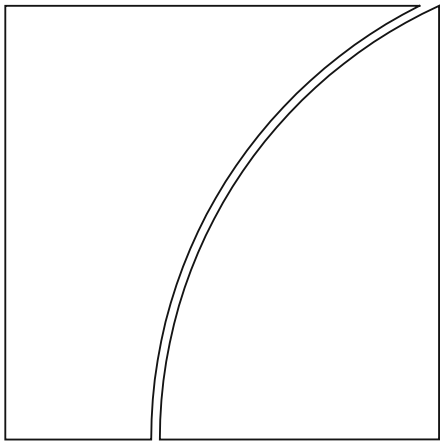


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Immigrants' skills and Capital Deepening: Evidence from Chile*

Alessandra Anna Palazzo,† and Carlos Madeira‡

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Abstract

We study the effect of migration on firms' capital deepening, leveraging a massive influx of immigrant workers with varying skill sets from Venezuela and Haiti in Chile between 2015 and 2019. Using a theoretical framework that allows for differential productivity between native and immigrant workers, we estimate how firm capital responds to increases in the supply of skilled and unskilled workers. Identification relies on the shift-share instrument to estimate firms' exposure to immigration shocks. We use unique employer-employee data to match worker characteristics, including country of origin and education level, to balance sheet data from firms' tax returns, providing highly detailed information about the labor composition and capital in the firm that is not available in other contexts. Our findings show that a 1 p.p. increase in the proportion of skilled immigrants relative to total skilled workers in the firm raises firms' capital per worker by 1 to 2%. The impact of skilled labor on capital deepening is nonlinear and declines as firms' immigrant concentration increases, consistent with our model's predictions. This nonlinear relationship is driven by the imperfect substitutability between immigrants and native workers within the same skill group.

JEL classification: D24; E23; J15; J24; J61; L60.

Keywords: Migration; Firms; Capital; Productivity; Chile.

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1 Introduction

Migration is a significant economic phenomenon and a key issue in development (WorldBank (2023)), with substantial impacts on economic outcomes and societies in sending and receiving countries. A central question for policymakers is how migration affects receiving countries. Immigrants can affect firm production and productivity through their labor, with broad implications for individual welfare and aggregate economic outcomes. While the effects of migration on the employment and wages of native workers have been particularly well-studied using individual data (including by Card (2001), Borjas (2003), Ottaviano and Peri (2012)), there is considerably less evidence regarding the impact of immigration on production within firms. The effects of migration on capital deepening, defined as an increase in the capital-to-labor ratio, is an important question to analyze, since it is a key driver of firms' productivity (Jorgenson and Griliches (1967)), innovation (Aghion and Howitt (2017)), economic growth and structural transformation, particularly in emerging markets (Acemoglu and Guerrieri (2008)). Furthermore, in an aging world, migration (Gaetano Basso and Peri (2019), Michał Burzyński and Rapoport (2018)) and labor market reforms (Ruy Lama Gustavo Leyva Carlos Urrutia (2022), Hassan Molana and Onwordi (2021)) are seen as essential boosts to economic efficiency (IMF (2025)).

This paper examines the effect of immigration on capital deepening, focusing on the relationship between immigrants' skills and firms' investment in capital. We analyze the quasi-natural experiment of the arrival of 1 million immigrant workers with varying skill levels in Chile between 2015 and 2019. We contribute to the existing literature by studying the relationship between capital deepening and the skills of immigrants at the firm level. The skill composition of immigrants plays a critical role in determining the impact of migration on capital deepening, as firms may adopt more capital-intensive production methods following an influx of skilled workers, or shift to more labor-intensive methods in response to an increase in unskilled workers (Dustmann and Glitz (2015)). This adjustment can also affect inequality, if capital is more complementary to skilled than to unskilled labor, an increase in capital intensity can widen wage inequality (Goldin and Katz (1998)), disproportionately benefiting skilled workers (Krusell et al. (2000); Acemoglu (2002)). In addition, capital-skill complementarity helps explain why previous studies have often found limited impacts of immigration on wages and employment for native workers (Lewis (2011)). If firms can adjust their capital structure in response to an increase in labor supply, the wage impact on native workers, particularly those with skills similar to those of immigrants, is

mitigated.

We start by introducing our theoretical framework and deriving testable predictions that guide our empirical analysis. We model the firm's production function using a constant elasticity of substitution (CES) structure that reflects key features of our setting. The production function incorporates workers with varying skill levels and assumes capital-skill complementarity, that is, the elasticity of substitution between unskilled workers and capital is higher than that between skilled workers and capital. Skilled and unskilled labor consists of both native and foreign workers[1], aggregated through a CES function to allow imperfect substitutability within skill groups. From this model, we derive predictions about the relationship between the share of immigrant workers in a firm and capital deepening. An increase in the share of skilled immigrants is expected to increase capital per worker, with a non-linear relationship. In contrast, the effect of unskilled immigrants is theoretically ambiguous, as unskilled labor may substitute for capital but also complement skilled labor. We empirically test these predictions using uniquely detailed administrative data from Chile.

During the past decade, Chile has experienced an unprecedented wave of immigration. Between 2014 and 2019, the share of immigrants in the labor force increased from 2.5% to approximately 11%. This rise was primarily driven by the arrival of Venezuelan immigrants following the intensification of the Venezuelan humanitarian crisis in 2015. Today, approximately 450,000 Venezuelans reside in Chile, making them the largest migrant group in the country. The second contributing factor to this surge was the arrival of Haitian immigrants following the 2010 earthquake. Chile provides a unique setting for studying the relationship between immigrant skills and capital deepening for two reasons. First, the education levels among immigrants coming to Chile vary widely, with a significant share of Venezuelan migrants holding university degrees, in contrast to those from Haiti and other Latin American countries. Second, unlike many other Latin American nations experiencing similar immigration inflows, most immigrants in Chile are employed in the formal sector.

We use a comprehensive administrative dataset covering the entire private sector in Chile, in which we observe the universe of formal workers and firms. We match each firm to its employees, identifying native and foreign workers, nationalities, and education levels. Furthermore, we link our matched employee-employer dataset to firms' confidential balance sheet data. We use data

[1]We use the terms "foreign workers" and "immigrants" interchangeably throughout the paper.

from 2010 to 2019 and restrict our sample to firms in the manufacturing sector. This is because the capital-skill complementarity we aim to analyze is traditionally well-identified in the manufacturing sector, particularly with a focus on capital equipment. In addition, the manufacturing sector employs a similar proportion of skilled and unskilled foreign workers.[2]

We estimate how firms' capital responds to changes in the share of skilled and unskilled immigrant workers. To address the endogeneity of firms' hiring decisions, we use a shift-share instrument Card (2001), constructed in two steps. First, we estimate a Poisson pseudo-maximum likelihood model using pre-shock firm-level characteristics to simulate the number of foreign workers by nationality in each firm in 2010, the first year in our sample. These simulated stocks are used to construct initial exposure shares. We rely on simulated, rather than actual, foreign worker numbers because only 16% of firms hired skilled immigrants in 2010, and 36% unskilled immigrants, resulting in zero exposure for most firms. Using actual shares would lead to an instrument that is zero for the majority of observations. In the second step, we combine the simulated exposure shares with the national growth rates of immigrants by country of origin (the "shifts"). To assess the robustness of the instrument, we conduct a series of falsification and robustness checks, following the approaches of Goldsmith-Pinkham et al. (2020) and Borusyak and Hull (2022).

Our results show that an increase in the share of skilled immigrants within firms leads to a statistically significant increase in capital per worker, consistent with the capital-skill complementarity framework we adopt. In contrast, a higher share of unskilled immigrants is associated with a decline in capital intensity, although this relationship is not statistically significant across all specifications. Importantly, we find that the effect of skilled immigration on capital deepening is non-linear: capital increases with the share of skilled immigrants up to a point, but the effect turns negative when their share exceeds approximately one-quarter of all skilled workers.[3] This non-linearity is driven by imperfect substitutability between immigrant and native workers. Our estimates indicate that skilled immigrants and natives are relatively complements, with an elasticity of substitution around 6. We also find evidence of relative complementarity between unskilled immigrants and unskilled native workers, with an estimated elasticity of substitution of approximately 8.

Our paper makes three key contributions to the literature. First, to the best of our knowledge,

[2]Table 8 in Appendix B presents the distribution of immigrants across sectors.

[3]Most firms in our sample have less than 30 percent skilled immigrant workers, with an average share of 10 percent.

we are the first to empirically test predictions about the relationship between immigrant skills and capital deepening at the firm level, using comprehensive administrative data. While previous studies have explored this relationship at broader levels, measuring the migration shock at industry or local labor markets, our firm-level analysis adds to this literature by revealing a positive but non-linear effect of the share of skilled immigrant workers on capital deepening within firms. Second, we show that the non-linear relationship is consistent with imperfect substitutability between immigrant and native workers. Our structural estimates of the elasticity of substitution within the same skill category suggest that this pattern may be partly driven by differences in how immigrant and native workers are allocated across tasks within firms. One possible interpretation is that if immigrant workers were employed in positions that better match their skill levels, the relationship between skilled immigration and capital deepening would be stronger and linear. Third, while capital-skill complementarity is well-documented in the context of the United States, we contribute to the literature by providing evidence from a different context. Using matched employer-employee data from Chile, we estimate the elasticity between capital and labor, demonstrating robust evidence of capital-skill complementarity in Chile's manufacturing sector.

Our paper primarily aligns with recent studies on migration and capital accumulation. In particular, Lafortune et al. (2019) estimate the elasticity of substitution between capital and labor in the U.S. manufacturing sector, showing that immigration-driven shifts in the skill mix during the 19th and 20th centuries caused capital and unskilled labor to shift from complements to substitutes. We build on the theoretical framework presented by Lafortune et al. (2019), but introduce two key differences. First, we allow immigrants and native workers to be imperfect substitutes, explicitly modeling skilled and unskilled labor as aggregates of both groups in the production function. This framework allows us to derive testable predictions about the impact of increasing immigrant workers within firms. Consequently, our empirical exercise examines the effect of a specific immigration shock on firms' capital intensity, rather than estimating the overall relationship between capital and labor.

Other recent studies have examined the impact of immigration on various firms' outcomes (see Caliendo et al. (2023), Peri (2012), Mitaritonna et al. (2017), Dustmann and Glitz (2015), Gray et al. (2020), Accetturo et al. (2012), Imbert et al. (2022), Altındağ et al. (2020)). Broadly, this literature demonstrates that firms respond to shifts in the local skill composition by adapting

their production technologies towards methods that rely on the more prevalent skill type. In particular, Caliendo et al. (2023) examine the impact of skilled Ukrainian refugees on capital accumulation across European countries. They find that nations that accumulated more capital saw increased output per worker and reduced wage inequality between low- and high-skilled workers. Similarly, Mitaritonna et al. (2017) find that an increase in high-skill immigration increases firms' total factor productivity, capital stock, wages, and exports within the manufacturing sector in France. Conversely, studies on low-skilled migration have shown that areas experiencing greater inflows of low-skilled immigrants tend to adopt more labor-intensive technologies (Peri (2012)). Similarly, firms exposed to rural low-skilled migration shift towards more labor-intensive and less capital-intensive products, and they experience a significant reduction in innovation and a lower probability of filing patents, as shown by Imbert et al. (2022). The context of our study differs from previous research in two key aspects. First, Latin America is characterized by predominantly intra-regional migration. As a result, most immigrants in Chile are Spanish speakers (except Haitians), facilitating their integration into the local labor market. Second, unlike many other countries that have primarily experienced low-skilled immigration, Chile has simultaneously received substantial inflows of both high- and low-skilled migrants. This skill composition allows us to examine how different types of migration affect firms depending on their production structure. For instance, firms in more capital-intensive sectors may benefit more from an influx of skilled immigrants, while those in labor-intensive sectors may be more affected by unskilled immigration.

In addition, we contribute to the literature estimating the elasticity of substitution between capital equipment and workers of different skill levels (Griliches (1969), Goldin and Katz (1998), Krusell et al. (2000)). While capital-skill complementarity has been extensively studied in developed economies like the U.S., evidence for developing countries remains limited, largely due to data constraints. Our access to extraordinary, comprehensive administrative data allows us to provide credible evidence of capital-skill complementarity in a Latin American country.

Finally, our paper contributes to the growing body of recent literature analyzing the effects of the Venezuelan migration wave on Latin American countries. In particular, recent papers including Ajzenman et al. (2022), Contreras and Gallardo (2020), and Arias and Guerra-Salas (2019) focus on labor market outcomes in Chile. Contreras and Gallardo (2020) find that the influx of Venezuelan immigrants has led to a 2-3 percent wage decline for less educated native

workers. Arias and Guerra-Salas (2019) demonstrate that immigrant workers in Chile are increasingly relocating to the informal sector. Finally, Ajzenman et al. (2022) show that there has been an increase in unemployment-related concerns and a negative and inaccurate perception of the actual effect of immigration on labor outcomes. In a similar study of the Venezuelan immigration to Peru, Boruchowicz et al. (2024) reveal relatively small effects of immigration on total employment, hours worked, and labor income per hour. However, since the Venezuelan immigrants were more educated than the Peruvian domestic labor force, Boruchowicz et al. (2024) find that this immigration changed the occupational structure of the labor force, leading to a reallocation of local workers (men and women) towards low-skilled jobs. Several studies have investigated the labor market impact in Colombia, including works by Ibáñez et al. (2024), Bahar et al. (2021), Lebow (2024), and Santamaria (2022). Notably, Delgado-Prieto (2023) highlights the importance of firm size in shaping immigration's impact on native workers, with wage and employment losses primarily concentrated in smaller firms. Our paper extends this literature by providing new insights into how immigration affects firms' skill level composition and capital intensity.

The rest of the paper is organized as follows. Section 2 provides an overview of the migration shock and the characteristics of the immigrants. Section 3 introduces a simple theoretical framework to motivate our empirical approach and details the empirical strategy. Section 4 presents the data and key descriptive statistics of the firms. Section 5 discusses the main empirical findings. In Section 6, we outline the methodology for estimating the elasticities of substitution and present the results. In Section 7, we present counterfactual simulations of an increase in the share of skilled and unskilled immigrants within firms and its impact on capital deepening under different parameter values. Finally, we offer concluding remarks.

2 Migration in Chile: Descriptive Evidence

During the past decade, Chile has experienced an unprecedented surge in immigration. Immigrants now represent almost 11% of workers, a substantial increase from just 2.5% in 2010. Figure 1, panel A, illustrates the evolution of the immigrant stock and their share of the total population between 2010 and 2019. Panel B of the same figure displays the number of requests for temporary and long-term residence permits over time, disaggregated by the five countries of origin contributing the largest number of new arrivals. As shown in panel B, the most substantial increase in

immigrant presence occurred between 2017 and 2019, largely due to the sharp rise in Venezuelan immigration starting in 2016.

Since 2016, the Venezuelan humanitarian crisis has led to large-scale emigration, with approximately 7.7 million Venezuelans seeking international protection and assistance. While many relocated to neighboring countries, particularly Colombia, Chile became a major destination. Today, approximately 450,000 Venezuelans reside in Chile, making them the largest migrant group in the country. Chile experienced the fastest increase in the presence of immigrants among host countries in the region during the period under analysis. Another significant factor contributing to the increase in the foreign-born population is the arrival of Haitian immigrants after the devastating 2010 earthquake in Haiti. In 2012, Chile hosted fewer than 2,000 Haitians; by the end of 2020, this number had increased to over 182,000. In particular, there was a sharp increase in the Haitian population around 2016-2017, as many people who had initially settled in other countries subsequently migrated to Chile. However, between 2018 and 2019, the number of permit requests from Haitian immigrants dropped sharply due to the introduction of a visa requirement in 2018. Under the new policy, Haitian nationals were required to obtain a visa from the Chilean consulate in Haiti before arrival, replacing the previous option of acquiring a 90-day tourist visa upon entry.[4] Additionally, Chile has experienced significant and consistent migration from neighboring countries, including Peru, Bolivia, and Colombia.

The pool of immigrants coming to Chile also differs in education level. Figure 2, panel A, shows the percentage of skilled immigrants over total immigrant workers and the percentage of skilled immigrants over total skilled workers. As the figure shows, there has been a steep increase in the proportion of immigrants with a college education ("skilled") among all immigrant workers, as well as among all skilled workers. Panel B shows the percentage of skilled immigrant workers by nationality over the years. Most Venezuelan immigrants have at least some college education. In contrast, immigrants from Haiti, Peru, Bolivia, and Colombia predominantly fall into the noncollege-educated category.

Figure 13 in Appendix A, panels A and B, illustrates the presence of foreign workers across regions in 2010 and 2019, measured as a percentage of total workers. These maps reveal a significant nationwide increase in the immigrant population, with particularly high concentrations in the northern regions, Arica y Parinacota, Antofagasta, and Tarapacá, as well as in the Metropoli-

[4] A similar requirement was later introduced for Venezuelan immigrants, although this occurred outside the analysis period.

tan Region of Santiago. By 2019, these areas had become major immigrant hubs. The share of foreign workers reached 19.5% in Arica y Parinacota, 21.7% in Antofagasta, 26.5% in Tarapacá, and 11.7% in Santiago, reflecting substantial increases from their 2010 levels of 7.6%, 7.1%, 11.3%, and 2.9%, respectively. While the northern regions stand out, the southern and central parts of the country also experienced a notable rise in immigrant presence. For instance, in the region of Magallanes, immigrants made up just 2.4% of the workforce in 2010, but this figure rose to nearly 10.8% by 2019. Figure 14 in Appendix A shows the municipal-level distribution of foreign workers in 2010 and 2019, as a share of the total workforce. The map highlights the substantial increase in immigrant presence and the wide variation in their distribution across municipalities. This variation in immigrant inflows, across municipality and over time, is central to our identification strategy.

3 Empirical Strategy

This section introduces the theoretical framework from which we derive testable predictions. Following this, we detail the empirical strategy employed to test these predictions.

