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Endogenous Migration in a Two-Country Model with Labor Market Frictions

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Abstract: We present a dynamic North-South model with search frictions and endogenous labor migration to study the long-run implications of labor factor mobility on labor market conditions and welfare. In the model, the high-TFP country (North) acts as the destination country for migration, while the low-TFP country (South) acts as the origin country. We prove that there always exists a unique steady-state equilibrium for the world economy, and find that a permanent increase in migration effort causes per capita income to rise in North and to fall in South. However, our simulations also show the existence of a job displacement effect in the host country that makes domestic employment fall in the long-run. In an extension of the baseline model, we test the long-run effects of a pro-employment protectionist policy of the destination country consisting in imposing a distortionary tax on the domestic firms hiring migrant workers. Our analysis shows that a positive tax rate on foreign employment can increase natives welfare, but only at the expense of losses in national production and employment. These results are robust across different degrees of substitutability between migrant and native workers.

JEL classification: F24, F41, J61, O15.

Keywords: North-South migration, Ramsey-Like Growth, International Labor Mobility, Frictional Unemployment.

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1 Introduction

This study develops a two-country Neoclassical model with labor market frictions and endogenous migration to analyze the long-run effects of international labor migration on macroeconomic performance and social welfare. The literature on international macroeconomics has so far paid a limited attention to the general-equilibrium implications of labor mobility. Studies that have analyzed the dynamic effects of migration by means of open economy frameworks include Galor (1986), Miyagiwa (1991), Reichlin and Rustichini (1998), Lundborg and Segerstrom (2000), Larramona and Sanso (2006), Klein and Ventura (2009), Kim et al. (2010), Levine et al. (2010), Mandelman and Zlate (2012), Khraiche (2015) and Parello (2017). These studies do not consider employment/unemployment issues that may arise as a result in the host country labor market. This study tries to bridge the gap of the literature and investigates how migration affects capital accumulation, labor market conditions and employment in both the origin and the destination economy. To this end, we extend the dynamic framework with labor market frictions developed by Hashimoto and Im (2016) to the case of a two-country model with international labor migration.

In order to build a model as tractable as possible, we focus on an asymmetric scenario in which the two-country economy is composed of a low-TFP economy (henceforth referred as "South") and a high-TFP economy (henceforth referred as "North"). Labor markets are characterized by frictional unemployment and, because of the difference in countries productivity, only workers in South find it profitable to look for a job abroad.

The choice of a frictional labor market allows us to (i) get a better grasp of the underlying interdependence between labor market conditions and migration dynamics; (ii) have a better comprehension of the main dynamic implications of migration on national saving, physical capital accumulation and social welfare. Indeed, in contrast to the bulk of the literature, in our model migrants never cut their ties with their original households, and optimally determine the amount of personal consumption, saving and remittances to be sent to the country of origin.[1]

Though most of the theoretical contributions on migration and growth consider domestic and immigrant workers as perfect substitutes in production, in this chapter we follow Parello (2017) and use a two-level production technology in which natives and immigrants enter production as imperfect substitutes. As the issue is controversial and the empirical literature has so far given no clear-cut results on this issue (see, e.g., Cortes, 2008; Card, 2009; Ottaviano and Peri, 2012), in order to account for the contribution of immigrants to the production process in North, we use a CES aggregator of domestic and migrant workers able to capture all degrees of substitutability between the two types of workers.

The model is solved for the steady-state equilibrium and then used to explore, through the

[1] According to World Bank (2018), the estimated remittances to low- and middle-income countries amount to \$466 billions in 2017. India (\$ 69 billions), China (\$ 64 billions), Philippines (\$ 33 billions) and Mexico (\$ 31 billions) are the largest recipient countries, as well as the top countries from which U.S. immigrant workers come from. See Rapoport and Docquier (2006) for an in-depth review of remittances behavior and their potential effects on developing countries growth.

use of several simulation exercises, the long-run effects of an increase in migration intensity on per capita consumption, employment, remittances and physical capital accumulation. Here, our ultimate goal is to investigate to what extent changes in labor market conditions, induced by labor mobility, represent a boon or a bane for both the origin and the destination country.

The main results of the study are the following. First, despite the analytical complexities of the model, we analytically prove that there always exists a unique steady-state equilibrium for the world economy. Second, we find that a permanent increase in migration flows causes per capita consumption to increase worldwide in the post-increase equilibrium. Third, higher migration intensity spurs job competition in the host labor market and generates a sort of "displacement effect" that hurts native employment. However, despite native displacement, increased migration causes overall employment to increase in the destination country, which in turn induces firms to increase capital accumulation. Fourth, increases in migration flows are found not to affect the equilibrium wage rate in South, while they are found to asymmetrically affect the equilibrium wage rates in North. Specifically, our simulations show that whilst immigrant employment suffers a loss in wages because of the competition coming from new immigrants, the equilibrium wage rate paid to native workers is positively affected by migration due to the imperfect substitutability hypothesis incorporated in the CES aggregator of labor types.

We also simulate the welfare effect of migration and find that, though emigration leads to a permanent increase in output per inhabitant in the host country and to a permanent fall in the source country, households welfare is found to increase in both countries, with Southern households gaining relatively more than the Northern ones. This result is due to the increase in the overall flow of remittances that prevents per capita consumption from falling because of the reduction in final output. Even though the final effect of increasing labor migration is a reduced flow of per capita remittances, the increased share of immigrant employment characterizing the post-shock equilibrium causes the overall flow of remittances to rise, thereby allowing households in South to compensate for the loss of income due to emigration.

In the last part of the chapter, we also consider an extension of the benchmark model to the case of a "protectionist" policy consisting in imposing a (distortionary) tax on firms hiring immigrant workers. In her 2017 French presidential campaign, right-wing candidate Marine Le Pen proposed to impose an extra tax on the employment of non-French workers with the aim of protecting national employment. We use Marine Le Pen's proposed policy as an example to assess up to what extent protectionist policies can be effective in slowing down migration and support national employment and welfare. We find that raising a 10 percent tax on immigrant employment is far from being employment enhancing for the receiving country. Specifically, we find that, though the imposition of a tax on foreign labor is able to increase native welfare, it fails to turn down the native displacement effect and leads to a permanent fall in per capita output and equilibrium employment of the receiving country.

Our study relates to the literature on migration and growth. In particular, our study closely relates to Mandelman and Zlate (2012) and Parello (2017). Mandelman and Zlate (2012) analyze the effects of a border enforcement between U.S. and Mexico through a two-country business cycle model of labor migration and remittances. In line with our findings, they show that when foreign labor becomes relatively scarce, immigrants earn higher wages and increase remittances to their countries of origin. At the same time, a lower share of migrant workers reduces capital accumulation and dampens labor productivity in the destination economy. However, the authors completely abstract from employment issues, so that the presence of potential displacement effects in the host economy are not considered in their model.

Similarly to us, Parello (2017) relies on a CES aggregator to aggregate across native and immigrant labor. However, in contrast to our study, Parello's analysis focuses on a full-employment small open economy with frictionless migration and finds that both local and global indeterminacy can emerge in the equilibrium. Our study improves upon Parello's in at least two respects. First, our model adopts a North-South approach rather than a small open economy approach to study the macroeconomic implications of migration. Second, in our model migration is not governed by a frictionless Harris-Todaro migration function as they are in Parello's, but rather it is the result of a utility-maximizing decision made by decentralized agents.

Our study also relates to the recent stream of the macroeconomic literature that studies the macroeconomic implications of migration (both legal and illegal) through search and matching models. Far from being vast, this literature includes papers by Ortega (2000), Liu (2010), Chassamboulli and Palivos (2014), Chassambouli and Peri (2015), and Battisti et al. (2018). In particular, a paper closely related to our analysis is Liu (2010), who employs a dynamic general equilibrium model with labor market frictions to explore the economic consequences of illegal migration. Although Liu abstracts from legal migration, the presence of search frictions allows him to identify a new channel through which migration, by intensifying job competition in the host country, lowers the job finding rate of native unemployed workers, hence generating a displacement effect in the host country. However, Liu's analysis focuses on a closed economy framework with exogenous migration.

The outline of the chapter is the following. Section 2 introduces the baseline version of our North-South model with migration and characterizes the search equilibrium. Section 3 describes the calibration procedure used to simulate the model and discusses the main macroeconomic implications of a permanent increase in Southern workers looking for a job in North. Section 4 presents an extension of the model in which a protectionist policy is introduced by the Northern government. The extended model is then used to analyze the long-run effects on the global economy of imposing a tax on the Northern firms that hire immigrant workers. Section 5 provides a sensitivity analysis on the elasticity of substitution between immigrant and native workers. Finally, Section 6 offers some concluding remarks.

2 The model

We consider a global economy consisting of two countries: a high-TFP North (denoted by N) and a low-TFP South (denoted by S). Each country produces a non-tradable aggregate good which can be interchangeably consumed or accumulated as physical capital.

In each country, the population consists of a unit continuum of infinitely-lived households, each of which comprises a continuum of identical individuals of measure one. Individuals are endowed with one unit of time, which they can spend either working for wages or searching for jobs. The countries are assumed to be symmetric in all respects but two. First, North is supposed to be more productive in terms of TFP than South. Second, only workers from South are supposed to migrate in search for better job opportunities and higher wages.

Time is set in continuous time, but for ease of exposition we will suppress the time variable t where no confusion arises. We begin by presenting a benchmark version of the model in which firms can freely hire foreign workers without incurring in any sort of restriction. In Section 4 we will relax this assumption by focusing on the special case in which the Northern government imposes a tax on firms hiring migrants in order to prioritize natives welfare.

2.1 Labor markets and matching

In this section, we describe how labor markets work in both North and South. The way unemployed workers and job vacancies meet follows a matching process similar to that developed by Pissarides (2000) and then extended by Shi and Wen (1997) and Hashimoto and Im (2016).

2.1.1 The Southern labor market

In South, the total population can be divided into job searchers (denoted by s_M), employed workers in North (denoted by m) and employed workers in South (denoted by n_S), such that the following resource constraint for labor applies at every moment in time

$$1 = n_S + s_M + m. \tag{1}$$

Among all job searchers, we assume that a fraction ϕs_M - with $\phi \in (0, 1)$ - resides and looks for jobs in North, while the complement fraction $(1-\phi)\, s_M$ resides and looks for jobs in South.[2] As in Shi and Wen (1997), in this chapter the notion of job searchers conforms to the notion of unemployment, so that at each moment of time $L_S \equiv n_S + (1-\phi)s_M$ is the size of the workforce of South and $(1-\phi)s_M/[n_S + (1-\phi)s_M]$ is its unemployment rate.

To create a productive job, vacancies and workers must match with each other. We assume that the process of matching is summarized by a matching function

$$z_S = \bar{z}_S \left[(1-\phi)\, s_M\right]^{1-\epsilon} v_S^{\epsilon}, \quad \bar{z}_S > 0, \quad \epsilon \in (0, 1), \tag{2}$$

where z_S is the number of job matches in South, $\bar{z}_S$ is a constant capturing the Southern efficiency of matching, v_S is the number of vacancies posted by Southern firms, and ϵ is a given parameter capturing the elasticity of the matching function with respect to vacancies.

