^{\frac{\sigma-1}{\sigma}}\left(\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}} \end{aligned}\tag{27}$$

Firm i's production technology is $y_i=\phi_i\sum_k N_{ik}$, so with total revenues given by (27), the profit maximization problem is:

$$\max_{\{N_{ik}\}_k}\left(\phi_i\sum_k N_{ik}\right)^{\frac{\sigma-1}{\sigma}}\left(\sum_k \Xi_{ik}\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}}-w\sum_k N_{ij}-\sum_k \Xi_{ik}f_{ik}$$

Conditional on $\Xi_{ik} = 1$, the first-order condition for N_{ik} is:

$$
\begin{aligned}
0 = &\frac{\sigma-1}{\sigma}\left(\phi_i \sum_j N_{ij}\right)^{\frac{\sigma-1}{\sigma}-1} \phi_i \left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}} \\
&+ \left(\phi_i \sum_j N_{ij}\right)^{\frac{\sigma-1}{\sigma}} \frac{1}{\sigma}\left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}-1} \alpha_{ik}E_k\left(1-\sigma\right)\tau_k\left(N_{ik}\right)^{-\sigma}\frac{\partial\tau_k\left(N_{ik}\right)}{\partial N_{ik}} \\
&- w
\end{aligned}
$$

Now substitute in y_i and multiply by N_{ik} throughout:

$$
\begin{aligned}
wN_{ik} = &\frac{\sigma-1}{\sigma}\left(y_i\right)^{\frac{\sigma-1}{\sigma}}\frac{N_{ik}}{\sum_j N_{ij}}\left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}} \\
&+ \left(y_i\right)^{\frac{\sigma-1}{\sigma}}\left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}} \frac{\alpha_{ik}E_k\tau_k\left(N_{ik}\right)^{1-\sigma}}{\sum_j \Xi_{ij}a_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}}\frac{1-\sigma}{\sigma}\frac{\partial\tau_k\left(N_{ik}\right)}{\partial N_{ik}}\frac{N_{ik}}{\tau_k\left(N_{ik}\right)}
\end{aligned}
$$

Now, the factor $\frac{\alpha_{ik}E_k\tau_k(N_{ik})^{1-\sigma}}{\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}}$ is the share of sales to k, since the foc's from above for any j,k give:

$$
q_{ij}\tau_k\left(N_{ik}\right)^{1-\sigma}\alpha_{ik}E_k = q_{ik}\tau_j\left(N_{ij}\right)^{1-\sigma}\alpha_{ij}E_j
$$

So we can write the share of revenues from sales to country k as:

$$
\begin{aligned}
\frac{x_{ik}}{\sum_j \Xi_{ij}x_j} &= \frac{\left(\frac{q_{ik}}{\tau_k(N_{ik})}\right)^{\frac{\sigma-1}{\sigma}}\left(\alpha_{ik}E_k\right)^{\frac{1}{\sigma}}}{\sum_j \Xi_{ij}\left(\frac{q_{ij}}{\tau_j\left(N_{ij}\right)}\right)^{\frac{\sigma-1}{\sigma}}\left(\alpha_{ij}E_j\right)^{\frac{1}{\sigma}}} \\
&= \frac{\tau_k\left(N_{ik}\right)^{1-\sigma}\alpha_{ik}E_k}{\sum_j \Xi_{ij}\tau_j\left(N_{ij}\right)^{1-\sigma}\alpha_{ij}E_j}
\end{aligned}
$$

So substitute in for revenues X_i and x_{ik} to write:

$$\frac{wN_{ik}}{X_i} = \frac{\sigma-1}{\sigma}\frac{N_{ik}}{\sum_j N_{ij}} + \frac{x_{ik}}{X_i}\frac{1-\sigma}{\sigma}\frac{\partial \log \tau_k(N_{ik})}{\partial \log N_{ik}}$$

6.2 Technology with productivity differences across countries

Here, we generalize the technology so that workers have different labor productivity that differs across source countries. Firm i's output is now

$$y_i = \phi_i \sum_j z_j N_{ij} \tag{28}$$

and workers from country j receive wage w_j. The first-order condition is now:

$$\begin{aligned} w_k = &\frac{\sigma-1}{\sigma}\left(\phi_i \sum_j z_j N_{ij}\right)^{\frac{\sigma-1}{\sigma}-1} \phi_i z_k \left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}} \\ &+ \left(\phi_i \sum_j z_j N_{ij}\right)^{\frac{\sigma-1}{\sigma}} \frac{1}{\sigma}\left(\sum_j \Xi_{ij}\alpha_{ij}E_j\tau_j\left(N_{ij}\right)^{1-\sigma}\right)^{\frac{1}{\sigma}-1} \alpha_{ik}E_k(1-\sigma)\,\tau_k\left(N_{ik}\right)^{-\sigma}\frac{\partial \tau_k(N_{ik})}{\partial N_{ik}} \end{aligned}$$

which can be written:

$$w_k N_{ik} = \frac{\sigma-1}{\sigma} r_i \frac{z_k N_{ik}}{\sum_j z_j N_{ij}} + \frac{1-\sigma}{\sigma} r_{ik} \frac{\partial \log \tau_k(N_{ik})}{\partial \log N_{ik}} \tag{29}$$

This cannot be used exactly like equation (14) above, because $\sum_j z_j N_{ij}$ is not observed. Instead we rewite it as:

$$w_k N_{ik} - \frac{1-\sigma}{\sigma} r_{ik} \frac{\partial \log \tau_k(N_{ik})}{\partial \log N_{ik}} = \frac{\sigma-1}{\sigma} r_i \frac{z_k N_{ik}}{\sum_j z_j N_{ij}} \tag{30}$$

and divide by the equation for natives, N_{i1}, which is $w_1 N_{i1} = \frac{\sigma-1}{\sigma} r_i \frac{z_1 N_{i1}}{\sum_j z_j N_{ij}}$,

$$\frac{w_k N_{ik} - \frac{1-\sigma}{\sigma} r_{ik} \frac{\partial \log \tau_k(N_{ik})}{\partial \log N_{ik}}}{w_1 N_{i1}} = \frac{z_k N_{ik}}{z_1 N_{i1}} \tag{31}$$

and rearrange,

$$w_k N_{ik} = w_1 N_{i1} \frac{z_k N_{ik}}{z_1 N_{i1}} + \frac{1-\sigma}{\sigma} r_{ik} \frac{\partial \log \tau_k \left(N_{ik}\right)}{\partial \log N_{ik}} \tag{32}$$

With the assumption that $\tau_k(N_{ik}) = e^{\beta' D_k}(1 + N_{ik})^{-\varepsilon}$, the elasticity in the last term is:

$$\frac{\partial \log \tau_k \left(N_{ik}\right)}{\partial \log N_{ik}} = -\varepsilon \frac{N_{ik}}{1 + N_{ik}} \tag{33}$$

so the first-order condition with productivity differences is:

$$w_k N_{ik} = w_1 N_{i1} \frac{z_k N_{ik}}{z_1 N_{i1}} + r_{ik} \frac{\sigma - 1}{\sigma} \varepsilon \frac{N_{ik}}{1 + N_{ik}} \tag{34}$$

Equation (34) is linear in the parameter ε, so it can be estimated via OLS by proxying for the term $\frac{z_k}{z_1}$ with country fixed effects.