3.1 Theoretical Framework

Consider a firm that produces goods combining capital, unskilled, and skilled labor. We assume the following production function:

$$F(K,U,S) = A\left(\left(K^{\frac{\lambda-1}{\lambda}} + U^{\frac{\lambda-1}{\lambda}}\right)^{\frac{(\epsilon-1)\lambda}{(\lambda-1)\epsilon}} + S^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where K represents capital, U is unskilled labor, and S is skilled labor. Assume the production has constant returns to scale and satisfies quasi-concavity constraints. The parameter λ represents the elasticity of substitution between capital and unskilled labor. Similarly, ϵ is the elasticity of substitution between skilled labor and the aggregator of capital and unskilled labor. We assume that capital is more complementary to skilled labor than to unskilled labor ($\lambda > \epsilon$ (see, for example, Goldin and Katz (1998))). We allow native and immigrant workers to be imperfect substitutes. Specifically, skilled and unskilled labor are defined as a combination of native (denoted as N) and foreign (denoted as F) workers, aggregated using a standard CES function

that is uniform across firms. The aggregation of native and foreign workers by skill category is defined as follows:

$$U = \left(U_N^{\frac{\sigma_u - 1}{\sigma_u}} + U_F^{\frac{\sigma_u - 1}{\sigma_u}} \right)^{\frac{\sigma_u}{\sigma_u - 1}}, \tag{2}$$

$$S = \left(S_N^{\frac{\sigma_s - 1}{\sigma_s}} + S_F^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}}. \tag{3}$$

where parameters σ_U and σ_S represent the elasticities of substitution between natives and immigrants. Given this production function, four parameters are key to understanding the effect of a change in the labor skill mix induced by an immigration shock on capital accumulation. The first is the elasticity of substitution between capital and unskilled labor, λ. The second is the elasticity of substitution between capital and skilled labor, ϵ. The third and fourth are the elasticities of substitutions between immigrant and native workers (skilled and unskilled).

3.1.1 Capital Accumulation

Following Lafortune et al. (2019), we assume that capital is perfectly mobile across all locations. As a result, the marginal product of capital is determined at the aggregate level, and the capital stock adjusts to equate the marginal product of capital with its cost:

$$F'_K(K, U, S) = r.$$

Given that the marginal product of capital is a function homogeneous of degree zero, we can express the condition in intensive form:

$$F'_K\left(\underbrace{\frac{K}{U_F + U_N + S_F + S_N}}_{k}, \underbrace{\frac{U}{U_F + U_N + S_F + S_N}}_{\tilde{u}}, \underbrace{\frac{S}{U_F + U_N + S_F + S_N}}_{\tilde{s}} \right) = r, \tag{4}$$

where we normalize inputs by the total number of workers. The variables U_F, U_N, S_F, and S_N denote the number of unskilled foreign, unskilled native, skilled foreign, and skilled native workers, respectively. Totally differentiating expression (4) with respect to intensive variables k,

$\tilde{u}$, $\tilde{s}$, we obtain[5]:

$$\frac{\Delta k}{k} = \kappa_1 \times \frac{\Delta s_F}{s_F} + \kappa_2 \times \frac{\Delta u_F}{u_F} + \kappa_3 \times \frac{\Delta u}{u}, \tag{5}$$

where s_F represents the proportion of skilled immigrants among all skilled workers in the firm ($s_F = \frac{\mathsf{S}_F}{\mathsf{S}_N + \mathsf{S}_F}$), u_F represents the proportion of unskilled immigrants among all unskilled workers in the firm ($u_F = \frac{U_F}{U_N + U_F}$), and u represents the overall proportion of unskilled workers in the firm ($u = \frac{U_F + U_N}{U_N + U_F + S_F + S_N}$). As a result, coefficients κ_1, κ_2, and κ_3 represent the sensitivities of changes in capital deepening to changes in the share of skilled immigrants among all skilled workers, the share of unskilled immigrants among all unskilled workers, and the change in the overall proportion of unskilled workers at the firm level, respectively. The two coefficients of interest are κ_1 and κ_2, which take the following forms:

$$\kappa_1 = \overbrace{\frac{\lambda \tilde{s}^{\frac{\epsilon-1}{\epsilon}} \left(k^{\frac{\lambda-1}{\lambda}} + \tilde{u}^{\frac{\lambda-1}{\lambda}}\right)}{\lambda \tilde{s}^{\frac{\epsilon-1}{\epsilon}} k^{\frac{\lambda-1}{\lambda}} + \epsilon y^{\frac{\epsilon-1}{\epsilon}} \tilde{u}^{\frac{\lambda-1}{\lambda}}}}^{-\frac{F_{k\tilde{s}}\,\tilde{s}}{F_{kk}\,k}} \times \overbrace{\frac{\left(s_F^{-\frac{1}{\sigma_s}} - (1-s_F)^{-\frac{1}{\sigma_s}}\right) s_F}{s_F^{\frac{\sigma_s - 1}{\sigma_s}} + (1-s_F)^{\frac{\sigma_s - 1}{\sigma_s}}}}^{\frac{\partial \tilde{s}}{\partial s_F}\frac{s_F}{\tilde{s}}},$$

$$\kappa_2 = \underbrace{\left(1 - \frac{\lambda \tilde{s}^{\frac{\epsilon-1}{\epsilon}} \left(k^{\frac{\lambda-1}{\lambda}} + \tilde{u}^{\frac{\lambda-1}{\lambda}}\right)}{\lambda \tilde{s}^{\frac{\epsilon-1}{\epsilon}} k^{\frac{\lambda-1}{\lambda}} + \epsilon y^{\frac{\epsilon-1}{\epsilon}} \tilde{u}^{\frac{\lambda-1}{\lambda}}}\right)}_{-\frac{F_{k\tilde{u}}\,\tilde{u}}{F_{kk}\,k}} \times \underbrace{\frac{\left(u_F^{-\frac{1}{\sigma_u}} - (1-u_F)^{-\frac{1}{\sigma_u}}\right) u_F}{u_F^{\frac{\sigma_u - 1}{\sigma_u}} + (1-u_F)^{\frac{\sigma_u - 1}{\sigma_u}}}}_{\frac{\partial \tilde{u}}{\partial u_F}\frac{u_F}{\tilde{u}}}.$$

Equation (5) implies testable predictions for the relationship between capital deepening and changes in the shares of skilled and unskilled foreign workers.

The parameter κ_1 captures the response of capital stock per worker to changes in skilled immigrants as a share of all skilled labor within the firm. The first component of κ_1, $\left(\frac{F_{k\tilde{s}}\,\tilde{s}}{F_{kk}\,k}\right)$, determines the effect of an increase in skilled workers on capital stock. This component is positive for all parameter values, indicating that an increase in the supply of skilled workers has a positive effect on capital deepening, driven by the complementarity between capital and skilled labor. The second component of κ_1, $(\frac{\partial \tilde{s}}{\partial s_F}\frac{s_F}{\tilde{s}})$, represents the change in the skilled labor aggregator due to an increase in the share of skilled immigrants and depends on the elasticity of substitution, σ_s, between skilled native and foreign workers. The function has an internal maximum (between

[5]see Appendix C for complete derivations

0 and 1) corresponding to the "optimal" combination of immigrants and natives. If foreign and native workers are not perfect substitutes, this component will be positive for small values of s_F and negative for larger values[6]. Section 7 presents counterfactual simulations, showing these two channels' contribution to the final effect on capital. In particular, if immigrants and native workers within the same skill group are perfect substitutes, the effect is larger and linear than if immigrants and natives are imperfect substitutes.

The parameter κ_2 is the effect of an increase in unskilled immigrants as a share of all unskilled labor within the firm on capital per worker. The expected sign of κ_2 is theoretically ambiguous. On one hand, unskilled workers can act as substitutes for capital, reducing the demand for capital. On the other hand, they can complement skilled workers, thereby increasing capital demand. However, for sufficiently high values of λ (indicating a higher elasticity of substitution between capital and unskilled labor), we anticipate the first component of κ_2, $\left(\frac{F_{k\tilde{u}}}{F_{kk}}\frac{\tilde{u}}{k}\right)$, to be negative. This suggests that an increase in unskilled labor reduces capital deepening. In Section 7, we show that as the gap between λ and ϵ widens, this negative effect becomes more pronounced. Similar to the case of skilled immigrants, the second component, $\left(\frac{\partial\tilde{u}}{\partial u_F}\frac{u_F}{\tilde{u}}\right)$, is positive when the share of unskilled immigrants (u_F) is low and becomes negative as u_F increases. This pattern reflects the imperfect substitutability between unskilled immigrants and native workers.

3.2 Identification Strategy

Based on the model's predictions, we estimate the following equation:

$$\ln(k_{i,t}) = \beta_1 \mathrm{s}_{F,it} + \beta_2 \mathrm{u}_{F,it} + \beta_3 \mathrm{u}_{it} + \beta_4 \mathrm{s}^2_{F,it} + \beta_5 \mathrm{u}^2_{F,it} + \beta_6 \mathrm{u}^2_{it} + \gamma X_{it} + \phi_t + \phi_j + \phi_c + \phi_s + \epsilon_{it} \quad (6)$$

where $k_{i,t}$ represents capital per worker in firm i and year t. The main variables of interest are the share of skilled immigrants over total skilled workers and the share of unskilled immigrants over total unskilled workers in a given firm and year ($\mathrm{s}_{F,it}$, $\mathrm{u}_{F,it}$). To account for overall changes in the firm's skill composition, we include a measure of the share of total unskilled workers in the firm every year (u_{it}). Since the response of capital to an increase in the share of foreign skilled and unskilled workers is non-linear, we include quadratic terms for each share. Additionally,

[6]If natives and foreign workers have the same productivity, the effect will turn negative when the share of immigrants is above 50%.

we incorporate year (t), sub-industry (j), municipality (c), and size category (s) fixed effects[7]. Municipalities and industry fixed effects control for constant (observable and unobservable) differences across municipalities or sectors. Year fixed effects account for national shocks common to all firms. We also include the firm's age and an indicator variable for whether a firm has multiple plants. Firm age is an important control, as it may affect the capacity to hire immigrants. For example, older and more established firms could be more familiar with the bureaucracy involved in hiring immigrants. Similarly, firms with multiple plants might have a more international exposure and, therefore, be more inclined to hire immigrants.

The share of a firm's foreign workers is not exogenous. Even after including fixed effects and additional controls, the coefficients β_1 and β_2 from an OLS estimate of equation 6 would be subject to bias due to simultaneity and potential omitted time-varying confounders. For example, the decision to hire immigrants is likely affected by firm-specific characteristics that might also influence capital investment decisions, leading to omitted variable bias. Additionally, demand shocks at the firm level can influence both hiring practices and capital accumulation. Moreover, simultaneity could arise if more capital-intensive firms are more likely to hire skilled immigrants, while more labor-intensive firms tend to hire unskilled immigrants.

To address the endogeneity and simultaneity issues, we instrument for firms' shares of foreign workers using changes in the local supply of such workers. Specifically, we use a shift share (or Bartik) instrument (Card (2001)), which has been extensively adopted in the migration literature. It exploits the "immigrant enclave" idea, assuming that individuals will prefer to settle where other individuals from the same nationality have settled in the past. The instrument is typically constructed as the product of the share of individuals from nationality n who settled in a given location in a base year (typically the start of the sample) and the growth rate at the national level of immigrants by nationality in each year considered.

In our context, we exploit variation at the firm level, which requires constructing the shift-share instrument at the firm level, introducing additional challenges. In the initial year of our analysis (2010), very few firms in Chile employed immigrant workers, reflecting the relatively small immigrant presence before 2015. Figure 9, panels A and B, in Appendix A, displays the distribution of the share of foreign skilled and unskilled workers at the firm level in 2010. Table 11 reports the percentage of firms hiring immigrants by year. As shown in the table, only 16% of

[7]We consider four firm size categories: Micro (less than 10 workers), Small (10 to 49 workers), Medium (50 to 199 workers), and Large (200 or more workers).

firms hired skilled foreign workers and 36% hired unskilled foreign workers in 2010. As a result, the exposure shares in a standard shift-share framework would be zero for a substantial portion of the sample, leading the predicted number of foreign workers to also be zero for most firms. Furthermore, Chile has quite possibly the highest firm creation and destruction rates among the OECD countries (Albagli et al. (2023)), which implies that many firms (especially micro, small and medium firms) did not exist during the initial period and therefore would be dropped from estimates using firm-specific exposure to foreign workers in 2010.

To address the mass at zero and the missing data for firms created after 2010, we predict firm-level exposure in the initial year using a Poisson Pseudo-Maximum Likelihood regressions (PPML) Model and pre-shock firm fixed characteristics. Specifically, we predict the number of skilled and unskilled foreign workers by nationality in 2010 at the firm level using a Poisson regression based on municipality (c), sub-industry (j), and the firm's size bin (s) information in the years previous to the immigration shock:

$$\hat{\mathbb{E}}(S_{in10}|\phi_s, \phi_j, \phi_c) = \exp\left(\phi_s * \phi_j * \phi_c\right), \tag{7}$$

$$\hat{\mathbb{E}}(U_{in10}|\phi_s, \phi_j, \phi_c) = \exp\left(\phi_s * \phi_j * \phi_c\right), \tag{8}$$

where $\hat{\mathbb{E}}(S_{in10}|\phi_s, \phi_j, \phi_c)$ and $\hat{\mathbb{E}}(U_{in10}|\phi_s, \phi_j, \phi_c)$ are the predicted stock of skilled and unskilled foreign workers, by nationality n, at firm level i, in 2010. Appendix D provides a detailed description of this step, along with summary statistics on the bins used in the estimation. Figures 7 and 8 present the correlation between the actual and predicted number of immigrants by main nationality within firms in 2010. Table 17 reports the predicted percentage of firms hiring skilled and unskilled foreign workers in 2010.

Using these simulated stocks for 2010, we construct the predicted exposure of firm i to the arrival of workers from nationality n as the ratio of the simulated number of skilled and unskilled foreign workers from nationality n in firm i to the total simulated foreign workers from nationality n across all firms in Chile in 2010:

$$\frac{\widehat{S_{in10}}}{S_{n10}} = \frac{\hat{\mathbb{E}}(S_{in10})}{\sum_i \hat{\mathbb{E}}(S_{in10})}, \tag{9}$$

$$\frac{\widehat{U_{in10}}}{U_{n10}} = \frac{\hat{\mathbb{E}}(U_{in10})}{\sum_i \hat{\mathbb{E}}(U_{in10})}. \tag{10}$$

Finally, we construct the predicted number of skilled and unskilled foreign workers at the firm level for year t. We do this by multiplying the simulated exposure shares for each nationality, as defined in equations 9 and 10, by the total inflow of skilled and unskilled immigrants at the national level from nationality n between year t and 2010. Therefore, we defined the predicted stock of skilled and unskilled foreign workers for each firm in year t as:

$$\widehat{S}_{F,it} = \sum_n \frac{\widehat{S_{in10}}}{S_{n10}} \times \Delta S_{F,tn}, \tag{11}$$

$$\widehat{U}_{F,it} = \sum_n \frac{\widehat{U_{in10}}}{U_{n10}} \times \Delta U_{F,tn} \tag{12}$$

where $\frac{\widehat{S_{in10}}}{S_{n10}}$ and $\frac{\widehat{U_{in10}}}{U_{n10}}$ are the predicted exposure to immigrants' shock by nationality n in 2010 in firm i and $\Delta S_{F,tn}$, $\Delta U_{F,tn}$ the total inflow of immigrants (skilled and unskilled) from nationality n between year t and 2010.

After computing the predicted number of skilled and unskilled foreign workers, defined as 11 and 12, we can construct our instrument for our main variables of interest: the predicted share of skilled foreign workers relative to total skilled workers in the firm ($\hat{z}^S_{it}$) and the predicted share of unskilled foreign workers relative to total unskilled workers in the firm ($\hat{z}^U_{it}$).

$$\hat{z}^S_{it} = \frac{\widehat{S}_{F,it}}{\widehat{S}_{F,it} + S_{N,i10}}, \tag{13}$$

$$\hat{z}^U_{it} = \frac{\widehat{U}_{F,it}}{\widehat{U}_{F,it} + U_{N,i10}}, \tag{14}$$

where $S_{N,i10}$ and $U_{N,i10}$ are respectively the number of skilled and unskilled native workers in the firm in 2010, as reported in tax returns. Therefore, firms' exposure to migration shocks is determined only by their location, industry, and size in the pre-shock period. Our main analysis accounts for these fixed effects and their interactions. We use the quadratic values of the predicted shares of skilled and unskilled foreign workers as instruments for the actual quadratic shares of foreign workers. Specifically, we estimate the following first stage equations:

$$x_{i,t} = \delta_1 \hat{z}^S_{it} + \delta_2 \hat{z}^U_{it} + \delta_3 u_{it} + \delta_4 (\hat{z}^S_{it})^2 + \delta_5 (\hat{z}^U_{it})^2 + \delta_6 u^2_{it} + \gamma X_{it} + \phi_t + \phi_j + \phi_c + \phi_s + \epsilon_{it} \tag{15}$$

where $x_i t$ corresponds to $s_{F,it}$, $u_{F,it}$, $s^2_{F,it}$, $u^2_{F,it}$ and all other variables are defined as in equation 6.

Recent literature has discussed the interpretation and properties of the shift-share instrument (Borusyak and Hull (2022), Goldsmith-Pinkham et al. (2020), Jaeger et al. (2018)). The key identification assumption, in our case, is that the predicted values of skilled and unskilled immigrants' shares affect firms' capital only through the actual shares and not through any other mechanism. Given that the Bartik instrument comprises two parts (the initial shares and the shifters), this assumption can be challenging to justify. Goldsmith-Pinkham et al. (2020) has argued that the exogeneity can be justified only in terms of the initial exposure share of the foreign population and that the instrument can be considered "equivalent" to using initial shares as instruments. On the other hand, Borusyak and Hull (2022) suggest that the exposure shares can be endogenous and that exogeneity stems from the aggregate shocks. Finally, Jaeger et al. (2018) discuss the issue of serial correlation in the context of shift-share instruments. If the spatial distribution of immigrants does not move much over time, the instrument can be serially correlated.