Equation (2) determines the flow of workers who find a job and who exit the unemployment pool within a time interval of length dt. Dividing both sides of (2) by $(1-\phi)\, s_M$ and v_N we obtain, respectively, the instantaneous probability that a Southern worker finds a job in her home country, and the instantaneous probability that a Southern vacancy is filled. Thus,

[2]The exogenous parameter ϕ determines the share of Southern-born workers that look for a job in North and can be interpreted as the share of effort on looking for a job abroad.

denoting with $\theta_S \equiv v_S/\left(1-\phi\right)s_M$ the vacancy-unemployment ratio, which we take as a measure of tightness of the labor market in South, these two probabilities can be written as

$$\frac{z_S}{\left(1-\phi\right)s_M} = \bar{z}_S\theta_S^{\epsilon} \equiv p\left(\theta_S\right) \tag{3}$$

$$\frac{z_S}{v_S} = \bar{z}_S\theta_S^{-(1-\epsilon)} \equiv q\left(\theta_S\right). \tag{4}$$

As it is easy to check, $p'\left(\theta_S\right) > 0$ and $q'\left(\theta_S\right) < 0$, so that market tightness makes it easier to find a job for a worker, but harder to fill a vacancy for a firm.

2.1.2 The Northern labor market

In North, the fraction of the population in work can be split into job searchers (denoted by s_N), and employed workers (denoted by n_N), such that, at each time t, it must be that

$$1 = n_N + s_M. \tag{5}$$

However, because a fraction of m individuals from South are currently working as employed workers for Northern firms and a fraction ϕs_M are residing in North as unemployed workers, the size of the labor force differs from that of the native population and is equal to $L_N = 1+m+\phi s_M$. Moreover, the size of the unemployment pool of North is also inclusive of immigrants workers and it equates $(s_N + \phi s_M)/(m + \phi s_M + s_N + n_N)$.

Denoting the number of vacancies posted by Northern firms as v_N, the matching function of North can be written as

$$z_N = \bar{z}_N\left(s_N + \phi s_M\right)^{1-\epsilon} v_N^{\epsilon}, \quad \bar{z}_N > 0, \tag{6}$$

where z_N is the number of job matches in South and $\bar{z}_N$ is the efficiency parameter of matching in North.

From (6), it follows that the Northern labor market tightness depends on both types of unemployed workers, i.e. native unemployed workers s_N and immigrant unemployment workers, ϕs_M. Hence, by defining the labor market tightness of North as $\theta_N \equiv v_N/(s_N + \phi s_M)$, it is easy to verify that an increase in immigration might worsen the conditions of the labor market of North through the term ϕs_M. Indeed, dividing both sides of (6) by $s_N + \phi s_M$ and v_N, we obtain the following pair of expressions for the job finding rate and vacancy filling rate

$$\frac{z_N}{s_N + \phi s_M} = \bar{z}_N\theta_N^{\epsilon} \equiv p\left(\theta_N\right) \tag{7}$$

$$\frac{z_N}{v_N} = \bar{z}_N\theta_N^{-(1-\epsilon)} \equiv q\left(\theta_N\right). \tag{8}$$

According to (7) and (8), the size of immigrant unemployment affects the probability that a firm or a worker (both native and immigrant) will meet a partner, implying that migration can exacerbate the negative search externality on native job searchers and firms.

2.2 Households

In each country $i = \{S, N\}$, households derive utility from consumption, c_i, and hold assets in the form of ownership claims on capital, k_i. We suppose that preferences are identical in the two countries and given by the life-time utility

$$U_i(t) = \int_0^\infty e^{-\rho t} \log(c_i)\, \mathrm{d}t, \quad \rho > 0, \quad i = \{S, N\}, \tag{9}$$

where ρ is the subjective discount rate of households.

Given an initial value for assets holding $k_i(0)$, the objective of the representative household of country i at time $t > 0$ is to choose a path for c_i to maximize (9) subject to a country-specific flow budget constraint. Following mainstream search literature, we assume that all household members completely insure each other against variations in labor income (see, e.g., Merz, 1995; Andolfatto, 1996). Since Southern households comprise migrants among their members, such an assumption implies that all migrant workers care about the welfare of their own household, and send home remittances, below denoted by R, in order to completely smooth risks in consumption within the household of origin.[3] As a consequence, the flow budget constraint of the representative household of South can be written as

$$\dot{k}_S = r_S k_S + w_S n_S + b_S(1-\phi)s_M + \pi_S + R - (c_S + \tau_S)(1 - m - \phi s_M), \tag{10}$$

where r_S the rate of return on Southern capital k_S, w_S is the wage rate received by each of the n_S household's member employed in South, b_S is the unemployment benefit paid to each of the $(1-\phi)s_M$ household's members who are currently unemployed, π_S is the instantaneous stream of profits paid by Southern firms and τ_S is the lump-sum tax of South paid by the $1 - m - \phi s_M$ members who reside in South at time t.

Similarly, the flow budget constraint of the representative household is given by

$$\dot{k}_N = r_N k_N + \pi_N + w_N n_N + b_N s_N - (\tau_N + c_N), \tag{11}$$

where r_N is the rate of return on Northern capital k_N, w_N is the wage rate received by each employed member of the household, b_N is the unemployment benefit paid to each of the s_N unemployed members, π_N is the instantaneous stream of profits paid by Northern firms and τ_N is the lump-sum tax paid by the household overall at time t.

According to (10) and (11), in each country i the stock of domestic capital k_i changes over time if and only if disposable income turns out to be either larger or smaller than consumption expenditure. When this happens, the rates at which each domestic economy accumulates capital equates its current income less the sum of consumption and taxation, and the dynamics of k_S and k_N are given by (10) and (11).

Standard maximization techniques yield the familiar Euler conditions

$$\dot{c}_S = c_S (r_S - \rho) \tag{12}$$

$$\dot{c}_N = c_N (r_N - \rho). \tag{13}$$

[3] Mandelman and Zlate (2012) make use of a similar risk sharing mechanism of remittances in their model.

2.3 Producers

In each country $i = \{S, N\}$, there is a continuum of perfectly-competitive firms producing the non-tradable good y_i by combining capital, k_i, and labor, ℓ_i, according to the Cobb-Douglas technology

$$y_i = A_i k_i^{\alpha} \ell_i^{1-\alpha}, \quad A_i > 0, \quad \alpha \in (0, 1),$$

where A_i (with $A_N > A_S$) is a given parameter capturing the level of TFP in country i at time $t > 0$, and α is the Cobb-Douglas parameter.

In South, labor input, ℓ_S, consists of only native Southern workers, n_S, while in North it is given by a mix of native Northern workers, n_N, and immigrant workers, m. Following Ottaviano and Peri (2012), we assume that the contribution of each labor input type to Northern production is captured by the CES aggregator, $\ell_N \equiv \left[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}\right]^{1/\eta}$, where $\lambda \in (0, 1)$ is the share parameter and $\eta < 1$ is the CES parameter. This implies that the production technology of South takes the form of the standard Cobb-Douglas

$$y_S = A_S k_S^{\alpha} n_S^{1-\alpha}, \tag{14}$$

while the production technology of North takes the form of a nested Cobb-Douglas production function with the CES-nest for the labour input

$$y_N = A_N k_N^{\alpha} \left[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}\right]^{(1-\alpha)/\eta}, \tag{15}$$

where the elasticity of substitution between the two types of labor inputs, i.e. migrant and native workers, is equal to $\sigma \equiv 1/(1-\eta)$.

2.3.1 Southern firms

In South, firms rent capital from the local households and hire workers on a frictional labor market. In doing so, they open vacancies in response to expected profits. Each vacancy costs the firm $\gamma_S > 0$ and matches with a worker at the rate $q(\theta_S)$, where θ_S is taken as given by the firm. Consequently, denoting the separation rate of Southern employment by δ_S, the time evolution of employment in South can be described by the following

$$\dot{n}_S = q(\theta_S) v_S - \delta_S n_S, \tag{16}$$

Given an initial level of local employment $n_S(0)$, Southern firms' objective is to choose paths for n_S and k_S to maximize the present value of expected future cash-flows

$$V_S(0) = \int_0^{\infty} e^{-\int_0^t r_S(\omega)\mathrm{d}\omega} \pi_S \mathrm{d}t, \tag{17}$$

subject to the dynamic equation (16) and

$$\pi_S = A_S k_S^{\alpha} n_S^{1-\alpha} - r_S k_S - w_S n_S - \gamma_S v_S. \tag{18}$$

Denoting the costate variable for n_S by ξ_S, the necessary and sufficient conditions for an optimum are given by

$$\xi_S = \frac{\gamma_S}{q(\theta_S)} \tag{19a}$$

$$r_S = A_S \alpha \left(\frac{k_S}{n_S}\right)^{-(1-\alpha)} \tag{19b}$$

$$\dot{\xi}_S = (r_S + \delta_S)\,\xi_S - \left[A_S(1-\alpha)\left(\frac{k_S}{n_S}\right)^{\alpha} - w_S\right], \tag{19c}$$

where (19a) and (19b) are the optimality conditions for posting vacancies and renting capital, and (19c) is a dynamic equation governing the time evolution of the shadow price ξ_S. The term in square brackets on the right-hand side of (19c) is particularly important for the development of the remaining parts of the model because it captures the firm's share of the quasi-rent generated by a job match. Consequently, in the remainder of the chapter we will denote it as

$$\triangle_S^f \equiv A_S(1-\alpha)(k_S/n_S)^{\alpha} - w_S. \tag{20}$$

Equations (19a) and (19c) can be used to obtain a dynamic law governing the conditions of the labor market. Indeed, combining (19a) and (19c), and then using (4) to substitute for $q(\theta_S)$, we get

$$\dot{\theta}_S = \left(\frac{\theta_S}{1-\epsilon}\right)\left[r_S + \delta_S - \frac{\triangle_S^f}{\gamma_S}\bar{z}_S\theta_S^{-(1-\epsilon)}\right], \tag{21}$$

Dynamic equation (21) is one of key equations of the model. It governs the dynamics of labor market tightness, θ_S, and characterizes the labor market conditions of South.

2.3.2 Northern firms

Similarly to South, Northern firms rent capital from households and hire workers on a frictional labor market. In doing so, they open vacancies in response to expected profits, each of which costs the firm $\gamma_N > 0$ and matches with a worker at the rate $q(\theta_N)$. Since all job searchers - i.e. native and immigrant unemployed workers - compete for the same vacancies v_N, the probability that a vacancy is matched with a worker of either the type "N" or "M" depends on the relative abundance of each labor type in the economy.

Let $\psi \equiv s_N/(\phi s_M + s_N)$ denote the relative abundance of native workers in the unemployment pool. For any given ψ, the probability that the vacancy is filled with the native worker is given by $q(\theta)\,\psi$, so that, at each moment of time, the motion of native employment in North is governed by

$$\dot{n}_N = q(\theta_N)\,\psi v_N - \delta_N n_N, \tag{22}$$

where δ_N is the separation rate of Northern employment.

Likewise, the probability that the vacancy is matched with an immigrant worker is given by $q(\theta_S)(1-\psi)$, while the time evolution of the immigrant employment is driven by

$$\dot{m} = q(\theta_N)(1-\psi)v_N - \delta_N m, \tag{23}$$

where $1-\psi = \phi s_M / (\phi s_M + s_N)$ captures the relative abundance of native workers in the unemployment pool of North.