Our context aligns with the framework proposed by Goldsmith-Pinkham et al. (2020), where the exogeneity of the instrument, conditional on the controls, stems from the exposure shares rather than the shocks themselves. The key identifying assumption is that the initial exposure shares, conditional on municipality, industry, and size fixed effects, are exogenous. That is, once we include controls for municipality, size, and industry fixed effects, no other firm-level variable explain the variation in the initial exposure.[8] This focus on shares is particularly relevant as our context is driven by two significant shocks: the influx of refugees from Venezuela and Haiti. As Borusyak and Hull (2022) highlight, the interpretation of the validity of the Bartik instrument arising from the exogeneity of shocks is appropriate when many independent shocks can be considered "as good as randomly assigned." If particular shocks dominate the variation, the argument for the exogeneity of the shocks becomes less plausible. Since our analysis focuses on a small number of specific, large migration shocks, interpreting the instrument through the variation in exposure shares is more appropriate in our setting. In addition, as outlined by Borusyak and Hull (2022), the argument for the exogeneity of the exposure shares is more plausible when the shares are tailored to a specific shock, such as exposure to migration in our case, rather than

[8]In a regression of initial exposure share for each nationality on a set of firm-level characteristics in 2010 and control for the interaction between municipality size and industry fixed effect, all the variation is completely explained by fixed effects and the coefficients on all firm level characteristics are individually and jointly equal to zero.

generic shares that could drive exposure to a wide variety of shocks [9]. Constructing shares specifically related to the migration shock makes it possible to strengthen the case for their exogeneity.

Following the approach proposed by Goldsmith-Pinkham et al. (2020) and Borusyak and Hull (2022), we conduct a series of tests to validate the exogeneity assumption underlying our instrument. First, we perform a pre-trend analysis to ensure that our results are not driven by pre-existing patterns in capital accumulation prior to the migration shock. Because our analysis focuses on the exogeneity of the firm-level simulated shares by nationality, we separately examine the five nationalities that contribute most to the variation in our sample: Venezuela, Haiti, Peru, Colombia, and Bolivia. Specifically, we regress changes in firm-level capital accumulation during the pre-period (2007 to 2009) on the interaction between the initial simulated exposure shares for each nationality, calculated based on 2010 data, and year fixed effects for 2007 to 2009. This test is analogous to the parallel pre-trends test used in a difference-in-differences framework, where firms with different predicted exposure shares should not exhibit differential trends in capital accumulation prior to the migration shock. The results of this pre-trend exercise, presented in Appendix A, confirm that no significant pre-existing differences in capital accumulation are associated with predicted exposure shares. Second, we construct Bartik instruments for skilled and unskilled immigrants using a "leave-one-out" approach. This involves excluding from the national yearly growth rate of immigrants by nationality the growth rate in the province and industry where the firm is located. By doing so, we mitigate concerns about a mechanical relationship between firm-level shocks and the Bartik instrument, which could potentially inflate the first-stage results (Borusyak and Hull (2022)). The results of this test are presented in Table 4 along with other robustness checks. Finally, we address the concern raised by Jaeger et al. (2018) regarding the correlation in the composition of immigrants over time. The critique suggests that if the composition of immigrants by nationality remains relatively stable, the Bartik instrument may conflate short- and long-run responses to immigrant arrivals. However, the immigration crises in Venezuela and Haiti have significantly altered the composition of immigrants in Chile, with a sharp increase in the share of immigrants from these countries in recent years. This contrasts with the earlier period, where Haitians and Venezuelans represented a small and geographically concentrated fraction of immigrants. Concurrently, the share of immigrants from other countries,

[9]For instance, they provide the example of industry exposure shares which might influence exposure to shocks of different types, in this case the exogeneity of the shares is harder to justify.

such as Argentina and European nations, has declined. This substantial shift in the composition of immigrant inflows over time is in contrast to the US context, for which the concerns raised by Jaeger et al. (2018) about the stability of immigrant composition do apply. Figure 4 in Appendix A shows how the composition of the stock of immigrants has changed during the analysis period.

4 Data

We merge data from multiple administrative sources in our analysis using Chile's unique official identifier, the RUT (Rol Único Tributario), which is assigned to every firm and every individual in the country.[10] This identifier allows us to merge multiple administrative sources.

Individual Data: First, we construct an individual-level dataset. We draw from three sources to gather individual-level information. First, the Civil Registry provides socio-demographic data for all individuals with an identification card in Chile, including Chileans, naturalized citizens, and foreign residents. Second, the Migration Department Dataset contains detailed records on all temporary and permanent residence permits issued by the Chilean Department of State and includes crucial variables such as country of origin, intended municipality of residence, date of birth, educational background, and labor market experience. Third, we access the Ministry of Education database, from which we take information on university completion for Chilean and foreign students pursuing higher education in Chile. We supplement these records with educational details from the Migration Department for foreign nationals who did not pursue education in Chile. We merge data from these three sources using the unique individual ID. This allows us to create an individual-level dataset that includes the individual identifier, nationality, country of birth, and education level of every person in the country from 2010 to 2019. Specifically, the final individual-level data set includes migrants and natives.

Employee Data: Second, we merge individual records to information from Chile's unemployment insurance (UI) system, which is administered by the Pension Authority (*Superintendencia de Pensiones*, in Spanish).[11] This dataset covers private-sector employees aged 18 and older who

[10]This study was developed within the scope of the research agenda conducted by the Central Bank of Chile (CBC) in economic and financial affairs of its competence. The CBC has access to anonymized information from various public and private entities, by virtue of collaboration agreements signed with these institutions.

[11]To secure the privacy of workers and firms, the CBC mandates that the development, extraction and publication of the results should not allow the identification, directly or indirectly, of natural or legal persons. Officials of the Central Bank of Chile processed the disaggregated data. All the analysis was implemented by the authors and did not involve nor compromise the *Superintendencia de Pensiones*. The same disclaimer is valid for our use

have signed contracts since October 2, 2002, regardless of nationality or migration status. It provides data on monthly earnings from all formal employment, education levels, and municipality of residence, though it excludes public sector workers. We create a comprehensive worker-level dataset that includes socio-demographic characteristics, monthly and annual earnings, and the municipality of residence.

Employer Data: Finally, we gather firm-level information from the Chilean tax authority (*Servicio de Impuestos Internos* (SII), in Spanish), using three key forms: J1887, F22 and F29.[12] Form J1887, the Annual Firms' Employees Report, includes data on annual wages, employment months, and whether workers are employed full-time or part-time. Forms F22 (Statement of Annual Income) and F29 (VAT Monthly Declaration) offer detailed information on a firm's sales, exports, and imports at a monthly frequency, and information on fixed asset purchases, fiscal credits, and other financial indicators at an annual frequency. These two forms also report the firms' registered municipality. We merge the worker-level dataset with firm-level balance sheet data using the worker and firm IDs from Form J1887. The worker-level dataset is collapsed at the firm level based on the firm's ID and then combined with the balance sheet data.

The final firm-level dataset includes detailed balance sheet and employment data, which allows us to explore the interactions between workers and firms in Chile's labor market. We exclude from the analysis all firms with fewer than five workers.[13] Tables 10 and 9 in Appendix B report the average firm size and the number of unique firms by size category. The average firm size over the analysis period is approximately 60 employees, and most firms are classified as micro or small.

Table 1 presents descriptive statistics at the firm level for the manufacturing sector, utilizing data from 2010 to 2019 for our main analysis.[14] We define capital per worker as total fixed assets divided by the number of employees in the firm, and we use the logarithm of this ratio as our main measure of capital intensity. Capital is derived from firm-level tax records and includes physical assets such as machinery, equipment, and buildings, excluding intangibles, revaluation reserves, transitory accounts, and short-term financial items. The average log real capital per worker in our sample is approximately 5, corresponding to around 148,000 pesos per worker in

of the workers and firms' data available from the *Servicio de Impuestos Internos*.

[12]The information contained in the databases of the Chilean IRS is of a tax nature originating in self-declarations of taxpayers presented to the Service; therefore, the veracity of the data is not the responsibility of the Service.

[13]Following the approach in Castillo et al. (2024), we exclude firms with fewer than five workers. In very small firms, separating aggregate firm performance from the performance of individual workers becomes difficult, which can compromise the interpretation of firm-level outcomes.

[14]Data from 2007 to 2009 are used for the pre-trend analysis.

real terms. The average firm in our dataset employs about 60 workers, implying a representative total capital stock of approximately 8.9 million pesos per firm.[15]

Capital in the tax records database is self-reported by firms and follows a balance sheet definition. Depreciation is included but reflects tax accounting rather than economic depreciation.[16] While we have very detailed firm balance sheet information from a source where misreporting is subject to legal liability, we only observe physical capital as a single item in a balance sheet designed to meet tax reporting requirements. Therefore, we do not observe a list of the different physical capital goods of each firm. This means we cannot build different capital measures considering distinct depreciation rules. Since we use the balance-sheet measures of capital, our measures can be understood as variables with measurement error regarding the true economic value of physical capital.

We define "skilled workers" as individuals who have completed college. Between 2010 and 2019, foreign workers as a share of all workers in the manufacturing sector grew significantly, rising from 3.7% to 16.9%. Growth rates were comparable for both skilled and unskilled migrants over this period. The share of skilled foreign workers as a proportion of all skilled workers more than quadrupled, increasing from 5% in 2010 to approximately 22% in 2019, an absolute increase of 17 percentage points. Similarly, the share of unskilled foreign workers as a proportion of all unskilled workers rose from 3.5% to about 16%, representing an absolute increase of 12.5 percentage points. While both the share of skilled and unskilled migrant groups experienced similar growth, the larger absolute increase in the share of skilled foreign workers underscores their greater role in reshaping the composition of the manufacturing workforce. Table 11 reports the percentage of firms hiring at least one immigrant worker in each year, disaggregated by total, skilled, and unskilled categories. As shown in the table, the share of firms hiring at least one skilled foreign worker increased from 16% in 2010 to 45% in 2019. Likewise, the share of firms hiring at least one unskilled foreign worker rose from 36% to 65% over the same period. Table 12 in Appendix B displays the increase in the share of foreign workers by their main nationality, Venezuela, Haiti, Peru, Bolivia, and Colombia. The table shows that the shares of foreign workers from Venezuela and Haiti have substantially increased over the analysis period. Finally, figures

[15] In nominal terms (not deflated), the average log capital per worker is approximately 16.

[16] Chile has allowed accelerated tax depreciation since 2003 to encourage investment. For example, machinery and vehicles can be fully depreciated over as little as 2–5 years. SMEs may access even faster schedules, and in certain years, 100% annual depreciation has been permitted. For details, see: `https://www.sii.cl/valores_y_fechas/tabla_vida_util_activo_inmovilizado.html`.

10 to 14 in Appendix A and tables 13 and 14 in Appendix B, show the distribution of the shares of foreign workers across municipalities, firms' size category and industries within manufacturing.

5 Results

5.1 Instrument Validity

Table 2 presents the first stage estimates corresponding to equation 15, which predicts the firms' shares of skilled and unskilled immigrants and the quadratic terms for each. In addition to the instruments for skilled and unskilled labor and their quadratic terms, all regressions include controls for the overall share of unskilled workers relative to total workers within the firm, firm age, a dummy variable indicating whether the firm operates multiple plants, and municipality, industry, and size-category fixed effects.

The joint F-statistics in all specifications are well above conventional thresholds for weak instrument concerns, providing strong support for the relevance of the instruments. The first stage coefficients indicate a strong and statistically significant relationship between the predicted and actual shares of immigrants.

Column one shows that a one percentage point increase in the predicted share of skilled immigrants is associated with a 0.43 pp increase in the firm's actual share of skilled immigrants. In contrast, Column two reports a 0.48 pp effect for unskilled immigrants. These coefficients confirm that the Bartik instruments strongly predict within-firm immigrant shares. The first stages for the squared terms, reported in columns three and four, show somewhat weaker but still meaningful predictive power. For the unskilled share, the predicted level and square statistically affect the actual square. However, while the predicted level is statistically significant in predicting the actual squared share for skilled immigrants, the squared predicted term is not significant. This suggests that most of the predictive power for the nonlinear skilled term comes through the level variable rather than its square. Overall, the results confirm the strong predictive power of the shift-share instruments for both linear and nonlinear immigrant share terms.

Figures 5 and 6 in Appendix A present the results from the pre-trend analysis, using data from 2007 to 2009. As one test of the assumptions underlying the validity of our instrument, we test whether firms' capital accumulation trends before the shock are systematically related to their predicted exposure to immigrants, as captured by the simulated exposure shares by nationality.

The logic of this test is that firms with different predicted exposure shares should not exhibit differential trends in capital accumulation prior to the migration shock. We implement it by estimating regressions using pre-2010 data, where the outcome is capital per worker at the firm level, and the key right-hand side variables are the interactions between source country-specific migrant shares and year fixed effects. We consider the shares for Venezuela, Peru, Haiti, Colombia, and Bolivia. The regressions also control for municipality, size, and industry fixed effects. Overall, we find no evidence of statistically significant differences in pre-trends. The differential exposure to foreign workers from these nationalities in 2010 does not significantly predict changes in capital intensity during the pre-period.

5.2 Main Results

Table 3 presents the main results for an increase in the share of skilled and unskilled immigrant workers within the firm on capital per worker. Column 1 reports the OLS estimates, while Columns 2 to 5 present results from the IV regressions. All regressions control for firm age and a dummy indicating whether the firm has multiple establishments. Columns 1 and 2 include year, municipality, industry, and size category fixed effects separately. Columns 3 to 5 introduce varying combinations of fixed effects interactions in the IV regressions to flexibly control for initial exposure shares in a non-parametric way. Given the inclusion of quadratic terms, we focus on interpreting the estimated relationships through marginal effects, which depend on the level of immigrant shares within the firm. Figure 3 displays the marginal effects of skilled and unskilled immigrant shares on capital per worker, along with 95% confidence intervals computed using the delta method. These effects are obtained from the coefficient estimates and standard errors reported in specification (2) of Table 3.

For skilled immigrants, the marginal effect is initially positive, reflecting capital-skill complementarity. However, the effect declines as the share of skilled immigrants increases and it becomes statistically insignificant beyond a 20% share and turns negative at higher levels (above 30%), even if these latter estimates are less precise. This nonlinear relationship aligns with the theoretical framework in Section 3.1.1, where imperfect substitutability between immigrant and native skilled workers implies diminishing marginal returns to an increase in the share of foreign workers.

We consider the distribution of skilled immigrant shares across firms to interpret these results

in context. As shown in Figures 10 to 12, most firms employ relatively low shares of skilled immigrants, with the distribution concentrated below 25% and a mode around 10%. Table 1 provides additional confirmation. Within this relevant range, the marginal effect of skilled immigrants on capital per worker is both positive and statistically significant. For instance, at a 10% immigrant share, a one percentage point increase is associated with an estimated 0.9% increase in capital per worker.

For unskilled immigrants, the estimated marginal effects on capital per worker are consistently negative across the observed range of shares. However, these effects are not statistically significant at conventional levels, suggesting that changes in unskilled immigrant shares are not associated with meaningful variation in firms' capital intensity.

While quadratic terms prevent direct interpretation of the raw coefficients, comparing the marginal effects derived from OLS and IV specifications remains informative. Three primary sources of bias may affect the OLS estimates: measurement error, omitted variable bias, and simultaneity. Measurement error in classifying worker skills can attenuate the estimated coefficients, biasing the effect of skilled immigrants downward and potentially inflating the unskilled effect. Omitted variable bias may arise if unobserved firm characteristics influence immigrant hiring and capital accumulation. Simultaneity bias may occur if capital-intensive firms are more likely to attract skilled immigrants, leading to reverse causality.

The IV-based marginal effects for skilled immigrants are larger in absolute value than their OLS counterparts, suggesting attenuation bias in the OLS estimates. In contrast, for unskilled immigrants, the IV estimates remain negative but are statistically insignificant.

5.3 Robustness Checks

We now discuss some potential threats to the validity of our IV estimates and present a series of robustness checks, including an alternative construction of the instrument and a set of sample restrictions. We summarize the results from a series of alternative specifications in Table 4.

First, we provide results using the "leave-out" instrument (column 2). In constructing this version of the instrument, we exclude the growth rate of the municipality where the firm is located from the national inflow of skilled and unskilled immigrants when predicting the stock of immigrants at the firm level. This addresses concerns about a possible mechanical relationship between firm-level migration inflows and the Bartik instrument, which could artificially inflate

the first-stage results.

Second, we present results for the balanced panel of firms (Column 3), which includes only those continuously observed from 2010 to 2019, approximately 75% of our sample. Firms in this subsample are, on average, larger at baseline and exhibit higher capital-per-worker ratios. By focusing on the balanced panel, we identify the effect of migration using only within-firm variation in capital intensity, thereby avoiding confounding effects from firm entry or exit, which may be systematically related to capital intensity. In this specification, the estimated effect of skilled immigration remains positive but is only marginally significant at the 10% level.

Lastly, we exclude certain firm categories in our analysis. Specifically, in column 4, we drop all firms located in Santiago, and in column 5, we exclude all firms with fewer than 10 employees. These are important robustness checks for two main reasons. First, for certain combinations of municipality, industry, and size characteristics, the instrument may be less powerful, as there are too many firms in the same group (defined by the interaction of municipality, industry, and size fixed effects, see Appendix D). This could result in less accurate predicted shares, as we assume that all firms within these groups have similar predicted values. The highest concentrations of firms are found in Santiago and among micro firms.

Additionally, we test robustness to a specification excluding Santiago because it not only has the highest firm concentration but also one of the highest concentrations of immigrants in the pre-period, which raises concerns that Santiago might disproportionately drive the results. Similarly, excluding micro firms is important because they are more likely to exhibit an immigrant share equal to one, often reflecting new businesses opened by immigrants during the study period, which could bias the estimated effects.

6 Elasticity of substitutions

To further explore the mechanisms driving our results, we estimate key elasticities of substitution between inputs in the production function. Specifically, we focus on two sets of elasticities: (i) the elasticities of substitution between immigrants and native workers within each skill group (skilled and unskilled), and (ii) the substitution between capital and labor inputs.

We begin by estimating the elasticities of substitution between immigrants and native workers within each skill group, skilled and unskilled. Understanding these substitutions patterns is es-

sential for explaining the nonlinear relationship between immigrant shares and capital deepening, as outlined in Section 3.1.1 and observed in the empirical results in Section 5.

Theoretically, the nonlinear effect of immigration on capital per worker derives from imperfect substitutability between immigrants and natives. Even within the same skill category, workers can differ in training, language, and institutional knowledge, and may face integration barriers. When foreign and native workers are not perfect substitutes, there exists an optimal mix in the workforce: small inflows of skilled immigrants can complement native workers and raise productivity, but as the immigrant share rises beyond this point, the marginal gains decline.

Empirically, this pattern is reinforced by the characteristics of firms with high immigrant shares. These are smaller firms, which are more likely to face financial and operational constraints that limit their ability to invest in capital and fully benefit from capital-labor complementarities. Furthermore, even when classified as skilled, immigrant workers may not be allocated to tasks that match their skill level, which decreases the productivity gains from higher immigrant shares.

We then estimate the elasticities of substitution between capital and labor, using the CES production structure introduced in Section 3.1.1. Specifically, we estimate the elasticity between capital and unskilled labor (λ), and the elasticity between skilled labor and the capital–unskilled labor bundle (ϵ). An elasticity of substitution between capital and skilled labor below one indicates capital-skill complementarity, which explains the positive and nonlinear response of capital per worker to skilled immigration found in the reduced-form results.

These elasticity estimates serve two key purposes. First, they provide a structural interpretation of the reduced-form results, allowing us to identify the mechanisms through which immigration affects capital accumulation. Second, they are used as inputs in the simulation exercises in Section 7, which decompose the contribution of capital-skill complementarity and substitution between immigrants and native workers to the observed impact on capital.

6.1 Immigrants and Native Workers

We start by estimating the degree of substitutability between immigrants and native workers within each skill group. As outlined in Section 3, skilled and unskilled labor are the combination of foreign and native workers aggregated according to a standard CES production function, which

is assumed to be uniform across firms:

$$U = \left(U_N^{\frac{\sigma_u - 1}{\sigma_u}} + U_F^{\frac{\sigma_u - 1}{\sigma_u}} \right)^{\frac{\sigma_u}{\sigma_u - 1}}, \tag{16}$$

$$S = \left(S_N^{\frac{\sigma_s - 1}{\sigma_s}} + S_F^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}}. \tag{17}$$

where σ_U and σ_S represent the elasticities of substitution between natives and foreign for unskilled and skilled workers, respectively. Using the expressions for the marginal product of labor for each worker category (skilled foreign, skilled native, unskilled foreign and unskilled native), we derive the following equations:

$$\log\left(\frac{w_{UF}}{w_{UN}}\right) = -\frac{1}{\sigma_u}\log\left(\frac{U_F}{U_N}\right), \tag{18}$$

$$\log\left(\frac{w_{SF}}{w_{SN}}\right) = -\frac{1}{\sigma_s}\log\left(\frac{S_F}{S_N}\right). \tag{19}$$

Here, $\log\left(\frac{w_{UF}}{w_{UN}}\right)$ and $\log\left(\frac{w_{SF}}{w_{SN}}\right)$ represent the log wage ratios of unskilled immigrants to unskilled natives and skilled immigrants to skilled natives, respectively. Similarly, $\log\left(\frac{U_F}{U_N}\right)$ and $\log\left(\frac{S_F}{S_N}\right)$ represent the log ratios of foreign-to-native employment for unskilled and skilled workers, respectively.

These expressions lead to the following regressions:

$$\log\left(\frac{w_{UF(i)}}{w_{UN(i)}}\right) = \gamma_1 \log\left(\frac{U_F(i)}{U_N(i)}\right) + \phi_i + \phi_t + +\epsilon_{i,t}, \tag{20}$$

$$\log\left(\frac{w_{SF(i)}}{w_{SN(i)}}\right) = \gamma_2 \log\left(\frac{S_F(i)}{S_N(i)}\right) + \phi_i + \phi_t + \epsilon_{i,t}, \tag{21}$$

where $\gamma_1 = -\frac{1}{\sigma_u}$ and $\gamma_2 = -\frac{1}{\sigma_s}$. We estimate these regressions at the firm level and include firm and year fixed effects to absorb unobserved, time-invariant heterogeneity across firms and common time shocks. We apply cell-size weights because only a subset of firms employs both immigrants and natives within each skill group, and weighting improves identification by giving more influence to firms with relevant variation in both groups. Following the approach developed in Caiumi and Peri (2024), we estimate equations (20) and (21) using the same instrumental variables approach as for capital deepening. Specifically, we use the predicted number of skilled and unskilled foreign workers, as described in section 3, as instruments for the actual number

of skilled and unskilled immigrants. For the number of skilled and unskilled native workers, we apply a similar shift-share transformation to construct predicted values, using the proportion of skilled and unskilled native workers in 2010 (the first year) and multiplying this by the national growth rate of skilled and unskilled native workers in each subsequent year:

$$\widehat{S}_{N,it} = \frac{\widehat{S_{i10}}}{S_{10}} \times \Delta S_{N,t},$$

$$\widehat{U}_{N,it} = \frac{\widehat{U_{i10}}}{U_{10}} \times \Delta U_{N,t}.$$

In Table 5, we present the results of our estimation. We show the negative inverse of each coefficient, which corresponds to the elasticity of substitution, and we use the delta method to calculate the standard errors. In Appendix B table 16, we show the coefficient obtained from 20 and 21. The elasticity of substitution between skilled foreign and native workers is 6, indicating that the degree of substitutability between immigrants and native workers is relatively low. The elasticity of substitution between immigrants and native unskilled workers is around 8. These findings suggest that immigrants and native workers within the same skill group are imperfect substitutes, with a degree of complementarity between foreign and native workers within each skill group. Notably, the degree of substitutability is lower among more skilled workers. These results align with recent estimates for the U.S., particularly those from Caiumi and Peri (2024), who find that the elasticities of substitution between foreign and native workers range from approximately 12 to 20, and are lower for more educated workers.

6.2 Capital-Labor Elasticities of Substitution

We now estimate the elasticities of substitution between capital and unskilled labor (λ), and between skilled labor and the capital–unskilled labor bundle (ϵ). For this section, we follow the approach of Raval (2019), deriving log-linear estimating equations from firms' optimality conditions. Similarly to the previous sections we rely on a shift-share approach.

First, by taking the optimality conditions for capital and unskilled workers and combining them, we derive the following expression to recover the elasticity of substitution, λ:

$$\log\left(\frac{rK}{w_u U}\right) = (1-\lambda)\log\left(\frac{r}{w_u}\right), \tag{22}$$

where r is the rental rate of capital and w_u the wage of total unskilled workers. $w_u U$ is the total wage bill for unskilled workers, and rK is the cost of capital.

Once we estimate λ , we can estimate the elasticity between skilled labor and capital/unskilled labor ϵ. In order to simplify the estimation, we define the bundle of unskilled labor and capital (X) as:

$$X = \left(K^{\frac{\lambda-1}{\lambda}} + \tilde{U}^{\frac{\lambda-1}{\lambda}} \right)^{\frac{\lambda}{\hat{\lambda-1}}}$$

and we recover P_x as the rental price of the bundle of capital and unskilled labor.

$$p_X = \left(r^{1-\lambda} + w_u^{1-\lambda} \right)^{\frac{1}{1-\lambda}}$$

Given X and p_x, estimation of the elasticity between goes to:

$$\log\left(\frac{p_X X}{w_s S}\right) = (1-\epsilon)\log\left(\frac{p_X}{w_s}\right). \tag{23}$$

where w_s is the wage of skilled workers and $w_s S$ is the total wage bill of skilled labor. Details on the derivation of w_u, w_s and P_X can be find in Appendix C.

Following equations 22 and 23 and Raval (2019), we estimate the following regressions:

$$\log\left(\frac{rK}{w_u U}\right) = \delta_1 \log\left(w_u\right) + \phi_t + \phi_j + \epsilon_{i,c,t,j}, \tag{24}$$

$$\log\left(\frac{p_X X}{w_s S}\right) = \delta_2 \log\left(\frac{p_X}{w_s}\right) + \phi_t + \phi_j + \epsilon_{i,p,t,j}, \tag{25}$$

where $\delta_1 = \lambda - 1$ and $\delta_2 = 1 - \epsilon$. We include year (ϕ_t) and industry (ϕ_j) fixed effects. Following Raval (2019), we treat the capital rental rate r as industry-specific and absorbed by fixed effects. Prices are measured at the industry level, while factor quantities and wage bills vary at the firm level, allowing us to estimate substitution patterns using within-industry cross-firm variation.

To address potential endogeneity in input prices, particularly if wage levels or input cost ratios are correlated with unobserved productivity shocks, we use Bartik-style shift-share instruments for skilled and unskilled labor costs. These instruments are constructed by interacting initial labor shares with national-level changes in immigrant inflows by skill group, providing exogenous variation in labor supply-driven wage shifts.

Table 5 presents the estimated elasticities. The elasticity of substitution between unskilled labor and capital is estimated at $\hat{\lambda} = 1.4$, while the elasticity between skilled labor and the capital–unskilled bundle is $\hat{\epsilon} = 0.53$. These estimates confirm the presence of capital–skill complementarity, with $\lambda > \epsilon$, indicating that skilled labor is more complementary to capital than unskilled labor.

7 Simulations

In this section, we simulate the effect of two immigration shocks, a 1 percent increase in the share of skilled foreign workers and a 1 percent increase in the share of unskilled foreign workers, on capital accumulation, under different values of the elasticity parameters. We examine how the response of capital per worker varies depending on the degree of substitutability between capital and labor, as well as between native and foreign workers within skill groups.

We begin by presenting the counterfactual effect of a 1 percent increase in the share of skilled foreign workers. To compute the capital response, we decompose the total effect into two components, as outlined in the theoretical framework in Section 3. The first component, $\left(\frac{F_{k\tilde{s}}}{F_{kk}}\frac{\tilde{s}}{k}\right)$, captures the direct effect of skilled labor on capital deepening through the production function. This expression follows the derivation in Lafortune et al. (2019).[17] The second component, $\left(\frac{\partial \tilde{s}}{\partial s_F}\frac{s_F}{\tilde{s}}\right)$, reflects how imperfect substitutability between native and foreign skilled workers amplifies or reduces the overall effect. This term captures the adjustment in the effective labor input driven by changes in the composition of the skilled workforce.

In all scenarios, we assume that the share of skilled immigrant workers as a proportion of all skilled workers at the firm level, denoted by s_F, is 10%, which corresponds to the average observed in the data.

In our first scenario, we assume that capital is "skill neutral," implying that the elasticity of substitution between capital and unskilled labor (λ) is equal to that between capital and skilled labor (ϵ). Specifically, we adopt a Cobb-Douglas production function and set both λ and ϵ equal to 1. The elasticities of substitution between immigrants and natives within skill groups, σ_s and σ_u, are set to the values estimated in Section 6. In the second scenario, we use the elasticity values estimated from the data for all parameters (λ, ϵ, σ_s, and σ_u). In the third scenario, we

[17] See Lafortune et al. (2019) for the derivation. In our setting, the unskilled wage bill share is assumed to be 0.5, and the skilled wage bill share is 0.2.

increase the gap between λ and ϵ while keeping σ_s and σ_u fixed at their estimated values. This isolates the role of capital-skill complementarity by increasing the substitutability of unskilled labor with capital relative to that of skilled labor with capital. Finally, in the fourth scenario, we use the estimated values for λ and ϵ but assume that immigrants and native workers within each skill group are perfect substitutes, setting $\sigma_s = \infty$ and $\sigma_u = \infty$. This exercise removes the effects of imperfect substitutability to illustrate its role in shaping the capital response.

These scenarios highlight the importance of both capital-skill complementarity and immigrant-native substitutability in determining changes in capital per worker. Specifically, when capital-skill complementarity is stronger, i.e., when λ is much larger than ϵ, the capital-skill effect on capital accumulation is substantially amplified.

Similarly, the effect also intensifies when immigrants and native workers within the same skill category are closer substitutes. This mechanism is a key driver of the non-linearity observed in our results. In the extreme case where immigrants and natives are perfect substitutes, the term $\left(\frac{\partial \tilde{s}}{\partial s_F}\frac{s_F}{\tilde{s}}\right)$ becomes equal to 1, effectively removing the non-linearity introduced by imperfect substitutability.

Next, in Table 7, we present the simulated effect of a 1% increase in the share of unskilled foreign workers, applying the same four scenarios and assuming that unskilled immigrants represent 10% of the firm's unskilled labor force ($u_F = 0.10$). When capital-skill complementarity is strong (i.e., when $\lambda > \epsilon$), the presence of additional unskilled labor reduces capital per worker.

Interestingly, under the estimated parameter values, the simulation predicts a small positive effect of unskilled immigration on capital deepening. This contrasts with the reduced-form estimates from Section 5, where we found a negative but statistically insignificant effect. However, the two approaches are not directly comparable. In the reduced-form analysis, we estimate the effect of a 1 percentage point increase in the share of unskilled immigrants, while simultaneously controlling for the share of skilled immigrants. In contrast, the simulations isolate the effect of a 1 percent increase in the unskilled immigrant share. The discrepancy therefore arises from differences in the magnitude of the shock, the functional form, or from interaction effects between skilled and unskilled labor that are accounted for in the reduced-form regression but not explicitly modeled in the simulation.

8 Discussion

This paper empirically investigates the impact of an immigration shock on firm-level capital deepening in Chile. Chile offers an ideal setting for this analysis, since it has recently emerged as a major destination for migrants in Latin America, with inflows characterized by diverse educational backgrounds. This heterogeneity enables us to study how immigrants' skills interact with firms' capital accumulation decisions. We model the firm's production process using a nested CES framework that incorporates differences in worker skill levels (skilled vs. unskilled), capital–skill complementarity (capital is more substitutable with unskilled than with skilled labor), and imperfect substitutability between immigrant and native workers.

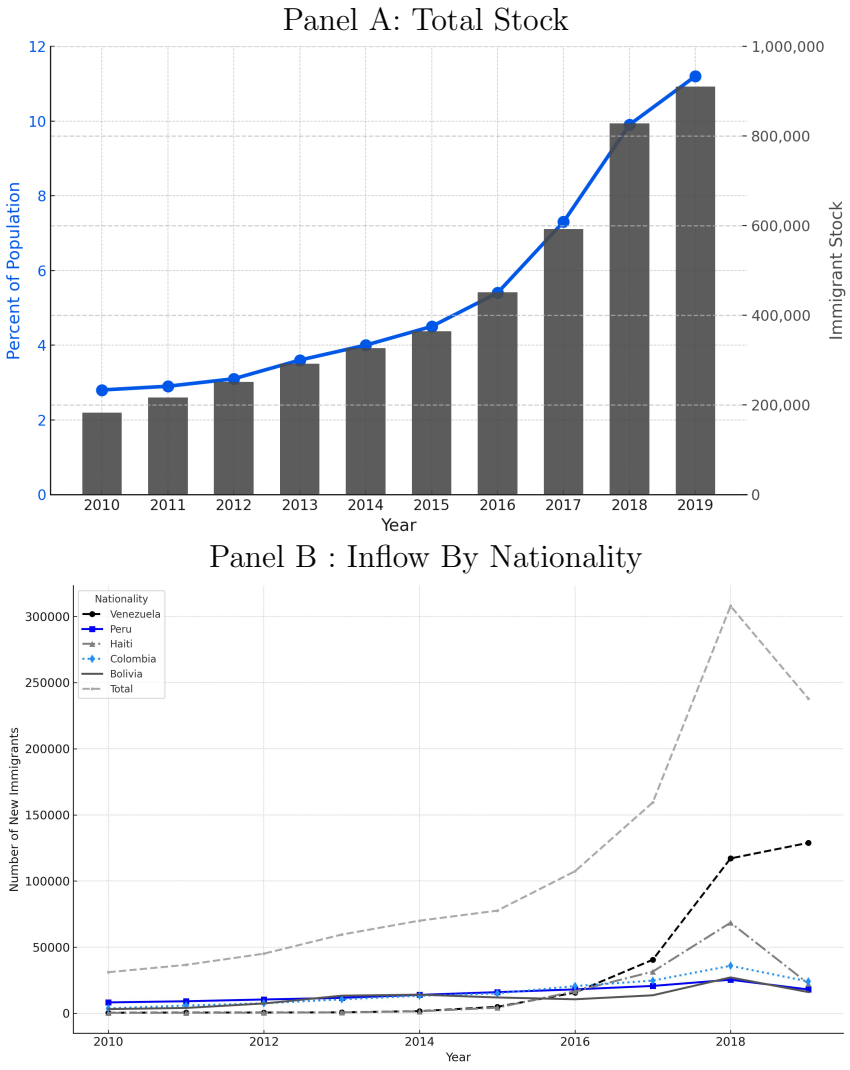
In the first part of the analysis, we adopt a reduced-form approach to estimate how capital accumulation responds to variation in the share of skilled and unskilled immigrants within the firm. We find that an increased share of skilled immigrants is associated with higher capital deepening, which aligns with the capital–skill complementarity hypothesis. However, this relationship is non-linear: the effect turns negative and statistically insignificant when the share of skilled immigrants exceeds 30 percent of the firm's total skilled labor. Our analysis suggests that this non-linearity arises from imperfect substitutability between immigrants and natives within the same skill group.

Next, we estimate the elasticities of substitution between capital and labor (both skilled and unskilled) following the approach proposed by Raval (2019). The results confirm the presence of capital–skill complementarity, with the elasticity of substitution between capital and skilled labor significantly lower than that between capital and unskilled labor.

We then use the estimated parameters to simulate the effect of an immigration shock on capital deepening under different values of the elasticities. The simulations show that capital accumulation is more responsive when capital–skill complementarity is stronger and when immigrant and native workers within skill groups are more substitutable. Our results underscore the importance of labor market integration. Policies that strengthen the alignment between immigrants' skills and the roles in which they are employed and, therefore, enhance the effective substitutability between immigrants and natives within skill groups can support capital accumulation.