Given a pair of initial conditions for native and immigrant employment, $n_N(0)$ and $m(0)$, the objective of the representative firm of North is to choose paths for n_N, k_N and m to maximize

$$V_N(0) = \int_t^{\infty} e^{-\int_t^h r_N(\omega)\mathrm{d}\omega} \pi_N \mathrm{d}h, \tag{24}$$

subject to (22), (23), and

$$\pi_N = A_N k_N^{\alpha} \left[(1-\lambda) n_N^{\eta} + \lambda m^{\eta}\right]^{(1-\alpha)/\eta} - r_N k_N - w_N n_N - w_M m - \gamma_N v_N. \tag{25}$$

Denoting the shadow prices of n_N and m by, respectively, ξ_N and ξ_M, the maximization entails the following set of first-order conditions

$$\xi_M + \psi(\xi_N - \xi_M) = \frac{\gamma_N}{q(\theta_N)} \tag{26a}$$

$$r_N = \alpha A_N k_N^{\alpha-1}[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}]^{(1-\alpha)/\eta} \tag{26b}$$

$$\dot{\xi}_N = (r_N + \delta_N)\xi_N - \left\{(1-\alpha)(1-\lambda) A_N k_N^{\alpha}[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} n_N^{\eta-1} - w_N\right\} \tag{26c}$$

$$\dot{\xi}_M = (r_N + \delta_N)\xi_M - \left\{(1-\alpha)\lambda A_N k_N^{\alpha}[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} m^{\eta-1} - w_M\right\}, \tag{26d}$$

where the first two equations (26a) and (26b) are the optimality conditions for posting vacancies and renting capital, and the two differential equations (26c) and (26d) are the two dynamic laws governing the time evolution of the shadow prices ξ_N and ξ_M. The two terms in curly brackets on the right-hand sides of (26c) and (26d) indicate the Northern firm's shares of the quasi-rent generated by the hiring of, respectively, a native and an immigrant worker, and are henceforth denoted by

$$\triangle_N^f \equiv (1-\alpha)A_N k_N^{\alpha}\left[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}\right]^{(1-\alpha-\eta)/\eta}(1-\lambda)n_N^{\eta-1} - w_N \tag{27}$$

$$\triangle_M^f \equiv (1-\alpha)A_N k_N^{\alpha}\left[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}\right]^{(1-\alpha-\eta)/\eta}\lambda m^{\eta-1} - w_M. \tag{28}$$

To obtain the dynamic equation governing the time path of θ_N, we proceed as follows. First, we define $\Omega \equiv \xi_N - \xi_M$, such that $\dot{\Omega} \equiv \dot{\xi}_N - \dot{\xi}_M$, and thus - via (26c) and (26d)

$$\dot{\Omega} \equiv (r_N + \delta_N)\Omega + \triangle_M^f - \triangle_N^f. \tag{29}$$

The variable Ω is a new endogenous variable to be determined in the equilibrium. It is equal the spread between the shadow price of native and immigrant employment and is thought to capture the relative convenience to hire an immigrant worker rather than a native worker.

Given Ω and its dynamic law (29), the next step consists in determining the dynamic law of θ_N. To do that, we time-differentiate (26a), and then use (8), (26c) and (26d) to substitute for $q(\theta_N)$, $\dot{\xi}_N$ and $\dot{\xi}_M$. This gives the following dynamic equation for θ_N

$$\dot{\theta}_N = \left(\frac{\theta_N}{1-\epsilon}\right)\left\{r_N + \delta_N - \left[\frac{\dot{\psi}\Omega - \psi\triangle_N^f + (1-\psi)\triangle_M^f}{\gamma_N}\right]\bar{z}_N\theta_N^{-(1-\epsilon)}\right\}, \tag{30}$$

Equations (29) and (30) are other two key equations of the model.

2.4 Remittances

In this chapter, both employed and unemployed immigrants remit part of their disposable income to their countries of origin.

Consider first the case of an employed immigrant worker that works at the current wage rate w_M and pays the lump-sum tax τ_N.At each moment of time, the worker saves a fraction of her income equal to the difference between the current disposable income, $w_M - \tau_N$, and consumption expenditure c_S. Hence, since the number of employed immigrants is equal to m, the aggregate flow of remittances coming from this type of immigrant worker is $R_E = (w_M - \tau_N - c_S)\, m$.

Consider now the case of an unemployed immigrant worker receiving the unemployment benefit b_M and paying the lump-sum tax τ_N. Similarly to the case of the Southern worker, her flow of remittances equates forgone consumption and can thus be written as the difference between disposable income, $b_M - \tau_N$, and consumption expenditure c_S. Because only ϕs_M units of Southern individuals reside in North as unemployed workers, the aggregate flow of remittances coming from this other type of immigrant worker is $R_U = (b_M - \tau_N - c_S)\, \phi s_M$.

Thus, by summing R_E and R_U, the overall flow of remittances moving from North to South at any moment of time is given by

$$R \equiv R_E + R_U = w_M m + b_M \phi s_M - (\tau_N + c_S)(m + \phi s_M). \tag{31}$$

2.5 Wage determination

In both countries, job matches generate economic quasi-rents and wages are set to share these quasi-rents through a wage Nash bargaining process. We assume that, in each country i, the bargained wage is the solution of the following maximization problem

$$w_i = \arg\max \left(\triangle_i^h\right)^{\chi} \left(\triangle_i^f\right)^{1-\chi}, \quad \chi \in (0,1),$$

where χ is the bargaining strength of workers, and $\triangle_i^h$ and $\triangle_i^f$ are the share of the match quasi-rent that go, respectively, to workers and firms.

In South, the joint value of the match is equal to the difference between the marginal productivity of labor, $\partial y_S / \partial n_S$, and the outside option of the Southern workers b_S. The share of the quasi-rent of firms, $\triangle_S^f$, is given by (20), while the share of workers can be obtained from the distribution rule $\triangle_S^h + \triangle_S^f = \partial y_S / \partial n_S - b_S$, and reads

$$\triangle_S^h = w_S - b_S. \tag{32}$$

Thus, using (20) and (32) to substitute for $\triangle_S^h$ and $\triangle_S^f$ in the above Nash bargaining program, and then solving the maximization for the bargained wage yields

$$w_S = \frac{\chi A_S (1-\alpha) \left(\frac{k_S}{n_S}\right)^{\alpha}}{1 - (1-\chi)\mu_S}, \tag{33}$$

where $\mu_S \in (0,1)$ denotes the replacement rate in South, so that $b_S \equiv \mu_S w_S$.

In North, the total value of the quasi-rent generated by a match depends on the type of the matched workers. In the case of a native worker, it is given by the difference between the marginal productivity of native labor, $\partial y_N/\partial n_N$, and the outside option of native workers b_N, while in the case of an immigrant worker, it is given by the difference between the marginal productivity of immigrant labor, $\partial y_N/\partial m$, and the outside option of immigrant workers b_M. Similarly to the case of the Southern economy, the shares of the quasi-rents that go to Northern firms are given by (27) and (28), while those that go to native and immigrant workers are determined from the two distribution rules $\triangle_N^h + \triangle_N^f = \partial y_N/\partial n_N - b_N$ and $\triangle_M^h + \triangle_M^f = \partial y_N/\partial m - b_M$. Indeed, solving these two equations for $\triangle_N^h$ and $\triangle_M^h$ and then substituting for $\triangle_N^f$ and $\triangle_M^f$ from (27) and (28), we obtain the following expressions

$$\triangle_N^h = w_N - b_N, \quad \triangle_M^h = w_N - b_M. \tag{34}$$

Plugging (27), (28) and (34), and then solving the resulting Nash bargaining problem for the two bargained wages of Northern and immigrant workers gives the following expressions

$$w_N = \frac{\chi\,(1-\alpha)\,A_N k_N^{\alpha}[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}]^{\frac{1-\alpha-\eta}{\eta}}\,(1-\lambda)\,n_N^{\eta-1}}{1-(1-\chi)\mu_N} \tag{35}$$

$$w_M = \frac{\chi\,(1-\alpha)\,A_N k_N^{\alpha}[(1-\lambda)n_N^{\eta} + \lambda m^{\eta}]^{\frac{1-\alpha-\eta}{\eta}}\,\lambda m^{\eta-1}}{1-(1-\chi)\mu_N}, \tag{36}$$

where $b_j \equiv \mu_N w_j$, and $\mu_N \in (0,1)$ is the replacement rate in North.

2.6 Governments

In this chapter, each local government is assumed to run a balanced-budget policy, in which social welfare expenditures are balanced by levying lump-sum taxes on the resident population.

From (1), it follows that the number of workers that currently reside in South and pay the lump-sum tax τ_S is $L_S = 1 - m - \phi s_M$, of which $(1-\phi)s_M$ of them are unemployed workers that receive the unemployment benefit $\mu_S w_S$ from the government. Accordingly, the Southern government's budget constraint can be written as

$$\tau_S(1 - m - \phi s_M) = \mu_S w_S (1-\phi) s_M. \tag{37}$$

Similarly, from (1), it follows that the number of individuals, both natives and immigrants, that currently reside in North and pay the lump-sum tax τ_N is $L_N = 1 + m + \phi s_M$, of which s_N natives and ϕs_M immigrants are currently unemployed workers receiving financial support from the Northern government. Thus, government's budget constraint in North can be written as

$$\tau_N(1 + m + \phi s_M) = \mu_N s_N w_N + \mu_N w_M \phi s_M. \tag{38}$$

Equations (37) and (38) complete the description of the model.

2.7 The steady-state equilibrium

In this section, we solve the model for the steady-state equilibrium. The general equilibrium of the model is characterized by a set of ten differential equations governing the long-run dynamics of the aggregate economy, and ten static equations establishing equilibrium relationships and prices.

The dynamic equations of the model are: the two Euler conditions for consumption (12) and (13); the two flow budget constraints of households, (10) and (11); the five dynamic laws for domestic employments, (16), (22) and (23), and labor market tightness, (21) and (30); the auxiliary costate variable capturing the relative shadow price of Northern employment, (29).

The ten static equations of the model are referred to: the resource constraints for all of the labor inputs, (1) and (5), the flow of remittances of immigrants (31), the ongoing levels of the interest rates and wages, (19b), (26b), (33), (35) and (36), and the balanced-budget rules of local governments (37) and (38).

In any steady-state equilibrium, consumption per capita, c_S and c_N, capital stocks, k_S and k_N, employments, n_S, n_N and m, labor market tightness, θ_S and θ_N, and the relative shadow price of Northern employment, Ω, are constant over time, as well as the flow of remittances, R, and input prices r_S, r_N, w_S, w_S and w_M. Formally, this means that, at each moment of time, it must be that $\dot{c}_S = \dot{k}_S = \dot{n}_S = \dot{m} = \dot{\theta}_S = \dot{c}_N = \dot{k}_N = \dot{n}_N = \dot{\theta}_N = \dot{\Omega} = 0$, such that the steady-state values of all of the aforementioned endogenous variables, denoted by "$\hat{}$", are defined by a set of thirteen steady-state conditions. Below we characterize the steady state system of the model.