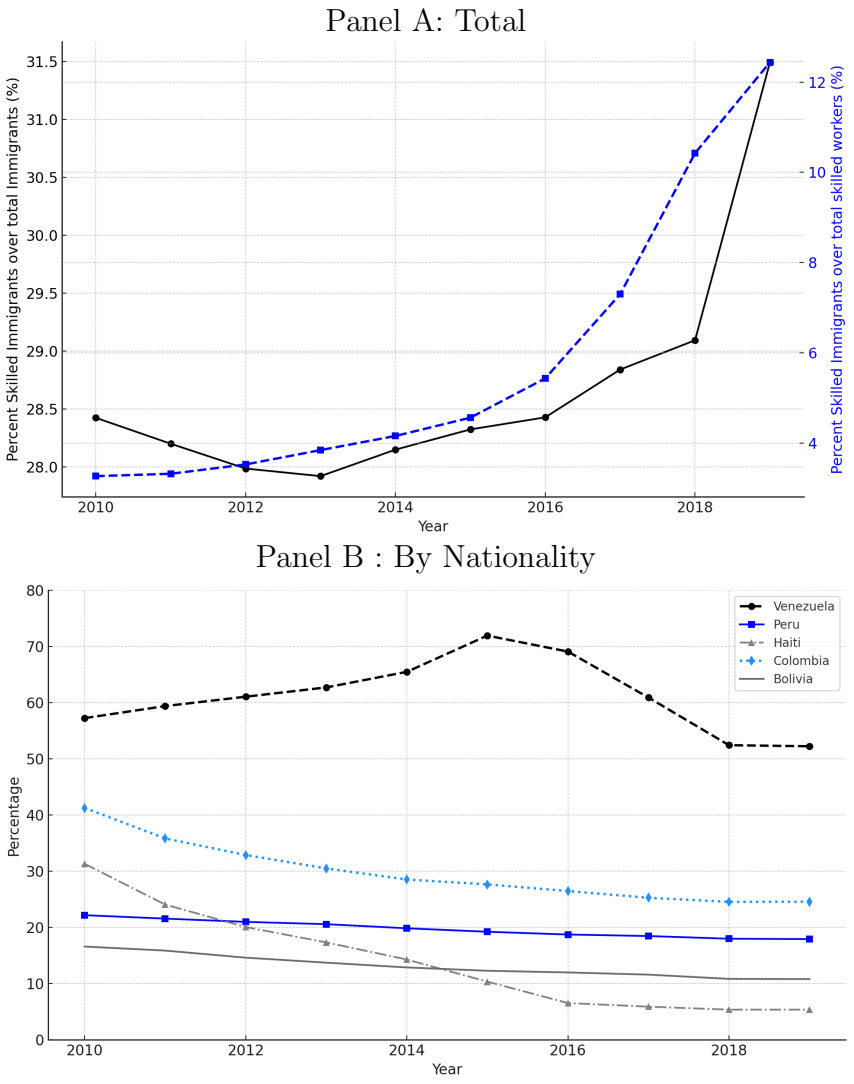
9 Figures and Tables

Figure 1: Immigration in Chile



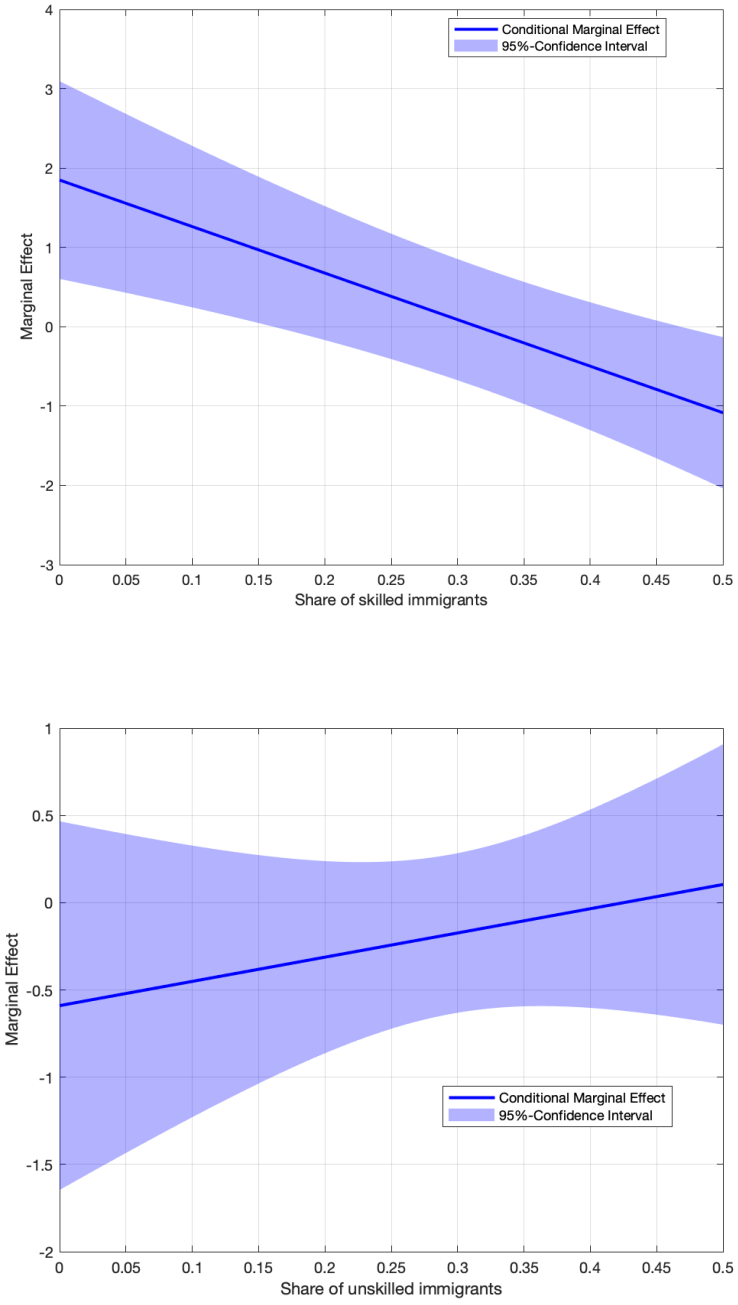
Notes: Author's calculations based on data from the Migration Department. Panel A shows the increase in the total stock of foreign workers from 2010 to 2019, as well as the percentage of foreign workers relative to the total workforce. Panel B shows the composition of the increase in the total inflow of migrants.

Figure 2: Immigrants Skills



Notes: Panel A reports the increase in the share of skilled immigrants relative to total immigrant workers, as well as the rise in the share of skilled immigrant workers as a percentage of total skilled workers. Panel B displays, for each nationality, the share of skilled immigrants relative to the total number of immigrants from that nationality.

Figure 3: Marginal Effects



Notes: The top figure plots marginal effects of change in share of skilled immigrants on capital accumulation along with 95-% confidence interval; while the bottom figure exhibits marginal effects of change in share of unskilled immigrants on capital accumulation along with 95-% confidence interval. We compute the confidence interval using the Delta-method.

Table 1: Manufacturing Sector Workers Characteristics (%)

Year	Capital	Share Sk.	Share Unsk.	Share Fore.	Share Sk. Fore.	Share Unsk. Fore.
2010	5.83	15.3%	84.7%	3.7%	5.1%	3.5%
2011	5.78	15.8%	84.2%	4.1%	5.3%	3.9%
2012	5.78	16.2%	83.8%	4.5%	5.6%	4.3%
2013	5.82	16.6%	83.4%	4.9%	6.0%	4.8%
2014	5.86	17.3%	82.7%	5.7%	6.8%	5.6%
2015	5.91	18.2%	81.8%	6.4%	7.1%	6.3%
2016	5.93	18.9%	81.1%	8.0%	8.5%	7.9%
2017	6.03	19.5%	80.5%	11.4%	12.8%	11.2%
2018	6.06	20.5%	79.5%	15.3%	19.0%	14.5%
2019	6.16	21.1%	78.9%	16.9%	22.5%	15.7%
Total	5.9	18%	82%	8%	10%	8%

Notes: The table presents summary statistics at the firm level for the dependent and independent variables used in the analysis, covering the period 2010 to 2019. Capital per Worker is calculated as the total capital divided by the total number of workers at the firm level, expressed in logarithmic form. Share Foreign is the share of total foreign workers in the firm over total workers within the firm. Share of Skilled Foreign is defined as the ratio of skilled foreign workers to the total skilled workers within the firm. Share of Unskilled Foreign is defined as the ratio of unskilled foreign workers to the total unskilled workers within the firm. Share of Skilled and Unskilled workers represent the ratio of the total number of skilled and unskilled workers to the total number of workers within the firm.

Table 2: First Stage

	(1) Share Skilled Foreign	(2) Share Unskilled Foreign	(3) (Share Skilled Foreign)^2	(4) (Share Unskilled Foreign)^2
$\hat{z}_{it}^S$	0.432***	-0.00651	0.174***	-0.0238***
	(0.0130)	(0.00731)	(0.0115)	(0.00554)
$\hat{z}_{it}^U$	0.0697***	0.475***	0.0304**	0.111***
	(0.0152)	(0.0113)	(0.0141)	(0.00966)
$(\hat{z}_{it}^S)^2$	-0.261***	0.0322***	-0.0202	0.0481***
	(0.0135)	(0.00755)	(0.0223)	(0.00586)
$(\hat{z}_{it}^U)^2$	0.0780***	-0.207***	0.108***	0.127***
	(0.0181)	(0.0159)	(0.0173)	(0.0152)
Controls	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Municipality FE	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓
Size FE	✓	✓	✓	✓
Observations	101137	101137	101137	101137
F-stats	1166.9	1422.2	786.2	648.7

Notes: Standard errors clustered at the municipality–industry–size category level are reported in parentheses, * p < 0.10, ** p< 0.05, *** p< 0.010. Share of Skilled Foreign is the total number of skilled foreign workers over total skilled workers within the firm. Share of Unskilled Foreign is the total number of unskilled foreign workers over total unskilled workers within the firm. $\hat{z}_{it}^S$ is the predicted share of foreign skilled workers in the firm over total skilled workers. $\hat{z}_{it}^U$ is the predicted share of foreign unskilled workers in the firm over total unskilled workers. Controls include the overall share of unskilled workers in the firm over total workers, the age of the firm and a dummy variable indicating whether the firm has multiple plants.

Table 3: Capital per Worker

	(1)	(2)	(3)	(4)	(5)
	Capital per Worker				
	OLS		IV		
Share Skilled Foreign	0.135**	1.849***	1.590**	1.884***	1.671**
	(0.0635)	(0.636)	(0.692)	(0.632)	(0.650)
Share Unskilled Foreign	-0.425***	-0.590	-0.819	-0.620	-0.498
	(0.0776)	(0.539)	(0.558)	(0.534)	(0.540)
(Share Skilled Foreign)^2	-0.342***	-2.933***	-3.119***	-3.079***	-2.831***
	(0.0717)	(0.795)	(0.876)	(0.794)	(0.813)
(Share Unskilled Foreign)^2	-0.0373	0.694	1.195	0.867	0.632
	(0.111)	(0.823)	(0.849)	(0.823)	(0.834)
Share Unskilled	-0.683***	-1.277***	-0.888**	-1.202**	-1.245***
	(0.212)	(0.477)	(0.438)	(0.467)	(0.473)
(Share Unskilled)^2	-0.976***	-0.473	-0.644*	-0.470	-0.470
	(0.151)	(0.347)	(0.332)	(0.343)	(0.347)
Controls	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
Municipality FE	✓	✓			
Industry FE	✓	✓			
Size FE		✓			
Mun. FE × Ind. FE			✓		
Ind. FE × Size FE				✓	
Mun. FE × Size FE					✓
Observations	101137	101137	101137	101137	101137

Notes: Standard errors clustered at the municipality–industry–size category level are reported in parentheses, * p < 0.10, ** p< 0.05, *** p< 0.010. Capital per worker is total capital over total workers at firm level, and it is measured in Log. Share of Skilled Foreign is the total number of skilled foreign workers over total skilled workers within the firm. Share of Unskilled Foreign is the total number of unskilled foreign workers over total unskilled workers within the firm. Share Unskilled is the total number of unskilled workers over total workers within the firm. Controls include the age of the firm and a dummy variable indicating whether the firm has multiple plants.

Table 4: Robustness Checks

	(1) Main Results	(2) Leave-One-Out	(3) Balanced Panel	(4) Excl. Santiago	(5) Excl. Micro
Share Skilled Immigrants	1.849***	1.848***	1.245*	2.10**	2.088**
	(0.636)	(0.636)	(0.636)	(0.720)	(0.685)
Share Unskilled Immigrants	-0.590	-0.590	-0.431	-0.547	-0.618
	(0.539)	(0.539)	(0.602)	(0.619)	(0.716)
(Share Skilled Immigrants)^2	-2.933***	-2.932***	-2.454***	-3.231***	-3.494***
	(0.795)	(0.795)	(0.922)	(0.903)	(0.905)
(Share Unskilled Immigrants)^2	0.694	0.694	0.327	1.020	0.545
	(0.823)	(0.824)	(1.142)	(0.976)	(1.237)
Share Unskilled	-1.277***	-1.276***	-2.560***	-1.404***	-2.338***
	(0.477)	(0.476)	(0.698)	(0.518)	(0.630)
(Share Unskilled)^2	-0.473***	-0.473***	0.297	-0.404	0.0488
	(0.347)	(0.347)	(0.488)	(0.373)	(0.439)
Controls	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
Municipality FE	✓	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓	✓
Size FE	✓	✓	✓	✓	✓
Observations	101137	101137	76527	99893	69056

Notes: Standard errors clustered at the municipality–industry–size category level are reported in parentheses, * p < 0.10, ** p< 0.05, *** p< 0.010. Capital per worker is total capital over total workers at firm level, and it is measured in Log. Share of Skilled Foreign is the total number of skilled foreign workers over total skilled workers within the firm. Share of Unskilled Foreign is the total number of unskilled foreign workers over total unskilled workers within the firm. Share Unskilled is the total number of unskilled workers over total workers within the firm. Controls include the age of the firm and a dummy variable indicating whether the firm has multiple plants.

Table 5: Elasticities of Substitution

Parameter	**Estimate**	**Standard Error**
Elasticity of Substitution (Unskilled) σ_u	8.47	(0.969)
Elasticity of Substitution (Skilled) σ_s	6.09	(2.473)
Elasticity of Substitution (Capital vs. Unskilled) λ	1.391	(0.0316)
Elasticity of Substitution (Capital vs. Skilled) ϵ	0.527	(0.0496)

Notes: This table presents the estimated elasticities of substitution, which describe the degree of substitutability between different factors of production in the labor market. Labor Substitution: σ_u represents the elasticity of substitution between unskilled foreign and native workers. σ_s represents the elasticity of substitution between skilled foreign and native workers. These estimates correspond to the inverse of $-\gamma_1$ and $-\gamma_2$ from Equations 21 and 21. Capital-Labor Substitution: λ represents the elasticity of substitution between unskilled labor and capital. ϵ represents the elasticity of substitution between skilled labor and capital. These estimates are obtained from Equations 24 and 25. Standard errors are computed using the Delta-method and are reported in parentheses.

Table 6: Simulated Impact of a 1% Increase in Skilled Immigrants

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Model Parameters				
λ (Capital-Unskilled Elasticity)	1	1.391	5	1.391
ϵ (Capital-Skilled Elasticity)	1	0.527	0.5	0.527
σ_s (Skilled Substitutability)	6.09	6.09	6.09	∞
σ_u (Unskilled Substitutability)	8.47	8.47	8.47	∞
s_F (Initial Share of Skilled Immigrants)		0.10		
Simulation Results				
Capital-Skill Complementarity Effect	0.28	0.64	1.45	0.64
Immigrant-Native Substitution Effect	0.75	0.75	0.75	1.00
Total Effect on Capital	0.21	0.48	1.08	0.64

Notes: This table reports the simulated change in capital resulting from a 1% increase in the share of skilled foreign workers, under four different parameter scenarios. The total effect reflects the interaction between capital-skill complementarity and immigrant-native substitution.

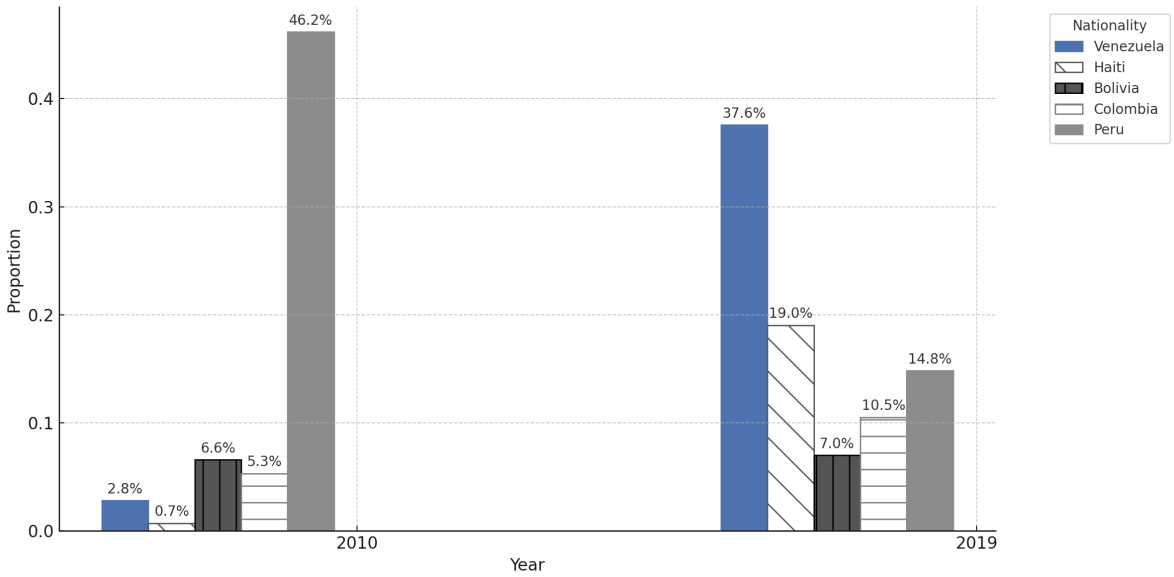
Table 7: Simulated Impact of a 1% Increase in Unskilled Immigrants

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Model Parameters				
λ (Capital-Unskilled Elasticity)	1	1.391	5	1.391
ϵ (Capital-Skilled Elasticity)	1	0.527	0.5	0.527
σ_s (Skilled Substitutability)	6.09	6.09	6.09	∞
σ_u (Unskilled Substitutability)	8.47	8.47	8.47	∞
u_F (Initial Share of Unskilled Immigrants)		0.10		
Simulation Results				
Capital-Skill Complementarity Effect	0.71	0.36	-0.45	0.36
Immigrant-Native Substitution Effect	0.82	0.82	0.82	1.00
Total Effect on Capital	0.58	0.30	-0.37	0.36

Notes: This table reports the simulated change in capital resulting from a 1% increase in the share of unskilled foreign workers, under four different parameter scenarios. The total effect reflects the combination of capital-skill complementarity and immigrant-native substitution.