We begin with the Euler conditions (12) and (13). In the steady-state, the domestic interest rates equate the marginal product of capital. Thus, we plug (19b) and (26b) into (12) and (13) yields

$$A_S\alpha\left(\frac{\hat{k}_S}{\hat{n}_S}\right)^{-(1-\alpha)} = \rho \tag{SS1}$$

$$\alpha A_N \hat{k}_N^{\alpha-1}\left[(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}\right]^{(1-\alpha)/\eta} = \rho. \tag{SS2}$$

The resource constraints of households are given by the flow budget constraints (10) and (11). Substituting for π_S and π_N from (18) and (25), and then using (33), (35) and (36) to substitute for w_S, w_N and w_M, we obtain

$$\begin{aligned} &A_S\hat{k}_S^{\alpha}\hat{n}_S^{1-\alpha}\left\{1+\frac{\mu_S\chi\left(1-\alpha\right)\left(1-\phi\right)\left(1-\hat{n}_S-\hat{m}\right)}{\left[1-\left(1-\chi\right)\mu_S\right]\hat{n}_S}\right\}+\hat{R}= \\ &=\gamma_S\hat{\theta}_S\left(1-\phi\right)\left(1-\hat{n}_S-\hat{m}\right)+\left(\hat{c}_S+\tau_S\right)\left[1-\hat{m}-\phi\left(1-\hat{n}_S-\hat{m}\right)\right] \end{aligned} \tag{SS3}$$

$$\begin{aligned} &\gamma_N\hat{\theta}_N\left[1-\hat{n}_N+\phi\left(1-\hat{n}_N-\hat{m}\right)\right]+\left(\hat{c}_N+\hat{\tau}_N\right)=A_N\hat{k}_N^{\alpha}\left[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}\right]^{\frac{1-\alpha}{\eta}}\times \\ &\times\left\{1+\frac{\chi\left(1-\alpha\right)\left[\mu_N\left(1-\lambda\right)\hat{n}_N^{\eta-1}\left(1-\hat{n}_N-\hat{m}\right)-\lambda\hat{m}^{\eta}\right]}{\left[1-(1-\chi)\mu_N\right]\left[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}\right]}\right\}, \end{aligned} \tag{SS4}$$

where, in order to obtain (SS3) and (SS4), the relationships $b_S = \mu_S w_S$, $b_N = \mu_N w_N$, $v_S = \theta_S\left(1-\phi\right)\left(1-n_S-m\right)$ and $v_N = \theta_N\left[1-n_N+\phi\left(1-n_N-m\right)\right]$ have been used.

The equilibrium flows of remittances, $\hat{R}$, and lump-sum taxes $\hat{\tau}_S$ and $\hat{\tau}_N$ appearing in (SS3) and (SS4) are determined by (31), (37) and (38). Using (1), (5), (33), (35) and (36) to substitute for s_N, s_M, w_S, w_N and w_M in (31), (37) and (38) and recalling that in this model $b_M = \mu_N w_M$, yields

$$\hat{R} = [\hat{m} + \mu_N \phi (1 - \hat{n}_S - \hat{m})] \frac{\chi (1-\alpha) A_N \hat{k}_N^{\alpha} [(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \lambda \hat{m}^{\eta-1}}{1-(1-\chi)\mu_N} -$$

$$- (\hat{\tau}_N + \hat{c}_S) [\hat{m} + \phi (1 - \hat{n}_S - \hat{m})] \tag{SS5}$$

$$\hat{\tau}_S [1 - \hat{m} - \phi (1 - \hat{n}_S - \hat{m})] = \mu_S \frac{\chi A_S (1-\alpha)(1-\phi)(1-\hat{n}_S - \hat{m})}{1-(1-\chi)\mu_S} \left(\frac{\hat{k}_S}{\hat{n}_S} \right)^{\alpha} \tag{SS6}$$

$$\hat{\tau}_N [1 + \hat{m} + \phi (1 - \hat{n}_S - \hat{m})] = \mu_N \chi (1-\alpha) A_N \hat{k}_N^{\alpha} [(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \times$$

$$\times \left\{ \frac{(1-\hat{n}_N)(1-\lambda)\hat{n}_N^{\eta-1} + \phi (1-\hat{n}_S - \hat{m}) \lambda \hat{m}^{\eta-1}}{1-(1-\chi)\mu_N} \right\}. \tag{SS7}$$

The time evolution of domestic employments is given by the dynamic equations (16), (22) and (23), while the conditions of the local labor markets are determined by (21) and (30). We begin by focusing on the steady-state conditions determining the values of domestic employments: $\hat{n}_S$, $\hat{n}_N$ and $\hat{m}$.

Using (4) and (8) to substitute for the job finding rates $q(\theta_S)$ and $q(\theta_N)$ from the right-hand sides of (16), (22) and (23), and recalling that $\psi = (1-n_N)/[1-n_N+\phi(1-n_N-m)]$, $v_S = \theta_S (1-\phi)(1-n_S-m)$ and $v_N = \theta_N [1-n_N+\phi(1-n_N-m)]$, we obtain the following triplet of steady-state conditions for native and migrant employments

$$(1-\phi)(1-\hat{n}_S-\hat{m}) \bar{z}_S \hat{\theta}_S^{\epsilon} = \delta_S \hat{n}_S \tag{SS8}$$

$$(1-\hat{n}_N) \bar{z}_N \hat{\theta}_N^{\epsilon} = \delta_N \hat{n}_N \tag{SS9}$$

$$\phi (1-\hat{n}_N-\hat{m}) \bar{z}_N \hat{\theta}_N^{\epsilon} = \delta_N \hat{m}. \tag{SS10}$$

Next, we turn to the labor-market tightness relationships (21) and (30). Recall that in the steady-state $\dot{\psi} = 0$. Thus, to obtain the steady-state conditions associated to (21) and (30) we proceed as follows. Firstly, we plug (33), (35) and (36) into the shares of quasi-rents of firms (20),(27) and (28). Then, we use the resulting expressions to substitutes for Δ_S^f, Δ_N^f and Δ_M^f in (21) and (30). Finally, we substitute for r_S and r_N from the right-hand sides of (21) and (30) by using first-order conditions (19b) and (26b). The result is

$$\alpha A_S \left(\frac{\hat{k}_S}{\hat{n}_S} \right)^{-(1-\alpha)} + \delta_S = (1-\alpha) A_S \left(\frac{\hat{k}_S}{\hat{n}_S} \right)^{\alpha} \frac{1-(1-\chi)\mu_S - \chi}{\gamma_S [1-(1-\chi)\mu_S]} \bar{z}_S \hat{\theta}_S^{-(1-\epsilon)} \tag{SS11}$$

$$\alpha A_N \hat{k}_N^{\alpha-1} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta} \right]^{(1-\alpha)/\eta} + \delta_N = (1-\alpha) A_N \hat{k}_N^{\alpha} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta} \right]^{\frac{1-\alpha-\eta}{\eta}} \times$$

$$\times \left\{ \frac{(1-\chi)(1-\mu_N) \left[(1-\hat{n}_N)(1-\lambda)\hat{n}_N^{\eta-1} + \phi (1-\hat{n}_N-\hat{m}) \lambda \hat{m}^{\eta-1} \right]}{\gamma_N [1-(1-\chi)\mu_N] [1-\hat{n}_N + \phi (1-\hat{n}_N-\hat{m})]} \right\} \bar{z}_N \hat{\theta}_N^{\epsilon-1}, \tag{SS12}$$

where, to obtain (SS11) and (SS12), we used $\psi = (1-n_N)/[1-n_N+\phi(1-n_N-m)]$.

Finally, setting the steady-state condition $\dot{\Omega} = 0$ to the auxiliary costate variable in equation (29), then using (26b) to substitute for the Northern interest rate, and equations (20), (27), (28), (33), (35) and (36) to substitute for all of firms' quasi-rent shares, Δ_S^f, Δ_N^f and Δ_M^f, and wage rates, w_S, w_N and w_M, we obtain the following steady-state condition for the auxiliary costate variable

$$\hat{\Omega} = \frac{(1-\alpha)A_N\hat{k}_N^{\alpha}\left[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}\right]^{\frac{1-\alpha-\eta}{\eta}}}{\left\{\alpha A_N\hat{k}_N^{\alpha-1}\left[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}\right]^{(1-\alpha)/\eta}+\delta_N\right\}}\times$$
$$\times\left\{\frac{(1-\chi)\left(1-\mu_N\right)\left[(1-\lambda)\hat{n}_N^{\eta-1}-\lambda\hat{m}^{\eta-1}\right]}{\gamma_N\left[1-(1-\chi)\mu_N\right]}\right\}. \qquad \text{(SS13)}$$

Equations (SS1)-(SS13) form a system of thirteen equations in thirteen unknowns: $\hat{c}_S$, $\hat{c}_N$, $\hat{k}_S$, $\hat{k}_N$, $\hat{R}$, $\hat{\tau}_S$, $\hat{\tau}_N$, $\hat{n}_S$, $\hat{n}_N$, $\hat{m}$, $\hat{\theta}_S$, $\hat{\theta}_N$, and $\hat{\Omega}$.

Proposition 1 *The model always predicts a unique, economically meaningful steady-state equilibrium with positive migration.*

Proof. See Appendix A. ■

Armed with this result, in the next section we will calibrate our model for the case of the U.S. economy and analyze the steady-state effects of a permanent increase in Southern workers looking for a job in North.

3 Rising migration effort in South

In the previous section, we have solved the model for the steady-state equilibrium and have demonstrated that the equilibrium with positive labor migration always exists and is unique. In what follows we explore the impact of an increase in migration flows by shocking the share of Southern unemployed members looking for a job in North, ϕ.[4] Due to the complexity of the model, we will perform this analysis through a simulation exercise. In doing so, we will take the period of the model to correspond to one quarter and calibrate all the exogenous parameters in order to match (*i*) the key statistics for the U.S. economy during the period 2007–2017; (*ii*) the recent empirical findings in the fields of international macroeconomics and international labor mobility.

3.1 Parametrization

Table 1 shows the benchmark values for all the calibrated parameters. Following Siegel (2002), we set the subjective discount rate ρ to 0.01, so that the annual interest rate is roughly 4%. Further, we choose the capital share parameter $\alpha = 0.33$ to match the empirical evidence of Gollin (2002). Hendricks (2002) finds – using data on immigrants earnings – that TFP contributes for a factor of 3 in explaining output per worker disparities between U.S. and low-income countries. For this reason, in the simulations we set $A_S = 1$ and $A_N = 3$.

[4] Several determinants may induce an increase in search effort for a job abroad – even exogenous ones, such as the erosion of political order recently experienced by a number of sending countries.

Parameter	Description	Value
ρ	Subjective discount rate	0.01
A_S	TFP of South	1
A_N	TFP of North	3
α	Capital share	0.33
σ	Substitution elasticity	20
λ	Productivity share	0.4206
ϕ	Share of Southern unemployed in North	0.2087
ϵ	Matching elasticity	0.5
χ	Worker bargaining power	0.5
δ_S	Southern separation rate	0.0475
δ_N	Northern separation rate	0.0488
γ_S	Southern vacancy cost	26.634
γ_N	Northern vacancy cost	74.235
$\bar{z}_S$	Southern matching efficiency	1
$\bar{z}_N$	Northern matching efficiency	1
μ_S	Southern replacement rate	0.31
μ_N	Northern replacement rate	0.62

Table 1: Benchmark parametrization of the model.

Recalling that $\sigma \equiv 1/(1-\eta)$, our choice of η is consistent with Ottaviano and Peri (2012), who find an elasticity of substitution between U.S. natives and immigrants with similar education and experience levels of 20. The share parameter $\lambda = 0.4206$ is thus chosen to match the wage ratio between native and migrant workers of 1.253 over the decade 2007-2017.[5]

As top sender countries are characterized by a lower unemployment rate than the U.S. during the considered period, we set the separation rates $\delta_S = 0.0475$ and $\delta_N = 0.0488$ so to match, respectively, the Mexico and U.S. unemployment rates of about 4.5% and 6.7%.[6] The share of Southern workers looking for a job abroad, ϕ, is instead set to match the equilibrium share of immigrant workers out of the total workforce in North close to the 13% of immigrant workers residing in U.S. over the period 2007-2017.[7] As far as the fiscal component is concerned, the Northern replacement rate μ_N is set to 0.62, soas to match the short-term unemployment

[5]Source: Current Population Survey (CPS) data.

[6]We take Mexico unemployment rate for reference as top sender country. The other top sender countries, namely China, India, and Philippines, have a similarly low unemployment rate of 4.4%, 3.6 and 3.4%, respectively. Source: International Labour Organization, ILOSTAT database.

[7]Source: America Community Survey (ACS) data.

benefits that single workers in the U.S. receive after loosing a job.[8] Because sending countries tend to have a far lower unemployment benefit coverage, we set the Southern replacement rate μ_S to 0.31, so that μ_N is twice as high as μ_S.[9]

Following the bulk of the literature on search and matching, we set the matching function parameter ϵ to 0.5 so as to allow it to fall within the range of estimates reported by Petrongolo and Pissarides (2001) and Mortensen and Nagypal (2007), and the worker bargaining power χ to 0.5, so as to meet the so-called Hosios condition (see Hosios, 1990). Further, we set the Southern vacancy cost to 26.634 so to obtain a Southern market tightness equal to one (i.e., as in Shimer, 2005, the worker finding rate is equal to the job finding rate), while the Northern vacancy cost is set to 74.235, coherently with U.S. market tightness of about 0.45.[10] Finally, we normalize the matching parameters $\bar{z}_S$ and $\bar{z}_N$ to one for simplicity.

Armed with the parametrization displayed in Table 1, in the next two sections we will evaluate the long-run effects of a 10% permanent increase in the share of Southern searchers looking for a job in North. We begin by assessing the macroeconomic effects of rising migration worldwide. Next, we turn to analyze the long-run impact on national welfare in both North and South.

3.2 The macroeconomic effects

Suppose both economies are in their own steady-state and suppose that at $t = 0$ an exogenous shock causes the share of search effort abroad ϕ to raise permanently by 10%. Table 2 shows the results of the comparative statics analysis.[11]

We begin from the Northern economy. In North, a permanent increase in the share of Southern searchers abroad, ϕ, makes immigrant employment in North, m, increase. This affects the economy in three different ways. Firstly, the rise in m increases the supply for labor in North and causes the marginal product of capital to deviate temporarily from its steady-state level, ρ. That causes firms to respond positively to the consequent increase in the marginal product of capital by spurring investment and capital accumulation until the marginal productivity equates the interest rate in the new steady state. Eventually, the increase in capital input (+1.11%), along with the increase in labor input, lead to a higher level of per capita output (+1.11%) and profits (+1.11%), and thus to higher per capita consumption in North (+0.54%).

Secondly, the rise in ϕ generates a slight displacement effect in the Northern labor market that hurts native employment. As both migrants and natives compete for the same vacancies, the increase in migration flows eventually lowers the amount of the employed natives (-0.02%), and increases that of the employed migrants (+10.59%). However, since competition between

[8] Source: OECD, Tax-Benefit Models

[9] In Appendix B we show a sensitivity analysis for different values of μ_S.

[10] Source: Federal Reserve Economic Data (FRED).

[11] As described in Section 2, in the model there are ten endogenous variables. Five of those are predetermined variables, and five are control variables. The Jacobian matrix of the linearized system evaluated around the steady-state possess five stable eigenvalues and five unstable ones, thus the Blanchard-Kahn conditions are met and the unique steady-state equilibrium is saddle-path stable (see Blanchard and Kahn, 1980).

Variable	South			North		
	Initial	Final	Variation	Initial	Final	Variation
c_i	4.3919	4.1444	0.51%	13.567	13.64	0.54%
k_i	149.85	147.04	-1.87%	562.84	569.118	1.11 %
n_i	0.8114	0.7962	-1.87%	0.9323	0.9322	-0.02%
m	n.a.	n.a.	n.a.	0.134	0.1548	10.59%
θ_i	1	1	0%	0.452	0.4498	-0.5%
y_i	4.5408	4.4558	-1.87%	17.056	17.246	1.11%
w_i	2.2188	2.2188	0%	7.9316	7.9361	0.06%
w_m	n.a	n.a.	n.a.	6.329	6.3011	-0.45%
Π_i	0.2161	0.2121	-1.87%	0.5352	0.5411	1.11%
R	0.2178	0.2325	6.76%	n.a.	n.a.	n.a.

Table 2: The steady-state effects of a 10% raising in migration effort – Comparative statics results.

workers intensifies due to the increase in the search effort coming from South, market tightness in North decreases in the post-shock equilibrium (-0.5%), implying a lower job-finding rate, $p(\theta_N)$, and a higher unemployment rate (+0.23%) for all Northern workers.

Lastly, a positive migration shock has asymmetric impacts on wages. Since migrants and natives are imperfect substitutes in production, the rise in the inflow of migrant workers increases competition among foreign-born workers, and decreases that among native workers. For this reason, the wage paid to migrant workers decreases (-0.45%), whereas the wage rate paid to domestic workers slightly increases (+0.06%). This completes the description of the macroeconomic effects in North of rising migration effort in South.

Consider now the Southern economy. Differently from North, in South the ultimate effect of a permanent rise in ϕ is to slim the local workforce and employment because of emigration. Southern firms respond to the fall in labor supply by reducing investment and shrinking the steady-state level of capital per worker (-1.87%). Consequently, in the post-shock steady-state equilibrium, per capita output, y_S, and profits, π_S, decrease permanently.

Interestingly, the fall in per capita income is not accompanied by a fall in consumption. As shown by Table 2, even though all the main macroeconomic variables of South experience a contraction, per capita consumption, c_S, shows a slight increase (+0.51%) because of the increase in remittances (+6.76% overall) due to the increase in emigration rate. In fact, since southern workers pool their income together regardless of their location, the increase in migration translates into a higher consumption for all Southern household's members around the world.

Curiously enough, despite the fall in labor supply due to emigration, in the long run the equilibrium wage rate of South does not change because of the shock. Such a finding is due to the interplay between the upward pressure coming from the reduced labor supply, and the downward pressure coming from lower capital accumulation. Eventually, the two effects compensate one another, thereby leading to no change in Southern wages in the post-shock equilibrium.

3.3 Welfare analysis

Once assessed the steady-state effects of migration on the main macroeconomic variables of the model, it is now time to restrict our attention to analyzing the long-run effects on consumer welfare. In doing so, we keep assuming that the global economy is in its own steady-state equilibrium and that, at $t = 0$, a shock causes the shock parameter ϕ to raise permanently by 10%.

From equation (9), we obtain the following indirect utility function we use as welfare index

$$\mathcal{W}_i = \frac{\log(\hat{c}_i)}{\rho},$$

which is a function of steady-state consumption $\hat{c}_i$.

As the steady-state consumption $\hat{c}_i$ depends on all the other steady-state variables of our model, an increase in ϕ generates an ambiguous impact on the households welfare that cannot be determined without a quantitative analysis. Our simulations show that the Southern welfare gain is around 0.35%, while the Northern welfare gain is about 0.2% (cf. Table 3).

	South			North		
Variable	Initial	Final	Variation	Initial	Final	Variation
c_i	4.3919	4.1444	0.51%	13.567	13.64	0.54%
W_i	147.98	148.49	0.35%	260.77	261.3	0.2 %

Table 3: Steady-state impact of migration on welfare.

This means that both households experience a welfare gain from an increased Southern search effort in North, though the Southern household gains relatively more than the Northern one.

4 Extension

In the baseline model of Section 2, central governments played no role in governing the process of labor migration. In this section, we extend the baseline model by assuming the existence of a protectionist government in North that wants to discourage domestic firms from hiring migrant workers through the imposing of a positive tax rate on immigrant employment. The main objective of the section is thus to study to what extent protectionist policies can be useful in improving employment opportunity for natives and rise national welfare.

We start by plugging the interventionist policy into the formal framework developed in Section 2. Then, we characterize the search equilibrium of the extended model and perform some comparative statics exercises for the case in which the Northern government introduces a 10 percent distortionary tax rate on domestic firms.

4.1 The search equilibrium with a protectionist government in North

Formally, the model is identical to that presented in the previous section except for the presence of a tax on foreign employment. Let $\tau_F \in [0,1)$ denote the tax rate on foreign employment in North. The new Northern government balance reads

$$\tau_N(1+m+\phi s_M)+\tau_F w_M m=\mu_N\left(s_N w_N+\phi s_M w_M\right), \tag{39}$$

where the left-hand side, i.e. (the government revenues), also includes the new term $\tau_F w_M m$, which indicates the amount of profits drained out from Northern firms that employ immigrant workers.

Households' preferences and firms' technologies are identical to those presented in Section 2. Consequently, no changes take places in the utility maximization problems of the Southern and Northern representative household, as well as in the profit maximization problem of the representative firm in South. However, the profit maximization of Northern producers changes to include the positive tax rate on foreign employment. In particular, because of the tax rate, the labor cost associated to each immigrant worker rises to $(1+\tau_F)\,w_M$, so the cash flow of the representative firm becomes

$$V_N(0)=\int_t^\infty e^{-\int_t^h r_N(\omega)\mathrm{d}\omega}\left[y_N-r_N k_N-w_N n_N-(1+\tau_F)\,w_M m-\gamma v_N\right]\mathrm{d}h. \tag{40}$$

The firm chooses quantities of v_N, k_N, m and n_N to maximize the (40) subject to the production technology (15) and the dynamic equations governing native and immigrant employment, (22) and (23). Using the same optimization methods employed to solve the dynamic problem of Section 2.3.2, we obtain the same first-orders conditions for v_N, k_N and n_N, but a different one for m, which reads

$$\dot{\xi}_M=(r_N+\delta_N)\,\xi_M-\Delta_M^f, \tag{41}$$

where the quasi-rent going to the representative Northern producer, Δ_M^f, in the presence of the distortionary tax is given by

$$\Delta_M^f\equiv(1-\alpha)\,\lambda A_N k_N^\alpha[(1-\lambda)n_N^\eta+\lambda m^\eta]^{\frac{1-\alpha-\eta}{\eta}}m^{\eta-1}-(1+\tau_F)w_M, \tag{42}$$

Using (42) to substitute for Δ_M^f in the Nash bargaining problem of Section 2.5, we obtain the following expression for the bargained wage rate of the immigrant workers

$$w_M=\frac{\chi\,(1-\alpha)\,\lambda A_N k_N^\alpha[(1-\lambda)n_N^\eta+\lambda m^\eta]^{\frac{1-\alpha-\eta}{\eta}}m^{\eta-1}}{\chi\tau_F+1-(1-\chi)\mu_N}, \tag{43}$$

which is decreasing in the new distortionary tax, τ_F, imposed by the government.