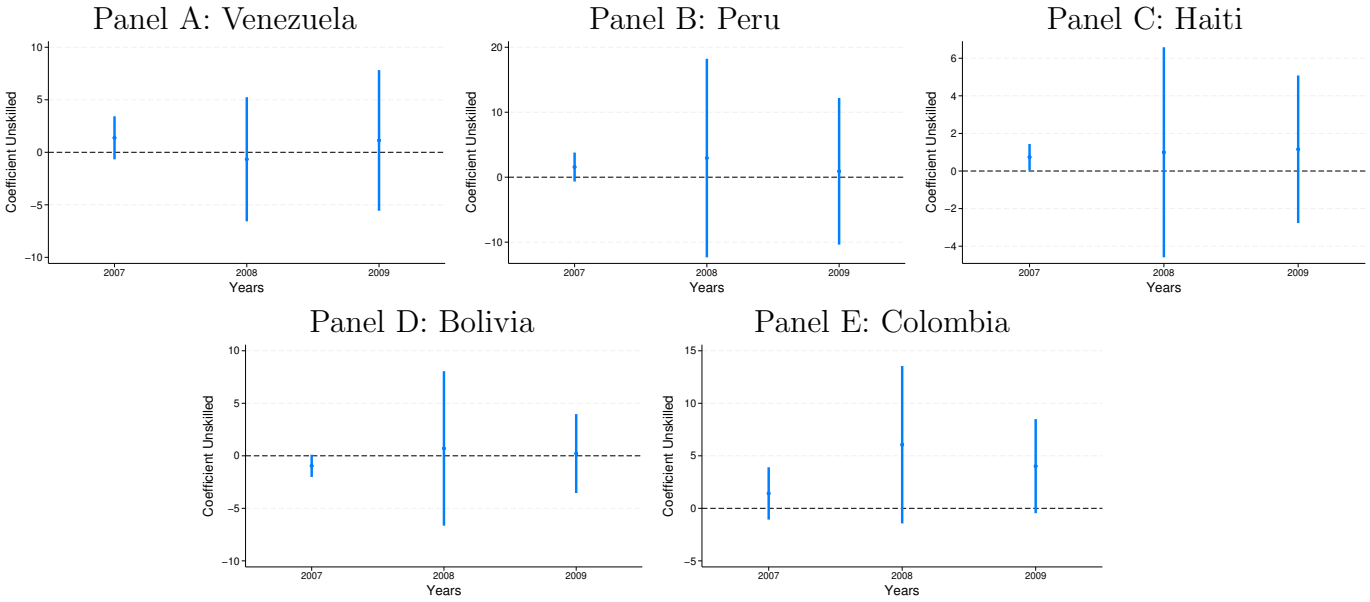
A Figures

Figure 4: Composition of Immigrants Stock By Nationality



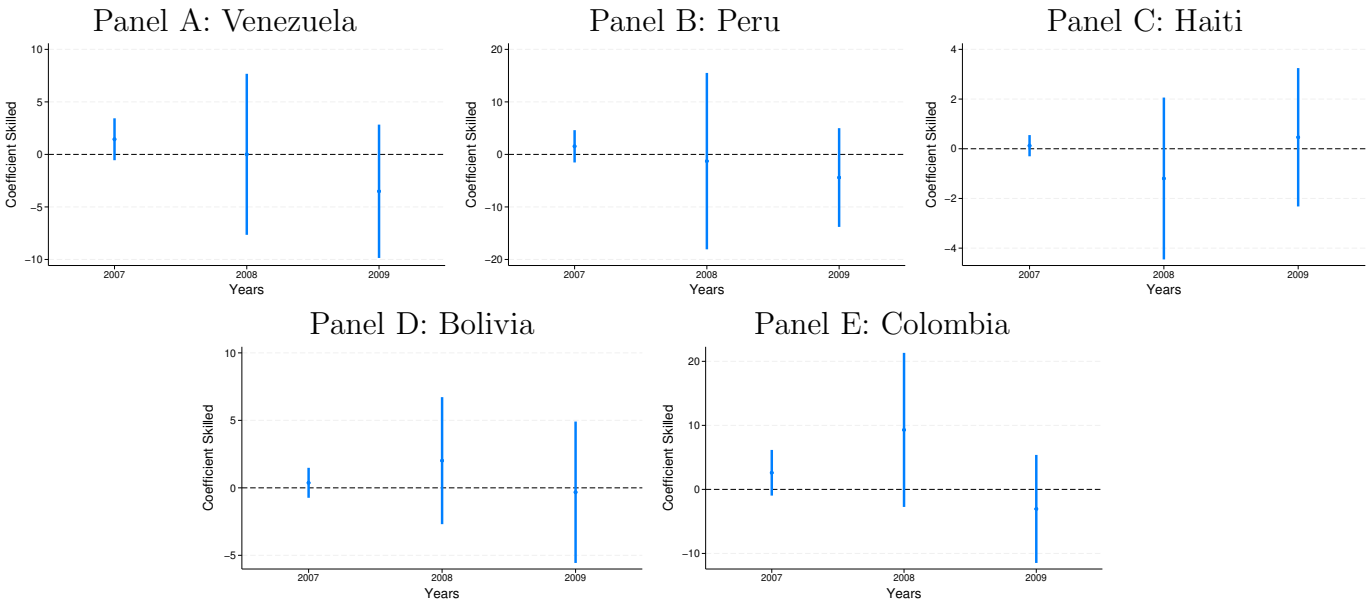
Notes: Author's calculations based on Migration Department Data. The figure displays the composition of immigrants by main country of origin in 2010 and 2019.

Figure 5: Pre-Trends: Unskilled



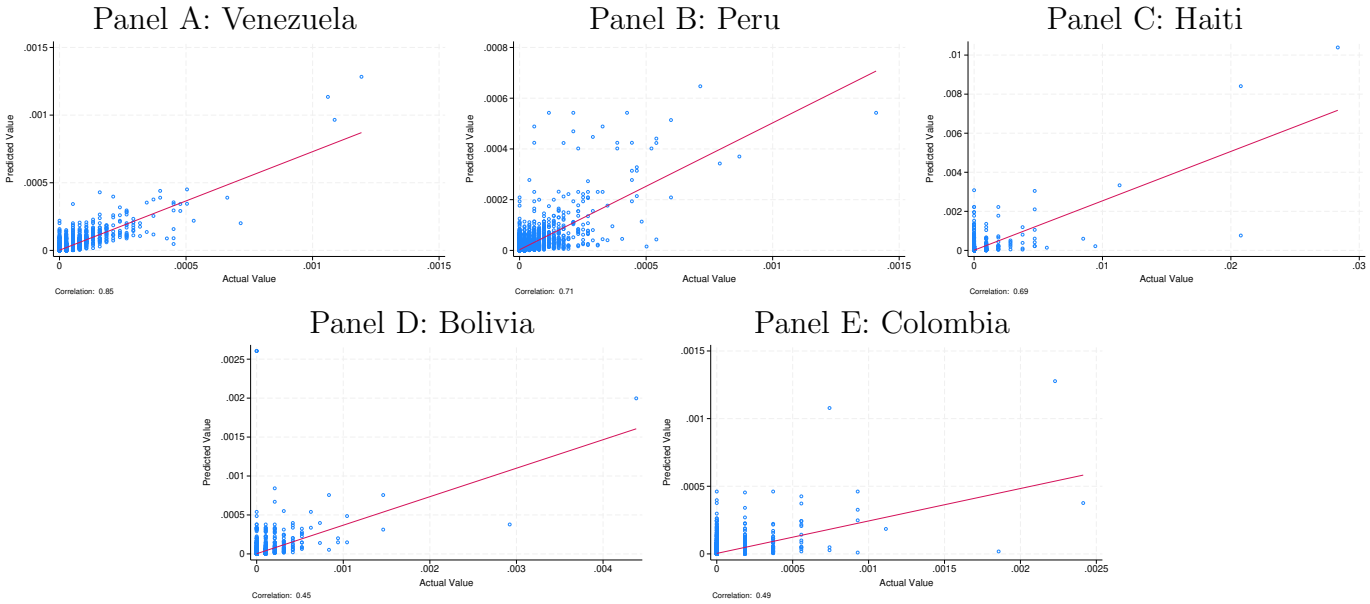
Notes: The figures display the results of the pre-trend test for the main immigrant shares by country of origin. Each point represents the coefficient from a regression of changes in capital on the 2010 share of immigrants from a given nationality, interacted with year fixed effects. Vertical lines indicate 95% confidence intervals.

Figure 6: Pre-Trends: Skilled



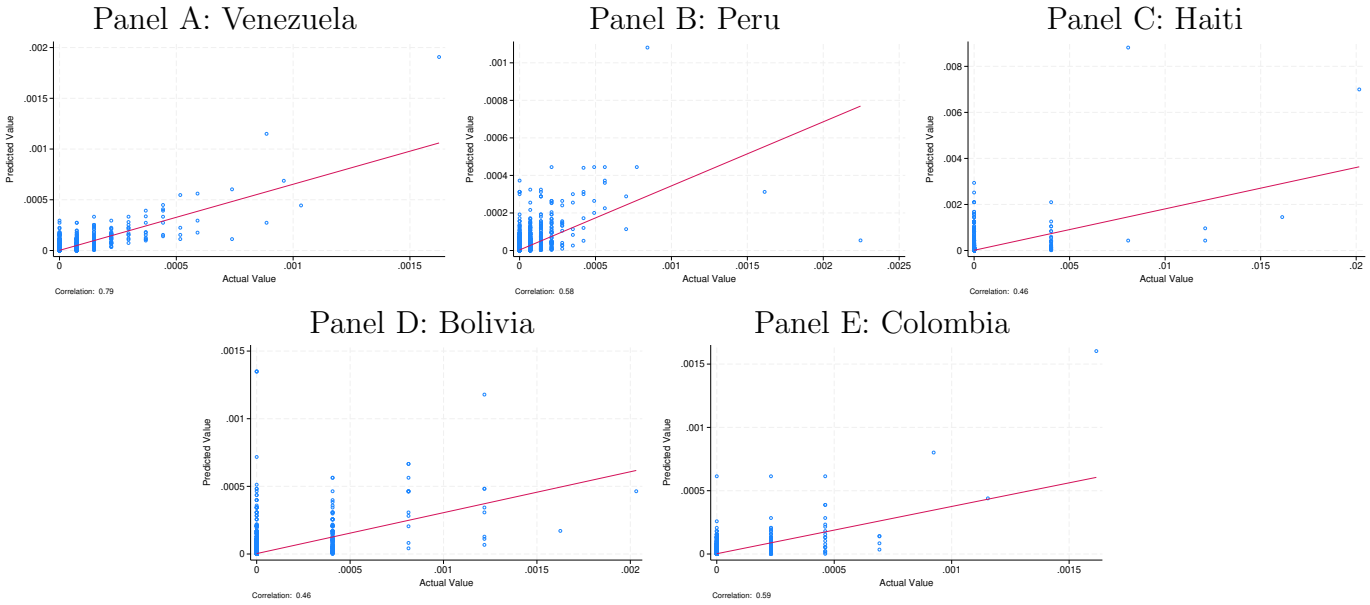
Notes: The figures display the results of the pre-trend test for the main immigrant shares by country of origin. Each point represents the coefficient from a regression of changes in capital on the 2010 share of immigrants from a given nationality, interacted with year fixed effects. Vertical lines indicate 95% confidence intervals.

Figure 7: Correlations: Unskilled



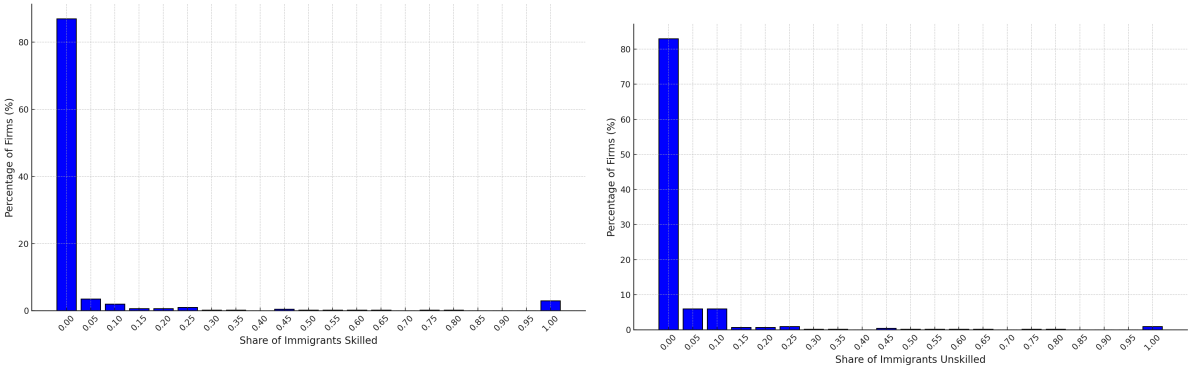
Notes: The figures display the correlation between the actual and predicted number of foreign unskilled workers at the firm level in 2010, based on estimates from the Poisson pseudo-maximum likelihood estimator (PPMLE).

Figure 8: Correlations: Skilled



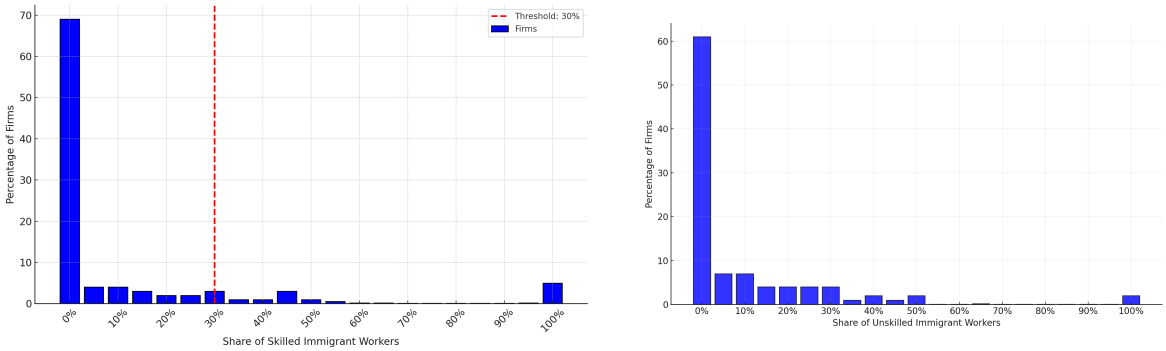
Notes: The figures display the correlation between the actual and predicted number of foreign skilled workers at the firm level in 2010, based on estimates from the Poisson pseudo-maximum likelihood estimator (PPMLE).

Figure 9: Distribution of Firms by Share of Immigrant Workers 2010



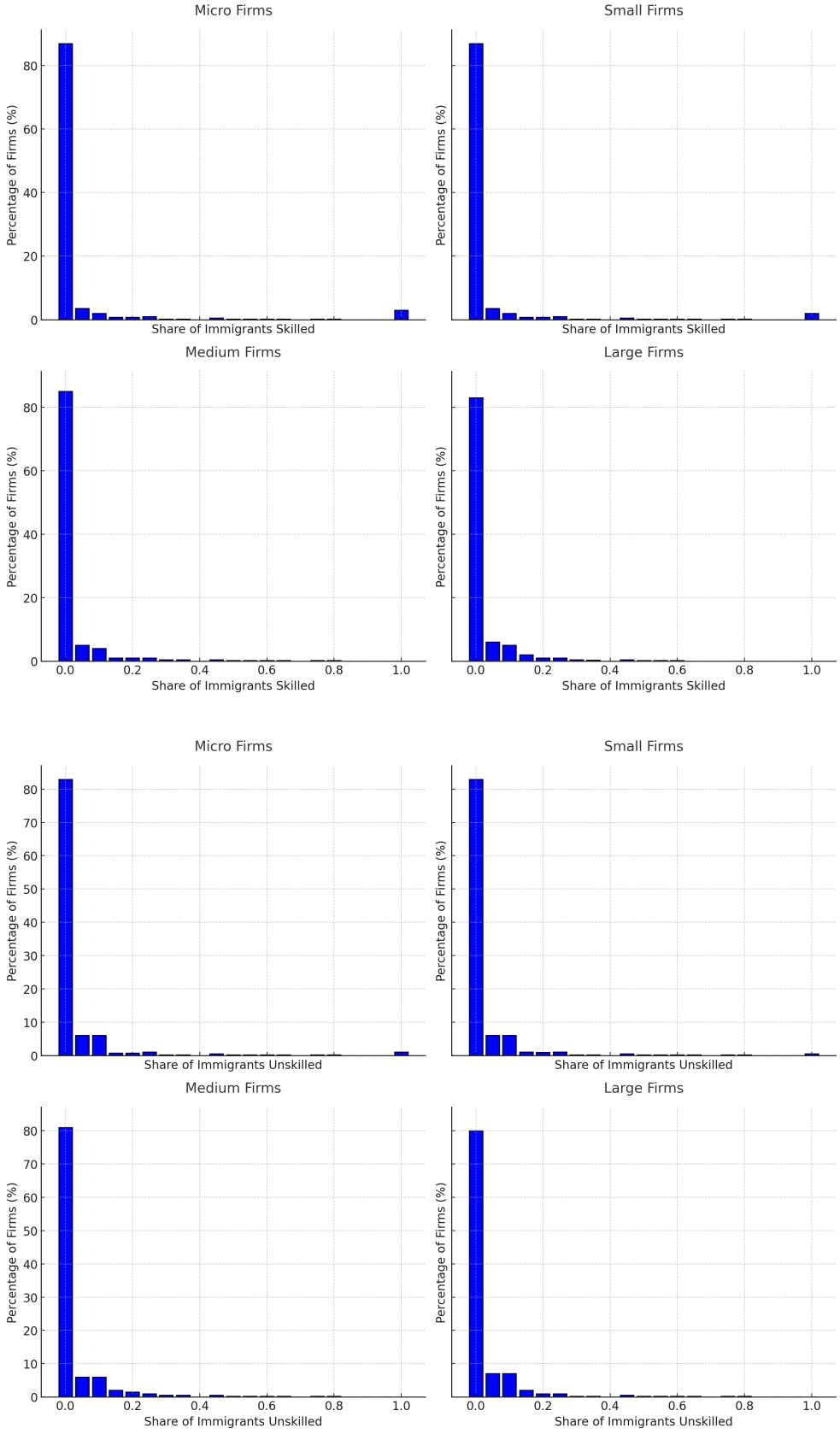
Notes: The left figure shows the percentage of firms categorized by the share of skilled immigrants among total skilled workers within the firm in 2010; while the right figure shows the percentage of firms categorized by the share of unskilled immigrants among total unskilled workers within the firm in 2010.