The dynamic and static equations of the extended model only differ from the benchmark model for the Northern firm surplus of hiring a migrant worker, which is now determined by equation (42), and by the new equation that determines the wage rate of immigrants (36). Overall, compared with the steady-state system of the baseline model of 2, the stationary conditions for variables $\hat{k}_S$, $\hat{k}_N$, $\hat{\tau}_S$, $\hat{n}_S$, $\hat{n}_N$, $\hat{m}$ and $\hat{\theta}_S$ do not change because of the protectionist government of North,[12] while the stationary conditions for the remaining endogenous variables $\hat{c}_S$, $\hat{c}_N$, $\hat{R}$, $\hat{\tau}_N$, $\hat{\theta}_N$ and $\hat{\Omega}$ do change considerably and have to be determined accordingly.

In fact, by making use of the same proceeding described in Section 2.7, it can be shown that the following steady-state equations hold for, respectively, households consumption, $\hat{c}_S$ and $\hat{c}_N$,

$$A_S \hat{k}_S^{\alpha} \hat{n}_S^{1-\alpha} \left\{ 1 + \frac{\mu_S \chi (1-\alpha)(1-\phi)(1-\hat{n}_S-\hat{m})}{[1-(1-\chi)\mu_S]\hat{n}_S} \right\} + \hat{R} =$$

$$= \gamma_S \hat{\theta}_S (1-\phi)(1-\hat{n}_S-\hat{m}) + (\hat{c}_S + \hat{\tau}_S)[1-\hat{m}-\phi(1-\hat{n}_S-\hat{m})] \tag{SS3.1}$$

$$\gamma_N \hat{\theta}_N [1-\hat{n}_N + \phi(1-\hat{n}_N-\hat{m})] + (\hat{c}_N + \hat{\tau}_N) = A_N \hat{k}_N^{\alpha} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}\right]^{\frac{1-\alpha}{\eta}} \{1 +$$

$$+ \frac{\chi(1-\alpha)}{(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}} \left[\frac{\mu_N (1-\lambda)\hat{n}_N^{\eta-1}(1-\hat{n}_N-\hat{m})}{1-(1-\chi)\mu_N} - \frac{\lambda \hat{m}^{\eta}}{\chi\tau_F + 1 - (1-\chi)\mu_N} \right] \Bigg\}, \tag{SS4.1}$$

remittances, $\hat{R}$, and Northern lump-sum tax, $\hat{\tau}_N$

$$\hat{R} = [\hat{m} + \mu_N \phi (1-\hat{n}_S-\hat{m})] \frac{\chi(1-\alpha) A_N \hat{k}_N^{\alpha} [(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \lambda \hat{m}^{\eta-1}}{\chi\tau_F + 1 - (1-\chi)\mu_N} -$$

$$- (\hat{\tau}_N + \hat{c}_S)[\hat{m} + \phi(1-\hat{n}_S-\hat{m})] \tag{SS5.1}$$

$$\tau_N [1 + \hat{m} + \phi(1-\hat{n}_S-\hat{m})] = \mu_N \chi (1-\alpha) A_N \hat{k}_N^{\alpha} [(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \times$$

$$\times \left\{ \frac{(1-\hat{n}_N)(1-\lambda)\hat{n}_N^{\eta-1}}{1-(1-\chi)\mu_N} + \frac{\phi(1-\hat{n}_S-\hat{m})\lambda\hat{m}^{\eta-1}}{\chi\tau_F + 1 - (1-\chi)\mu_N} \right\}. \tag{SS7.1}$$

Similarly, the steady-state equation for the labor market tightness of North changes, as the profitability of firms from migrant employment is affected by the distortionary tax τ_F. The result is

$$\alpha A_N \hat{k}_N^{\alpha-1} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}\right]^{(1-\alpha)/\eta} + \delta_N = (1-\alpha) A_N \hat{k}_N^{\alpha} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}\right]^{\frac{1-\alpha-\eta}{\eta}} \times$$

$$\Bigg\{ \frac{(1-\chi)(1-\mu_N)(1-\hat{n}_N)(1-\lambda)\hat{n}_N^{\eta-1}}{\gamma_N [1-(1-\chi)\mu_N][1-\hat{n}_N + \phi(1-\hat{n}_N-\hat{m})]} +$$

$$+ \frac{[\chi(\tau_F - 1) + 1 - (1-\chi)\mu_N]\phi(1-\hat{n}_N-\hat{m})\lambda\hat{m}^{\eta-1}}{\gamma_N [\chi\tau_F + 1 - (1-\chi)\mu_N][1-\hat{n}_N + \phi(1-\hat{n}_N-\hat{m})]} \Bigg\} \bar{z}_N \hat{\theta}_N^{-(1-\epsilon)}. \tag{SS12.1}$$

Finally, the steady-state equation for the auxiliary costate variable $\hat{\Omega}$ reads

$$\hat{\Omega} = \frac{(1-\alpha) A_N \hat{k}_N^{\alpha} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}\right]^{\frac{1-\alpha-\eta}{\eta}}}{\left\{ \alpha A_N \hat{k}_N^{\alpha-1} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda\hat{m}^{\eta}\right]^{(1-\alpha)/\eta} + \delta_N \right\}} \times$$

$$\times \left\{ \frac{(1-\chi)(1-\mu_N)(1-\lambda)\hat{n}_N^{\eta-1}}{\gamma_N [1-(1-\chi)\mu_N]} - \frac{[\chi(\tau_F - 1) + 1 - (1-\chi)\mu_N]\lambda\hat{m}^{\eta-1}}{\gamma_N [\chi\tau_F + 1 - (1-\chi)\mu_N]} \right\}. \tag{SS10.1}$$

[12] Namely, these conditions are (SS1), (SS2), (SS6), (SS8), (SS9), (SS10) and (SS11).

This completes the description of the steady-state equilibrium of the extended version of the model. In the next section, we will assess the steady-state effects of the immigration tax on the same endogenous variables discussed in Section 3.

4.2 Taxing immigrant employment

Suppose that both economies are in their own steady-state equilibrium, and suppose that at $t = 0$ the Northern government decides to lay a tax rate of 10% on the wage rate paid by native employers to immigrant workers. Making use of the same parametrization adopted in the baseline model, Table 5 reports the steady-state effects of the policy on the main macroeconomic variables of the model.[13]

	South			North		
Variable	Initial	Final	Variation	Initial	Final	Variation
c_i	4.3919	4.339	-1.2%	13.567	13.627	0.44%
k_i	149.85	150	0.1%	562.84	562.23	-0.11 %
n_i	0.8114	0.8122	0.1%	0.9323	0.9319	-0.05%
m	n.a.	n.a.	n.a.	0.134	0.1391	-0.61%
θ_i	1	1	0%	0.452	0.4456	-1.41%
y_i	4.5408	4.5453	0.1%	17.056	17.037	-0.11%
w_i	2.2188	2.2188	0%	7.9316	7.9314	-0.%
w_m	n.a	n.a.	n.a.	6.329	5.9032	-6.73%
Π_i	0.2161	0.2163	0.1%	0.5352	0.5307	-0.83%
R	0.2178	0.173	-20.11%	n.a.	n.a.	n.a.
$\mathcal{W}_i$	147.98	146.76	-0.82%	260.77	261.2	0.17%

Table 4: The steady-state effects of a 10% tax on immigrant employment – Comparative statics results.

In North, a 10 percent tax rate on immigrant wages affects the macroeconomic equilibrium through two interlinked channels: labor market conditions and capital accumulation. First, the introduction of the tax rate τ_F lowers Northern firms profitability (-0.83%) which, in turn, open less job vacancies (i.e. the market tightness decreases by 1.41%), hurting not only migrant employment (-0.61%), but also native one (-0.05%). Second, the overall fall in employment caused by the tax on migration induces Northern firms to rent less capital (-0.11%) and reduce production (-0.11%). This further result is due to the unitary elasticity of substitution between capital and labor inputs displayed by the Cobb-Douglas type production technology (15) used

[13] As in the quantitative analysis of the baseline model, the Blanchard-Kahn conditions are met and the unique steady-state equilibrium is saddle-path stable.

in North.

It is worth noticing how, despite of worsened labor market conditions, both native consumption and welfare increase due to the lower lump-sum tax that Northern workers pay in the post-shock steady-state (+0.44% and +0.17%, respectively). Indeed, taxing immigrant employment makes government revenues increase and, as a consequence, Northern government will lower the lump-sum tax paid by all workers residing in North until the budget balances again.

In South, the imposing of a positive tax rate on foreign employment in North affects the local macroeconomic equilibrium only indirectly through changes in the equilibrium flows of migration and per capita remittances. Firstly, the cut in immigrant employment undertaken in North significantly reduces the equilibrium wage rate of immigrant workers (-6.73%), and discourages Northern firms from employing immigrants, thereby implying that in the post-policy long-run equilibrium the share of household's members participating to the Southern labor market increases, making employment in South to raise by 0.11%. Secondly, increased labor supply induces Southern firms to increase their demand for capital (+0.11%), temporary speeding up the pace of capital accumulation and thus increasing production (+0.11%).

Curiously, Southern wage rates are not affected by the protectionist policy of North. Indeed, according to Table 5, in the post-policy steady state wages do not experience any change in their equilibrium levels because of the tax policy. Such a surprisingly result can be explained through the interaction of two offsetting effects, in which the shift in the labor demand schedule that positively affects w_S works simultaneously together with the increase in the labor supply that negatively affects w_S for compensating with each other.

Finally, concerning remittances, Table 5 shows that the downward correction on migrant wages generates a dramatic fall in remittances (-20.11%). Far from being harmless, the fall in remittances heavily affects Southern welfare because of the permanent fall in per capita consumption (-1.2%), which in turn causes the welfare index to decrease by 0.82%.

5 Sensitivity analysis on the elasticity of substitution

Because of the empirical disagreement on the degree of substitutability between immigrant and native workers (see Borjas et al., 2012), in this section we perform a sensitivity analysis on the elasticity of substitution between immigrant and native workers, σ. In these simulations we account for parametrization of $\sigma = (20, 50, 100, 1000)$ for both the baseline and the extended model. Table 5 shows the results of the sensitivity analysis.

Even when considering the case with the highest degree of substitutability ($\sigma = 1000$), the main results obtained in Section 3 and 4 hold unaffected, that is: (i) an increase in migration is able to slightly displace native employment but, at the same time, increases Northern production as well as welfare in both North and South; (ii) the imposition of a tax on firms hiring immigrant workers fails to promote native employment, though it is able to increase native welfare at the expense of capital accumulation and production.

This result underlines that our findings are robust to the assumption of imperfect substitutability between immigrant and native workers. Indeed, all steady-state variations preserve

Variable	Baseline				Extension			
	$\sigma = 20$	$\sigma = 50$	$\sigma = 100$	$\sigma = 1000$	$\sigma = 20$	$\sigma = 50$	$\sigma = 100$	$\sigma = 1000$
c_N	0.54	0.49	0.47	0.46	0.44	0.42	0.41	0.41
c_S	0.51	0.49	0.48	0.47	-1.2	-1.17	-1.15	-1.14
k_N	1.11	1.06	1.04	1.02	-0.11	-0.1	-0.1	-0.1
k_S	-1.87	-1.88	-1.88	-1.88	0.1	0.09	0.09	0.09
n_N	-0.02	-0.02	-0.02	-0.02	-0.05	-0.05	-0.04	-0.04
n_S	-1.87	-1.88	-1.88	-1.88	0.1	0.09	0.09	0.09
m	10.59	10.52	10.5	10.49	-0.61	-0.58	-0.57	-0.56
θ_N	-0.5	-0.6	-0.64	-0.67	-1.41	-1.34	-1.32	-1.3
θ_S	0	0	0	0	0	0	0	0
Y_N	1.11	1.06	1.04	1.02	-0.11	-0.1	-0.1	-0.1
Y_S	-1.87	-1.88	-1.88	-1.88	0.1	0.09	0.09	-0.09
w_N	0.06	0.02	0.01	0.	-0.	-0.	-0.	-0.
w_M	-0.45	-0.18	-0.09	-0.	-6.73	-6.75	-6.75	-6.76
w_S	0	0	0	0	0	0	0	0
Π_N	1.11	1.06	1.04	1.02	-0.83	-0.79	-0.77	-0.76
Π_S	-1.87	-1.88	-1.88	-1.88	0.1	0.09	0.09	0.09
R	6.76	7.65	8.01	8.36	-20.11	-23.17	-24.24	-25.30
$\mathcal{W}_N$	0.2	0.18	0.18	0.17	0.16	0.16	0.16	0.16
$\mathcal{W}_S$	0.35	0.33	0.33	0.32	-0.82	-0.8	-0.79	-0.79

Table 5: Sensitivity analysis on σ – steady-state variations in percentage points.

the same sign as in the benchmark parametrization, with differences in magnitudes being overall very modest. In particular, higher parametrizations of σ translate in slightly less optimistic post-shock variation for South and North in the benchmark version of our model. As the degree of substitutability between immigrants and natives increases, firms profitability from employing an additional immigrant decreases, so that capital accumulation and production decrease as well. In the extreme case of $\sigma \to \infty$, immigrant and native workers are perfect substitutes in production, and an increase in migration flows produce the same wage effects for both native and immigrant workers. That is why Table 5 shows that, as σ increases, variations on immigrant and native wages converge to the same percentage, 0, in the benchmark version of our model.

As far as the extended version of the model is concerned, higher calibration values of σ lead to less optimistic results for the North, but less pessimistic results for the South. This is because, as Northern firms find optimal to employ less immigrant workers when σ is higher, the protectionist policy turns out to benefit from a lower number of immigrants, thus generating a slightly lower welfare variations in both South and North.

6 Conclusions

In this chapter, we have analyzed the macroeconomic and social welfare impacts of international labor mobility through a two-country Ramsey-Cass-Koopmans model with labor market frictions and endogenous migration. In the model, workers have the opportunity to migrate from a low-TFP South towards a high-TFP North. The structure of the model enables us to (1) capture the effect of migration on the employment opportunities of native workers; (2) endogenously take into account the migration decision made by foreign workers; (3) address the role of remittances in consumption smoothing across the two economies. These aspects are largely overlooked by the general-equilibrium literature on migration and growth, which tends to abstract from employment issues and worker's decision on migration and remittances.

The analysis shows that there always exists a unique steady-state equilibrium for the world economy. In order to provide an assessment of the long-run impacts of a rise in migration effort on a global scale, we have calibrated our two-country model and performed a numerical simulation. Overall, our simulations generate three major findings. First, a permanent increase in migration causes per capita income and capital accumulation to rise in North, and to fall in South. Nonetheless, per capita consumption increases not only in the Northern country, but also in the Southern country, where a higher overall flow of received remittances is the main responsible for this result. Second, higher migration intensity spurs job competition in North, and generates a slight "displacement effect" that harms native employment. This result is consistent with what found by Card (2001) and Liu (2010), but in contrast with Ortega (2000), Moreno-Galbis and Tritah (2016), and Chassamboulli and Palivos (2014), who find that search friction may explain a positive employment effect of immigrants on natives. Third, households welfare is found to increase in both countries, with households welfare increasing relatively more in the low-TFP than in the high-TFP economy.

In the second part of this chapter, we have developed an extended version of the model in order to analyze to what extent a protectionist policy in North is able to support national employment and welfare by imposing a distortionary tax on the domestic firms who hire foreign workers in place of native ones. Our simulation shows that: on the one hand, this policy fails to promote native employment in North, damaging employers profitability who, as a consequence, post less job vacancies for both immigrants and natives, reducing capital accumulation and production as a consequence; on the other hand, the protectionist policy is able to slightly increase native consumption by redistributing the additional government revenues to unemployed workers in North.

We further perform a sensitivity analysis and find that, for both versions of the model, our results are robust across different degrees of substitutability between migrant and native workers.

Our analysis can be extended to address several issues for future research. One significant issue to be pursued in future work is to allow for endogenous growth. A number of studies have included migration flows in endogenous growth models, notably considering the role of immigrants on technological progress and their contribution to innovation (see, e.g., Lundborg and Segerstrom, 2000; Kim et al., 2010; Levine et al., 2010). However, these studies rely on the assumption of full employment labor markets, leaving potential interdependence concerns between labor market conditions and growth dynamics thus far unexplored. Another interesting issue to be considered is to extend our model for financial integration across the two economies. As empirical research suggests, migration may spur bilateral trade through a number of channels and, in turn, differently affect the relationship between migration and growth dynamics.

Appendix

A Proof of Proposition 1

This appendix provides the formal demonstration of the existence and unicity of the steady-state equilibrium of the model described in Section 2. To soften the notational burden, in what follows we adopt the following collection of given parameters: $\Psi_S \equiv (\alpha A_S/\rho)^{\frac{1}{1-\alpha}}$, $\Psi_N \equiv (\alpha A_N/\rho)^{\frac{1}{1-\alpha}}$, $\Phi_S \equiv (1-\phi)\,\bar{z}_S\delta_N$ and $\Phi_N \equiv \phi\bar{z}_N\delta_S$.

The system (SS1)-(SS13) used to solve the steady-state equilibrium of the model has a recursive structure. First, equations (SS1), (SS2), (SS8), (SS9) and (SS10) can be solved simultaneously for $\hat{k}_S$, $\hat{k}_N$, $\hat{n}_S$, $\hat{n}_N$ and $\hat{m}$ to get the following five steady-state conditions

$$\hat{k}_S = \frac{\Psi_S\Phi_S\hat{\theta}_S^{\epsilon}}{\delta_S\delta_N + \Phi_N\hat{\theta}_N^{\epsilon} + \Phi_S\hat{\theta}_S^{\epsilon}} \equiv \hat{k}_S(\hat{\theta}_S, \hat{\theta}_N) \tag{A1}$$

$$\hat{k}_N = \Psi_N\left[\lambda\left(\frac{\Phi_N\hat{\theta}_N^{\epsilon}}{\Phi_N\hat{\theta}_N^{\epsilon} + \delta_N\delta_S + \Phi_S\hat{\theta}_S^{\epsilon}}\right)^{\eta} + (1-\lambda)\left(\frac{\bar{z}_N\hat{\theta}_N^{\epsilon}}{\delta_N + \bar{z}_N\hat{\theta}_N^{\epsilon}}\right)^{\eta}\right]^{\frac{1}{\eta}} \equiv k_N(\hat{\theta}_S, \hat{\theta}_N) \tag{A2}$$

$$\hat{n}_S = \frac{\Phi_S\hat{\theta}_S^{\epsilon}}{\delta_S\delta_N + \Phi_N\theta_N^{\epsilon} + \Phi_S\hat{\theta}_S^{\epsilon}} \equiv \hat{n}_S(\hat{\theta}_S, \hat{\theta}_N) \tag{A3}$$

$$\hat{n}_N = \frac{\bar{z}_N\hat{\theta}_N^{\epsilon}}{\delta_N + \bar{z}_N\hat{\theta}_N^{\epsilon}} \equiv \hat{n}_N(\hat{\theta}_N) \tag{A4}$$

$$\hat{m} = \left(\frac{\Phi_N\hat{\theta}_N^{\epsilon}}{\Phi_N\hat{\theta}_N^{\epsilon} + \delta_N\delta_S + \Phi_S\hat{\theta}_S^{\epsilon}}\right) \equiv \hat{m}(\hat{\theta}_S, \hat{\theta}_N). \tag{A5}$$

Next plugging $\hat{k}_S(\hat{\theta}_S, \hat{\theta}_N)$, $\hat{k}_N(\hat{\theta}_S, \hat{\theta}_N)$, $\hat{n}_S(\hat{\theta}_S, \hat{\theta}_N)$ and $\hat{m}(\hat{\theta}_S, \hat{\theta}_N)$ into equation (SS11), after heavy simplification, we obtain the steady-state value for the Southern labor market tightness

$$\hat{\theta}_S = \left\{\frac{(1-\alpha)(1-\chi)A_S\,(1-\mu_S)\,\bar{z}_S\Psi_S^{\alpha}}{\gamma_S\,[1-\mu_S\,(1-\chi)]\left(\alpha A_S\Psi_S^{\alpha-1} + \delta_S\right)}\right\}^{\frac{1}{1-\epsilon}}. \tag{A6}$$

Based on functions (A1)-(A5), we can establish the following lemma.