Figure 10: Distribution of Firms by Share of Immigrant Workers 2016-2019



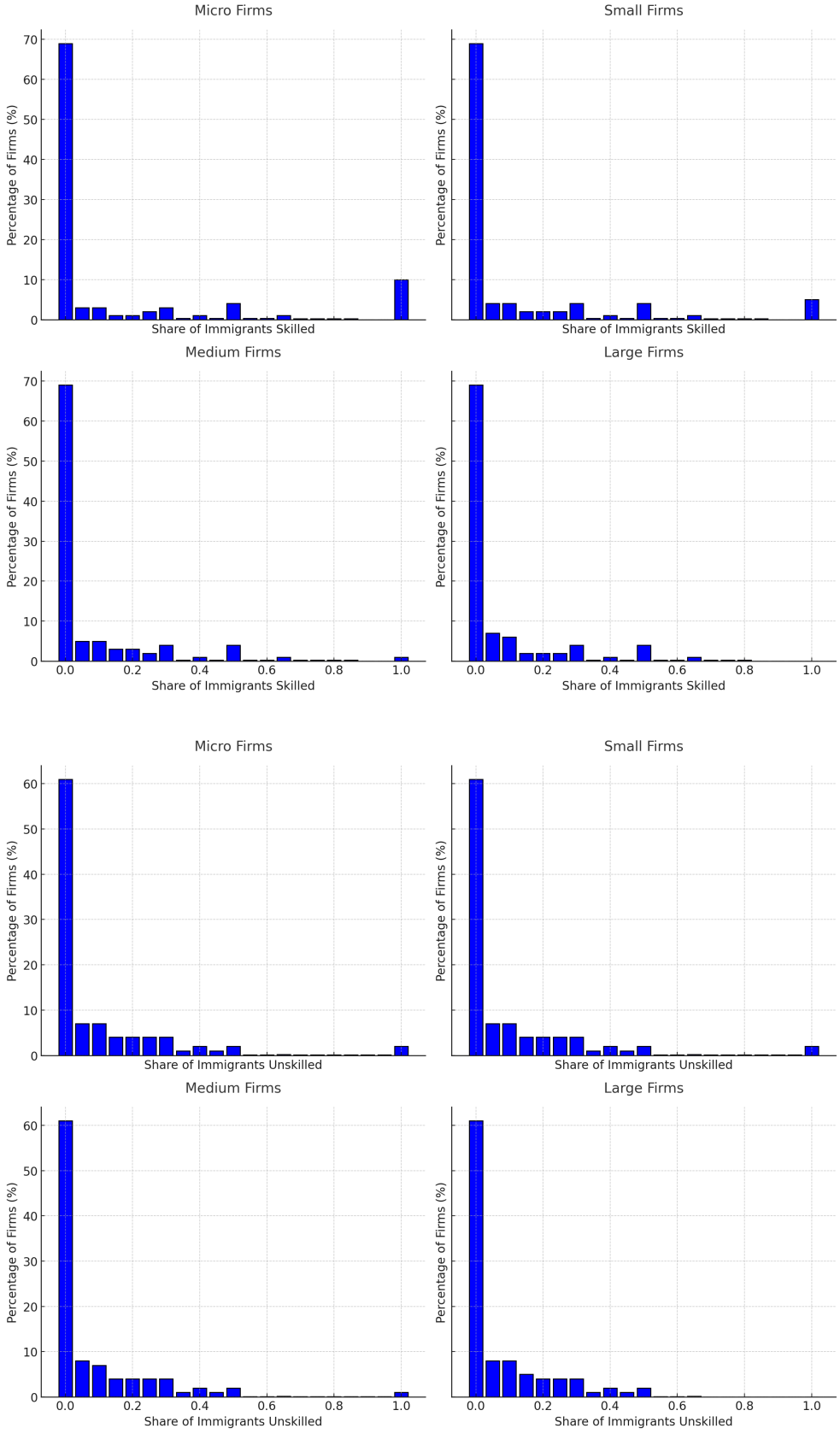
Notes: The left figure shows the percentage of firms categorized by the share of skilled immigrants among total skilled workers within the firm during the period from 2016 to 2019.; while the right figure shows the percentage of firms categorized by the share of unskilled immigrants among total unskilled workers within the firm during the period from 2016 to 2019.

Figure 11: Distribution of Firms by Share of Immigrant Workers 2010, by Size Category



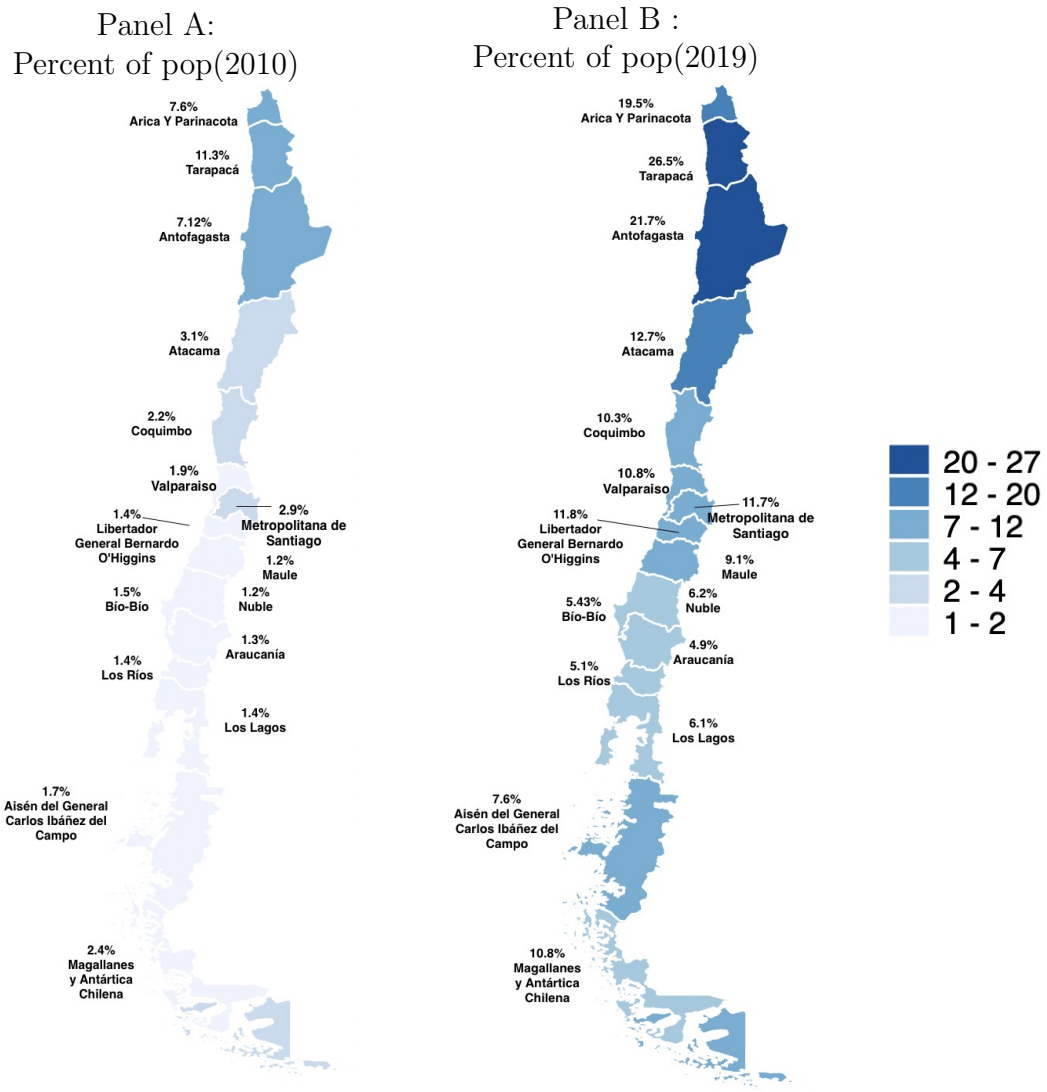
Notes: The top figure shows the percentage of firms, by size category, categorized by the share of skilled immigrants among total skilled workers within the firm in 2010; while the bottom figure shows the percentage of firms, by size category, categorized by the share of unskilled immigrants among total unskilled workers within the firm in 2010.

Figure 12: Distribution of Firms by Share of Immigrant Workers 2016-2019, by Size Category



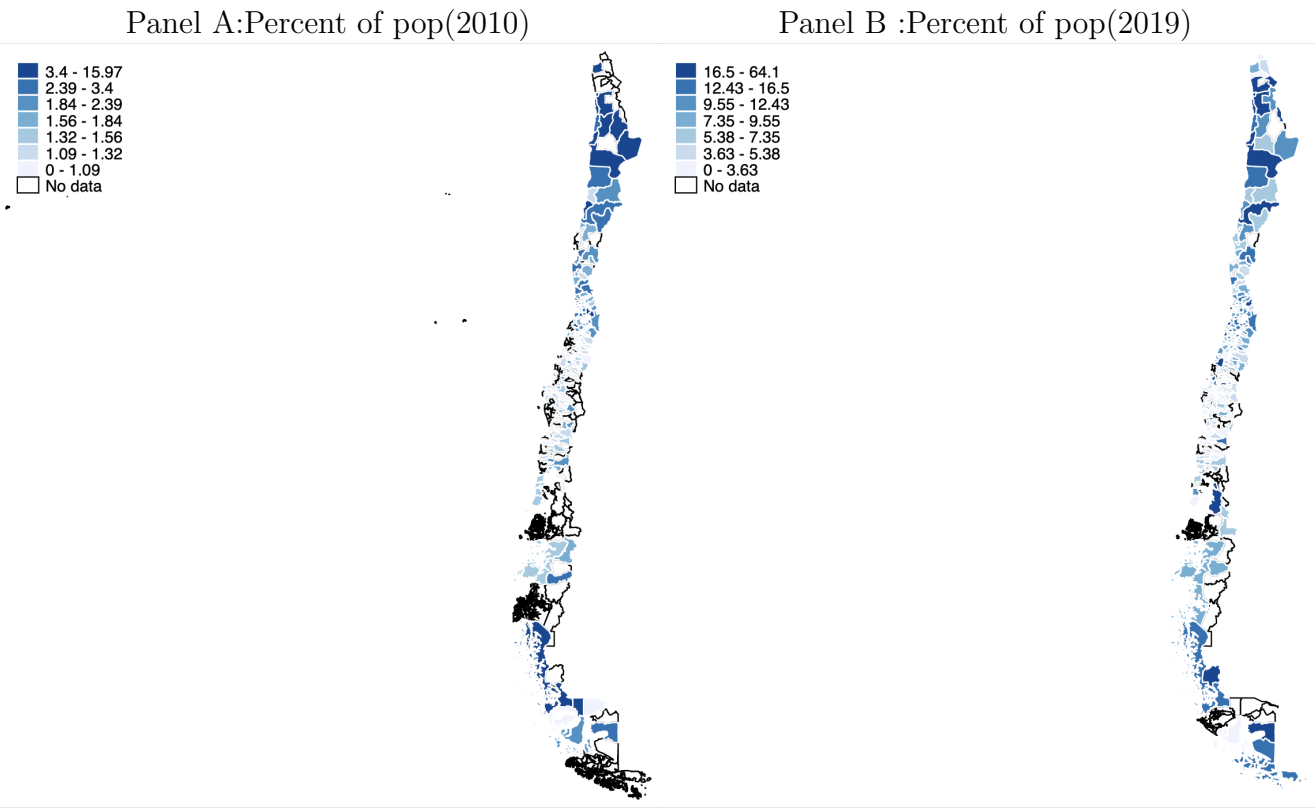
Notes: The top figure shows the percentage of firms, by size category, categorized by the share of skilled immigrants among total skilled workers within the firm in 2010; while the right figure shows the percentage of firms, by size category, categorized by the share of unskilled immigrants among total unskilled workers within the firm in 2010.

Figure 13: Regional Distribution



Notes: Author's calculations based on Migration Department Data. The figure displays the percentage of foreign workers relative to the total workers by region in 2010 (Panel A) and 2019 (Panel B).

Figure 14: Immigrants Distribution by Municipality (% population)



Notes: Author's calculations based on data from the Migration Department. The figure shows the percentage of foreign workers relative to the total number of workers by municipality in 2010 (Panel A) and 2019 (Panel B). The scale of the map differs across panels to improve readability. "No data" indicates municipalities with fewer than 25 foreign or total workers, which cannot be displayed for data confidentiality reasons.

B Tables

Table 8: Distribution of Firms and Foreign Workers by Industry

Industry	N. Firms (%)	N. Foreign Workers (%)	N. Foreign Skilled Workers (%)	N. Foreign Unskilled Workers (%)
Hotels and Restaurants	32.37%	33.28%	33.20%	29.53%
Construction	11.75%	14.61%	7.21%	16.08%
Business Services	12.67%	14.60%	18.60%	10.04%
Manufacturing	10.65%	12.60%	9.27%	9.85%
Transport, Storage, and Communication	8.79%	7.80%	8.46%	5.74%
Agriculture, Livestock and Fishing	7.50%	6.92%	2.62%	15.93%
Personal Services	9.05%	5.80%	7.15%	3.04%
Financial Services	3.93%	2.25%	9.98%	6.32%
Real Estate and Business Activities	2.19%	0.64%	0.66%	0.47%
Electricity, Gas, and Water Supply	0.56%	0.90%	0.38%	0.28%
Mining	0.51%	0.42%	1.21%	1.40%

Notes: This table reports the percentage distribution of firms and foreign workers by industry in Chile over the period 2010–2019. Worker categories include total, skilled, and unskilled foreign workers.

Table 9: Number of Unique Firms by Size Category

Size Category	**Number of Firms**
Micro	7,715
Small	10,360
Medium	2,392
Big	806
Total	21,273

Notes: This table shows the number of unique firms in the manufacturing sector by size category. Firm size categories are based on the number of employees. Micro: 1–9 employees; Small: 10–49; Medium: 50–199; Large: 200 or more.

Table 10: Average Firm Size by Year

Year	**Mean Firm Size**
2010	57.2093
2011	58.4546
2012	59.1627
2013	58.3655
2014	57.1548
2015	57.0921
2016	58.0685
2017	60.4236
2018	59.7408
2019	60.3593
Total	58.5656

Notes: This table shows the average number of employees per firm in each year, based on employer-employee administrative data.

Table 11: Share of Firms Hiring Immigrants by Year

Year	Any Immigrants	Skilled Immigrants	Unskilled Immigrants
2010	40.7%	16.1%	36.1%
2011	42.2%	17.0%	37.6%
2012	43.2%	17.8%	38.5%
2013	43.9%	18.5%	39.3%
2014	45.1%	19.5%	40.2%
2015	46.9%	20.7%	41.9%
2016	50.8%	24.0%	45.4%
2017	61.3%	31.7%	55.5%
2018	69.1%	40.1%	62.5%
2019	71.6%	45.3%	64.6%

Notes: This table shows the percentage of firms that hired at least one immigrant worker in each year, separately for total, skilled, and unskilled immigrants.

Table 12: Percentage of Immigrants by Country of Origin Relative to Total Workers in Manufacturing (2010–2019)

Year	Venezuela	Peru	Haiti	Colombia	Bolivia
2010	0.80%	1.90%	0.05%	0.13%	0.25%
2011	0.74%	2.00%	0.08%	0.27%	0.32%
2012	0.72%	2.10%	0.15%	0.43%	0.41%
2013	0.69%	2.10%	0.18%	0.56%	0.58%
2014	0.71%	2.20%	0.26%	0.74%	0.81%
2015	0.77%	2.40%	0.48%	0.90%	0.88%
2016	1.10%	2.50%	1.30%	1.20%	0.81%
2017	2.50%	2.50%	2.90%	1.50%	0.80%
2018	4.90%	2.40%	4.20%	1.60%	0.85%
2019	6.50%	2.40%	4.20%	1.50%	0.92%
Total	1.90%	2.20%	1.30%	0.87%	0.66%

Notes: This table reports the share of immigrant workers from selected origin countries in the Chilean manufacturing sector, expressed as a percentage of total workers in manufacturing, over the period 2010–2019.

Table 13: Immigrant Share by Country of Origin and Firm Size

Firm Size	Venezuela	Peru	Haiti	Colombia	Bolivia
Micro	2.0%	2.5%	1.3%	1.0%	0.8%
Small	1.9%	2.4%	1.5%	0.9%	0.7%
Medium	1.5%	1.6%	1.1%	0.6%	0.4%
Big	1.2%	0.9%	0.6%	0.4%	0.2%
Total	1.9%	2.2%	1.3%	0.9%	0.7%

Notes:This table reports the share of immigrant workers from selected countries by firm size category. Each cell shows the percentage of a firm's workforce from that country within the specified size group.

Table 14: Distribution of Skilled and Unskilled Foreign Workers Across Sub-Industries in Manufacturing

Industry	**Skilled (2010)**	**Unskilled (2010)**	**Skilled (2019)**	**Unskilled (2019)**
Fishing industry	4.49%	5.09%	3.91%	4.53%
Meat production	2.93%	3.35%	3.34%	3.69%
Canned food production	2.18%	3.26%	2.62%	3.99%
Oil production	0.00%	0.27%	0.39%	0.29%
Dairy products manufacturing	3.14%	3.14%	3.14%	2.62%
Milling	1.12%	0.88%	0.77%	0.22%
Animal food production	0.00%	0.34%	0.39%	0.40%
Bakeries	7.06%	12.35%	13.55%	17.34%
Pasta and other flour products manufacturing	0.00%	0.00%	0.14%	0.11%
Various other food products manufacturing	2.73%	3.06%	4.72%	4.06%
Wine and other fermented alcoholic beverages production	2.98%	2.62%	1.73%	2.33%
Alcohol and liquor production	0.00%	0.00%	0.22%	0.12%
Beer production	0.60%	0.21%	0.64%	0.29%
Non-alcoholic beverages manufacturing	1.81%	1.15%	1.78%	0.97%
Tobacco products manufacturing	0.00%	0.00%	0.21%	0.07%
Textile products manufacturing	2.11%	3.11%	1.69%	2.08%
Garment manufacturing	3.69%	4.83%	2.80%	3.08%
Leather and related products manufacturing, except footwear	0.00%	0.57%	0.30%	0.33%
Footwear manufacturing	0.00%	0.77%	0.53%	0.29%
Wood products production	3.19%	4.11%	2.70%	4.56%
Paper manufacturing	3.12%	2.39%	3.19%	2.28%
Printing	3.05%	2.46%	3.18%	2.10%
Fuel production	0.00%	0.00%	0.14%	0.07%
Basic chemical industries	3.37%	1.70%	2.12%	0.99%
Pharmaceutical industry and hygiene products manufacturing	5.50%	2.39%	5.21%	2.27%
Other chemical industries	2.25%	1.50%	1.78%	0.98%
Rubber products manufacturing	0.73%	0.87%	1.15%	0.77%
Plastic products manufacturing	4.47%	5.96%	4.21%	6.07%
Glass and glass products manufacturing	0.78%	0.85%	0.91%	0.90%
Other non-metallic mineral products manufacturing	3.09%	2.76%	2.32%	2.92%
Basic iron and steel industries	1.21%	1.08%	0.96%	0.85%
Basic non-iron metal industries	0.83%	0.33%	0.40%	0.37%
Metal products manufacturing	11.62%	12.24%	8.34%	10.61%
Electronic machinery and office equipment manufacturing	3.28%	2.12%	4.26%	2.31%
Other machinery and equipment manufacturing	5.29%	3.76%	4.45%	3.53%
Transport equipment manufacturing	1.28%	1.66%	1.09%	1.27%
Furniture manufacturing	2.80%	4.53%	2.89%	4.32%
Other manufacturing industries	6.60%	5.07%	7.50%	5.98%

Notes: This table presents the percentage distribution of skilled and unskilled foreign workers in Chile's manufacturing sector across sub-industries in 2010 and 2019.

Table 15: Elasticity of Substitution between Immigrants and Natives by Skill Group

	(1) $\log\left(\frac{w_{SI}}{w_{SN}}\right)$	(2) $\log\left(\frac{w_{UI}}{w_{UN}}\right)$
$\log\left(\frac{S_I}{S_N}\right)$	-0.164	
	(0.0423)	
$\log\left(\frac{U_I}{U_N}\right)$		-0.118
		(0.0135)
Year FE	✓	✓
Firm FE	✓	✓
Observations	26128	56154

Notes: The table reports the coefficients for the estimated elasticities of substitution between immigrant and native workers by skill group. Column (1) presents results for skilled workers, and Column (2) for unskilled workers. The estimates correspond to equations 20 and 21 in the main text. All regressions are estimated using instrumental variables (IV) and include firm and year fixed effects.
* p < 0.10, ** p < 0.05, *** p < 0.01.

Table 16: Elasticity of Substitution between Capital and Skilled and Unskilled labor

	(1) $\log\left(\frac{rK}{w_u U}\right)$	(2) $\log\left(\frac{p_X X}{w_s S}\right)$
$\log\left(\frac{r}{w_u}\right)$	-0.391	
	(0.0316)	
$\log\left(\frac{p_X}{w_s}\right)$		0.473
		(0.0496))
Year FE	✓	✓
Industry FE	✓	✓
Observations	125766	99002

Notes: The table reports the coefficients for the estimated elasticities of substitution between capital and skilled and unskilled labor. Column (1) presents results for unskilled workers, and Column (2) for skilled workers. The estimates correspond to equations 22 and 23 in the main text. All regressions are estimated using instrumental variables (IV) and include industry and year fixed effects.
* p < 0.10, ** p < 0.05, *** p < 0.01.

C Derivations

C.1 Derivations for Section 3

We assume that firms produce according to the following production function:

$$F\left(K,U,S\right)=A\left(\left(K^{\frac{\lambda-1}{\lambda}}+U^{\frac{\lambda-1}{\lambda}}\right)^{\frac{(\epsilon-1)\lambda}{(\lambda-1)\epsilon}}+S^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{C.1}$$

where variables U and S define "aggregators" of unskilled and skilled labor, respectively. Parameter λ defines the elasticity of substitution between capital and unskilled labor, while parameter ϵ stands for the elasticity of substitution between capital and skilled labor. The "aggregators" of unskilled and skilled labor have the form:

$$U = \left(U_N^{\frac{\sigma_u-1}{\sigma_u}}+U_F^{\frac{\sigma_u-1}{\sigma_u}}\right)^{\frac{\sigma_u}{\sigma_u-1}} \tag{C.2}$$

$$S = \left(S_N^{\frac{\sigma_s-1}{\sigma_s}}+S_F^{\frac{\sigma_s-1}{\sigma_s}}\right)^{\frac{\sigma_s}{\sigma_s-1}} \tag{C.3}$$

where U_F defines unskilled immigrants (foreigners), U_N unskilled natives, S_F skilled immigrants, and S_N skilled natives. Parameters σ_u and σ_s represent the elasticities of substitution between unskilled natives/immigrants and skilled natives/immigrants, respectively.

We assume that capital features free mobility across regions with interest rate r. Therefore, the capital optimality condition for each firm is:

$$F'_K\left(K,U,S\right)=r, \tag{C.4}$$

where marginal product of capital equates to the interest rate. Given that marginal product of capital is homogeneity of degree zero, we can re-define this expressions above in the intensive form:

$$F'_K\left(\underbrace{\frac{K}{U_F+U_N+S_F+S_N}}_{\tilde{k}},\underbrace{\frac{U}{U_F+U_N+S_F+S_N}}_{\tilde{u}},\underbrace{\frac{S}{U_F+U_N+S_F+S_N}}_{\tilde{s}}\right)=r, \tag{C.5}$$

where we normalize inputs by total number of workers (both skilled/unskilled and natives/immigrants).

Let us define variables $\tilde{k}$, $\tilde{u}$, and $\tilde{s}$. First, variable $\tilde{k}$ defines capital per worker:

$$k = \frac{K}{U_F + U_N + S_F + S_N},$$

Variables $\tilde{u}$ and $\tilde{s}$ can be derived as functions of u_F (the share of unskilled immigrant of total unskilled workers at a given firm), s_F (the share of skilled immigrant of total skilled workers at a given firm), and u (share of unskilled workers of all workers at a given firm):

$$\tilde{u} = \left((1-u_F)^{\frac{\sigma_u - 1}{\sigma_u}} + u_F^{\frac{\sigma_u - 1}{\sigma_u}} \right)^{\frac{\sigma_u}{\sigma_u - 1}} \times u, \tag{C.6}$$

$$\tilde{s} = \left((1-s_F)^{\frac{\sigma_s - 1}{\sigma_s}} + s_F^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}} \times (1-u), \tag{C.7}$$

where variables u_F, s_F, and u are defined according to:

$$u_F = \frac{U_F}{U_N + U_F}, \tag{C.8}$$

$$s_F = \frac{S_F}{S_N + S_F}, \tag{C.9}$$

$$u = \frac{U_F + U_N}{U_N + U_F + S_F + S_N}. \tag{C.10}$$

Totally differentiating expression (C.5) with respect to intensive variables k, $\tilde{u}$, $\tilde{s}$, we obtain:

$$F_{kk} k \frac{\Delta k}{k} = -F_k \tilde{s} \tilde{s} \frac{\Delta \tilde{s}}{\tilde{s}} - F_k \tilde{u} \tilde{u} \frac{\Delta \tilde{u}}{\tilde{u}}, \tag{C.11}$$

where $\frac{\Delta k}{k}$, $\frac{\Delta \tilde{s}}{\tilde{s}}$, and $\frac{\Delta \tilde{u}}{\tilde{u}}$ represent percentage change of intensive variables (therefore, can be associated with logs in the empirical specification). In turn, $\frac{\Delta \tilde{s}}{\tilde{s}}$, and $\frac{\Delta \tilde{u}}{\tilde{u}}$ can be expressed as:

$$\frac{\Delta \tilde{s}}{\tilde{s}} = \frac{\partial \tilde{s}}{\partial s_F} \times \frac{\Delta s_F}{\tilde{s}} + \frac{\partial \tilde{s}}{\partial u} \times \frac{\Delta u}{\tilde{s}}, \tag{C.12}$$

$$\frac{\Delta \tilde{u}}{\tilde{u}} = \frac{\partial \tilde{u}}{\partial u_F} \times \frac{\Delta u_F}{\tilde{u}} + \frac{\partial \tilde{u}}{\partial u} \times \frac{\Delta u}{\tilde{u}}. \tag{C.13}$$

Using the fact that F'_k is homogeneous of degree zero, we obtain:

$$F_{kk} \times k = -F_{k\tilde{s}} \times \tilde{s} - F_{k\tilde{u}} \times \tilde{u}, \tag{C.14}$$

and combining it with equations (C.11), (C.12), (C.13), and (C.14), we obtain the following expression for capital accumulation:

$$\begin{aligned}\frac{\Delta\tilde{k}}{k} = &\frac{F_{k\tilde{s}}\tilde{s}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} \times \left(\frac{\partial\tilde{s}}{\partial s_F}\times\frac{\Delta s_F}{\tilde{s}} + \frac{\partial\tilde{s}}{\partial u}\times\frac{\Delta u}{\tilde{s}}\right) \\ &+\frac{F_{k\tilde{u}}\tilde{u}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} \times \left(\frac{\partial\tilde{u}}{\partial u_F}\times\frac{\Delta u_F}{\tilde{u}} + \frac{\partial\tilde{u}}{\partial u}\times\frac{\Delta u}{\tilde{u}}\right)\end{aligned} \tag{C.15}$$

Substituting equations (C.12) and (C.13) into the above equation, we obtain:

$$\begin{aligned}\frac{\Delta k}{k} = &\frac{F_{k\tilde{s}}\tilde{s}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} \times \frac{\partial\tilde{s}}{\partial s_F}\frac{s_F}{\tilde{s}} \times \frac{\Delta s_F}{s_F} + \\ &+\frac{F_{k\tilde{u}}\tilde{u}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} \times \frac{\partial\tilde{u}}{\partial s_{uf}}\frac{s_{uf}}{\tilde{u}} \times \frac{\Delta u_F}{u_F} + \\ &+\left(\frac{F_{k\tilde{s}}\tilde{s}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} \times \frac{u}{u-1} + \frac{F_{k\tilde{u}}\tilde{u}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}}\right) \times \frac{\Delta u}{u},\end{aligned} \tag{C.16}$$

where

$$\begin{aligned}\frac{F_{k\tilde{s}}\tilde{s}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} &= \frac{\lambda\tilde{s}^{\frac{\epsilon-1}{\epsilon}}\left(k^{\frac{\lambda-1}{\lambda}}+\tilde{u}^{\frac{\lambda-1}{\lambda}}\right)}{\lambda\tilde{s}^{\frac{\epsilon-1}{\epsilon}}k^{\frac{\lambda-1}{\lambda}}+\epsilon\tilde{y}^{\frac{\epsilon-1}{\epsilon}}\tilde{u}^{\frac{\lambda-1}{\lambda}}}, \\ \frac{F_{k\tilde{u}}\tilde{u}}{F_{k\tilde{s}}\tilde{s}+F_{k\tilde{u}}\tilde{u}} &= 1-\frac{\lambda\tilde{s}^{\frac{\epsilon-1}{\epsilon}}\left(k^{\frac{\lambda-1}{\lambda}}+\tilde{u}^{\frac{\lambda-1}{\lambda}}\right)}{\lambda\tilde{s}^{\frac{\epsilon-1}{\epsilon}}k^{\frac{\lambda-1}{\lambda}}+\epsilon\tilde{y}^{\frac{\epsilon-1}{\epsilon}}\tilde{u}^{\frac{\lambda-1}{\lambda}}}, \\ \frac{\partial\tilde{s}}{\partial s_F}\frac{s_F}{\tilde{s}} &= \frac{\left(s_F^{-\frac{1}{\sigma_s}}-(1-s_F)^{-\frac{1}{\sigma_s}}\right)s_F}{s_F^{\frac{\sigma_s-1}{\sigma_s}}+(1-s_F)^{\frac{\sigma_s-1}{\sigma_s}}}, \\ \frac{\partial\tilde{u}}{\partial u_F}\frac{u_F}{\tilde{u}} &= \frac{\left(u_F^{-\frac{1}{\sigma_u}}-(1-u_F)^{-\frac{1}{\sigma_u}}\right)u_F}{u_F^{\frac{\sigma_u-1}{\sigma_u}}+(1-u_F)^{\frac{\sigma_u-1}{\sigma_u}}}.\end{aligned}$$

C.2 Derivations for Section 6

$$F(K,U,S) = A\left(\left(K^{\frac{\lambda-1}{\lambda}} + U^{\frac{\lambda-1}{\lambda}}\right)^{\frac{(\epsilon-1)\lambda}{(\lambda-1)\epsilon}} + S^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}$$

In this section we derive the rental price P_x for the bundle of unskilled labor and capital (X) defined as:

$$X = \left(K^{\frac{\lambda-1}{\lambda}} + \tilde{U}^{\frac{\lambda-1}{\lambda}}\right)^{\lambda/\lambda\hat{-}1}$$

Taking the input r and w_U as given, the firm profit maximization problem is :

$$\max_{K,U} p_X\left(\left(K^{\frac{\lambda-1}{\lambda}} + \tilde{U}^{\frac{\lambda-1}{\lambda}}\right)^{\lambda/\lambda\hat{-}1}\right) - rK - w_u U$$

Taking the optimality conditions with respect to capital and unskilled workers:

$$\begin{aligned} X^{\frac{1}{\lambda}}K^{\frac{-1}{\lambda}} &= \frac{r}{p_X}, \\ X^{\frac{1}{\lambda}}U^{\frac{-1}{\lambda}} &= \frac{w_u}{p_X}, \end{aligned}$$

and re-arranging these expressions:

$$\begin{aligned} K &= \left(\frac{r}{p_X}\right)^{\lambda} X, \\ U &= \left(\frac{w_U}{p_X}\right)^{\lambda} X. \end{aligned}$$

We can therefore write the capital and unskilled labor CES aggregator as:

$$X = \left(\left(\frac{r}{p_X}\right)^{1-\lambda} X^{\frac{\lambda-1}{\lambda}} + \left(\frac{w_U}{p_X}\right)^{1-\lambda} X^{\frac{\lambda-1}{\lambda}}\right)^{\lambda/\lambda-1}$$

and equivalently:

$$1 = \left(\left(\frac{r}{p_X}\right)^{1-\lambda} + \left(\frac{w_U}{p_X}\right)^{1-\lambda}\right)^{\lambda/\lambda-1}$$

And we can recover p_X from this expression:

$$p_X = \left(r^{1-\lambda} + w_u^{1-\lambda}\right)^{1/\lambda-1}$$

In a similar way, we can obtain expressions for the wage of unskilled and skilled labor as:

$$\begin{aligned} w_U &= \left({w_{UF}}^{1-\sigma_u} + w_{UN}^{1-\sigma_u}\right)^{1/\sigma_u - 1}, \\ w_S &= \left({w_{SF}}^{1-\sigma_s} + w_{SN}^{1-\sigma_s}\right)^{1/\sigma_s - 1}, \end{aligned}$$

where w_{SF}, w_{SN}, w_{UF}, w_{UN} are respectively the wages of skilled foreign workers, skilled native workers, unskilled foreign workers and unskilled native workers.

D Prediction of Firm-Level Immigrant Stocks in 2010 Using PPMLE

We use a Poisson Pseudo-Maximum Likelihood Estimation (PPMLE) approach to predict initial firm-level exposure to immigration. Specifically, we estimate the number of skilled and unskilled foreign workers by nationality at the firm level in 2010 using a Poisson regression model that includes fixed effects for municipality (c), sub-industry (j), and firm size category (s).

The predictions are based on the following specification:

$$\hat{\mathbb{E}}(S_{in10}|\phi_s, \phi_j, \phi_c) = \exp\left(\phi_s * \phi_j * \phi_c\right), \tag{D.17}$$

$$\hat{\mathbb{E}}(U_{in10}|\phi_s, \phi_j, \phi_c) = \exp\left(\phi_s * \phi_j * \phi_c\right), \tag{D.18}$$

where:

- $\hat{\mathbb{E}}(S_{in10}|\phi_s, \phi_j, \phi_c)$ and $\hat{\mathbb{E}}(U_{in10}|\phi_s, \phi_j, \phi_c)$ denote the predicted stock of skilled and unskilled foreign workers of nationality n at firm i in 2010.
- ϕ_s, ϕ_j, and ϕ_c are fixed effects for firm size category, sub-industry, and municipality, respectively.

Each bin (ϕ_s, ϕ_j, ϕ_c) is defined by the interaction of three categorical variables:

- Municipality: The geographical location of the firm, based on administrative boundaries. There are 345 municipalities in total
- Industry: The firm's main economic activity, categorized into 38 sub-industries in the manufacturing sector.

- Firm Size: A categorical measure of firm size based on the number of employees. Firms are divided into four size categories: Micro,Small, Medium, Large.

In total, **7,785 combinations** are present in the data used to estimate the model.

The effective grouping structure, used internally by the regression via the interaction of the three fixed effects, exhibits the following distribution:

Statistic	**Value**
Smallest Group Size	1 firm
Mean Group Size	30 firms
Median Group Size	10 firms
99th Percentile Group Size	100 firms

The average size of the bins—formed by the interaction of municipality, sub-industry, and firm size category—is approximately 30 firms. The largest observed groups contain around 100 firms. A small number of outliers, with more than 100 firms per bin, correspond primarily to combinations of firms located in Santiago and classified as micro-enterprises. These extreme cases are excluded in robustness checks to ensure that the results are not driven by disproportionately large bins. Table 17 compares the actual share of firms hiring skilled and unskilled foreign workers in 2010 with the predicted values obtained from the Poisson Pseudo Maximum Likelihood Estimator (PPMLE).

Table 17: Actual vs Predicted Share of Firms Hiring Foreign Workers in 2010

Category	**Actual Share**	**Predicted Share (PPMLE)**
Skilled Foreign Workers	16.1%	70.8%
Unskilled Foreign Workers	36.1%	87.2%

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