Lemma 1 *$\hat{k}_S(\hat{\theta}_N)$, $\hat{k}_n(\hat{\theta}_N)$, $\hat{n}_S(\hat{\theta}_N)$, $\hat{n}_N(\hat{\theta}_N)$ and $\hat{m}(\hat{\theta}_N)$ are positive-valued functions for any $\hat{\theta}_N \in (0,\infty)$. Moreover, $k_S(\hat{\theta}_N)$ and $n_S(\hat{\theta}_N)$ are monotonically decreasing, while $k_N(\hat{\theta}_N)$, $n_n(\hat{\theta}_N)$ and $m(\hat{\theta}_N)$ are monotonically increasing and concave.*

Proof. It is easy to check that, since all parameters are positive, and the restrictions $\lambda \in (0,1)$, $\mu_S \in (0,1)$, $\alpha \in (0,1)$ and $\chi \in (0,1)$ apply, functions (A1)-(A5) and equation (A6) determine positive steady-state values for any $\hat{\theta}_N \in (0,\infty)$. Moreover, taking the partial derivative of (A1) and (A3) with respect to $\hat{\theta}_N$ yields

$$\hat{k}_S'(\hat{\theta}_N) = -\frac{\epsilon\Phi_N\Phi_S\Psi_S\hat{\theta}_N^{\epsilon-1}\theta_S^{\epsilon}}{\left(\delta_N\delta_S + \Phi_N\hat{\theta}_N^{\epsilon} + \Phi_S\hat{\theta}_S^{\epsilon}\right)^2} < 0$$

$$\hat{n}_S'(\hat{\theta}_N) = -\frac{\epsilon\Phi_N\Phi_S\hat{\theta}_N^{\epsilon-1}\hat{\theta}_S^{\epsilon}}{\left(\delta_N\delta_S + \Phi_N\hat{\theta}_N^{\epsilon} + \Phi_S\hat{\theta}_S^{\epsilon}\right)^2} < 0,$$

where $\hat{\theta}_S$ is a positive collection of parameters determined by equation (A6). Taking the first and second derivatives of (A2) and (A4), and recalling that $\epsilon \in (0, 1)$, we obtain

$$\hat{n}'_N(\hat{\theta}_N) = \frac{\epsilon \delta_N \bar{z}_N \hat{\theta}_N^{\epsilon-1}}{\left(\delta_N + \bar{z}_N \hat{\theta}_N^{\epsilon}\right)^2} > 0$$

$$\hat{n}''_N(\hat{\theta}_N) = \frac{\epsilon \delta_N \bar{z}_N \hat{\theta}_N^{\epsilon-2}\left[(\epsilon-1)\delta_N - (\epsilon+1)\bar{z}_N \hat{\theta}_N^{\epsilon}\right]}{\left(\delta_N + \bar{z}_N \hat{\theta}_N^{\epsilon}\right)^3} < 0$$

$$\hat{m}'(\hat{\theta}_N) = \frac{\epsilon \Phi_N \hat{\theta}_N^{\epsilon-1}\left(\delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}\right)}{\left(\delta_N \delta_S + \Phi_N \hat{\theta}_N^{\epsilon} + \Phi_S \hat{\theta}_S^{\epsilon}\right)^2} > 0$$

$$\hat{m}''(\hat{\theta}_N) = \frac{\epsilon \Phi_N \hat{\theta}_N^{\epsilon-2}\left(\delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}\right)\left[(\epsilon-1)\left(\delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}\right) - (\epsilon+1)\Phi_N \hat{\theta}_N^{\epsilon}\right]}{\left(\delta_N \delta_S + \Phi_N \hat{\theta}_N^{\epsilon} + \Phi_S \hat{\theta}_S^{\epsilon}\right)^3} < 0.$$

Finally, equation (A2) can be rewritten as follows

$$k_N(\hat{\theta}_N) = \Psi_N \left[\lambda \hat{m}^{\eta}(\hat{\theta}_N) + (1-\lambda)\hat{n}_N^{\eta}(\hat{\theta}_N)\right]^{\frac{1}{\eta}}. \tag{A2.1}$$

Since the functional form of $\hat{k}_N(\hat{\theta}_N)$ depends on $\hat{n}_N(\hat{\theta}_N)$ and $\hat{m}(\hat{\theta}_N)$, which are monotonically increasing and concave, we can conclude that $\hat{k}'_N(\hat{\theta}_N) > 0$ and $\hat{k}''_N(\hat{\theta}_N) < 0$. That completes the proof of Lemma 1.■

We now turn to the steady-state value of the Northern market tightness, $\hat{\theta}_N$. Using $\hat{k}_S(\hat{\theta}_N)$, $\hat{k}_N(\hat{\theta}_N)$, $\hat{n}_S(\hat{\theta}_N)$, $\hat{n}_N(\hat{\theta}_N)$ and $\hat{m}(\hat{\theta}_N)$ to substitute into equation (SS12), we obtain the following steady-state condition for the Northern market tightness

$$\begin{aligned}
&(\delta_N + \rho)\,\gamma_N \hat{\theta}_N \left[1 + (\chi - 1)\mu_N\right]\left(2\Phi_N \hat{\theta}_N^{\epsilon} + (1+\phi)\delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}\right) = \\
&= \Psi_N^{\alpha}(1-\chi)\,(1-\mu_N)\left(\delta_N + z_N \hat{\theta}_N^{\epsilon}\right)\left(\Phi_N \hat{\theta}_N^{\epsilon} + \delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}\right) \times \\
&\times (1-\alpha) A_N \left[\lambda \left(\frac{\Phi_N \hat{\theta}_N^{\epsilon}}{\Phi_N \hat{\theta}_N^{\epsilon} + \delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}}\right)^{\eta} + (1-\lambda)\left(\frac{z_N \hat{\theta}_N^{\epsilon}}{\delta_N + z_N \hat{\theta}_N^{\epsilon}}\right)^{\eta}\right]^{\frac{1}{\eta}}.
\end{aligned} \tag{A7}$$

Lemma 2 (*a*) *the function appearing on the left-hand side of* (A7) *is monotonically increasing and convex within* $\hat{\theta}_N \in (0, \infty)$*, and the function appearing on the right-hand side of* (A7) *is monotonically increasing and concave within* $\hat{\theta}_N \in (0, \infty)$*;* (*b*) *There exists only one intersecting point between the left- and right-hand side of* (A7)*.*

Proof. We begin by demonstrating the first part of the Lemma. The left- and right-hand-side of (A7) can be defined as follows

$$LHS(\hat{\theta}_N) = (\delta_N + \rho)\,\gamma_N \hat{\theta}_N \left[1 + (\chi - 1)\mu_N\right]\left(2\Phi_N \hat{\theta}_N^{\epsilon} + (1+\phi)\delta_N \delta_S + \Phi_S \hat{\theta}_S^{\epsilon}\right)$$

$$RHS(\hat{\theta}_N) = \Psi_N^{\alpha-1}(1-\chi)\,(1-\mu_N)\, g(\hat{\theta}_N) h(\hat{\theta}_N)(1-\alpha) A_N \hat{k}_N(\hat{\theta}_N),$$

where $g(\hat{\theta}_N) \equiv \left(\delta_N + z_N\hat{\theta}_N^{\epsilon}\right)$, $h(\hat{\theta}_N) \equiv \left(\Phi_N\hat{\theta}_N^{\epsilon} + \delta_N\delta_S + \Phi_S\hat{\theta}_S^{\epsilon}\right)$, and $\hat{k}_N(\hat{\theta}_N)$ is defined by equation (A2.1).

Function $LHS(\hat{\theta}_N)$ approaches 0 when $\hat{\theta}_N$ approaches 0, and $+\infty$ when $\hat{\theta}_N$ approaches $+\infty$. Since $\mu_N \in (0,1)$, we have that

$$LHS'(\hat{\theta}_N) = \gamma_N\left(\delta_N + \rho\right)\left[\left(\chi - 1\right)\mu_N + 1\right]\left[2\left(\epsilon + 1\right)P_N\hat{\theta}_N^{\epsilon} + \left(\phi + 1\right)\delta_N\delta_S + P_S\theta_S^{\epsilon}\right] > 0$$

$$LHS''(\hat{\theta}_N) = 2\epsilon(\epsilon + 1)\gamma_N P_N\left(\delta_N + \rho\right)\left((\chi - 1)\mu_N + 1\right)\hat{\theta}_N^{\epsilon - 1} > 0.$$

All these considerations lead us to conclude that the left-hand side of (A7) is monotonically increasing and concave for $\hat{\theta}_N > 0$.

We now turn to function $RHS(\hat{\theta}_N)$. $RHS(\hat{\theta}_N)$ approaches 0 when $\hat{\theta}_N$ approaches 0, while it approaches $+\infty$ when $\hat{\theta}_N$ approaches $+\infty$. Taking first and second derivatives of functions $g(\hat{\theta}_N)$ and $h(\hat{\theta}_N)$, it is easy to check that both functions are monotonically increasing and concave. Since all components of $RHS(\hat{\theta}_N)$ are monotonically increasing and concave for $\hat{\theta}_N \in (0,\infty)$, we can conclude that the function $RHS(\hat{\theta}_N)$ is monotonically increasing and concave as well. As a result, there exists only one intersecting point within $\hat{\theta}_N \in (0,\infty)$ such that $LHS(\hat{\theta}_N) = RHS(\hat{\theta}_N)$. That demonstrates the second part of the Lemma. ■

Figure 1 provides a graphical representation of the result obtained in Lemma 2. As $LHS(\hat{\theta}_N)$ is convex and $RHS(\hat{\theta}_N)$ is concave, and both functions approach 0 as $\hat{\theta}_N$ approaches 0, there exists only one value $\hat{\theta}_N \in (0,\infty)$ that solves equation (A7). Once $\hat{\theta}_N$ is obtained, $\hat{k}_S$, $\hat{k}_N$, $\hat{n}_S$, $\hat{n}_N$ and $\hat{m}$ can be recovered.

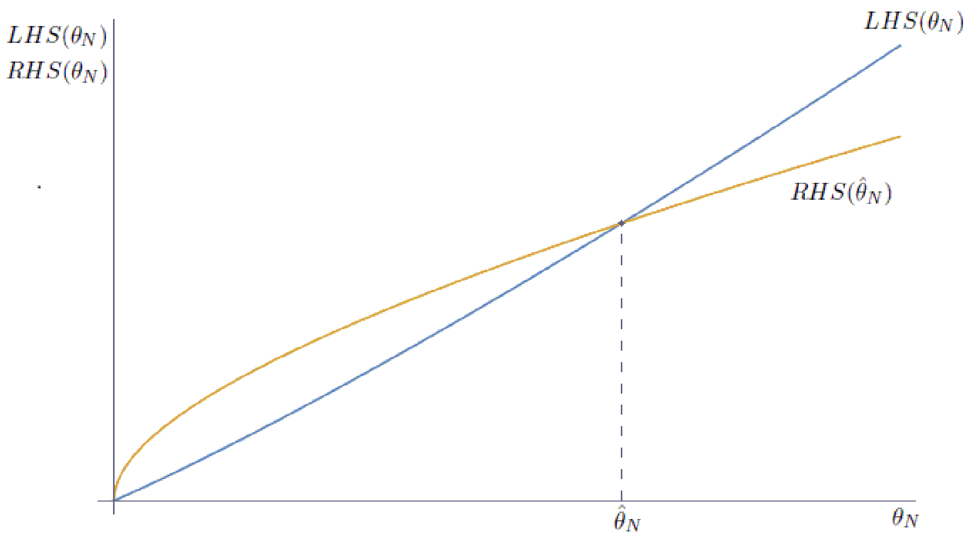

Figure 1: Steady-state value of the Northern labor market tightness.

Finally, using equation (SS5) to substitute $\hat{R}$ in equation (SS3), and plugging $\hat{k}_S$, $\hat{k}_N$, $\hat{n}_S$, $\hat{n}_N$, $\hat{m}$, $\hat{\theta}_S$ and $\hat{\theta}_N$ into equations (SS3), (SS4), (SS6), (SS7), and (29), we obtain the steady-state values for variables $\hat{c}_S$, $\hat{c}_N$, $\hat{\tau}_S$, $\hat{\tau}_N$ and $\hat{\Omega}$

$$\hat{c}_S = A_S \hat{k}_S^{\alpha} \hat{n}_S^{1-\alpha} + \frac{\chi(1-\alpha)\lambda A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \hat{m}^{\eta}}{1-(1-\chi)\mu_N} -$$
$$- \gamma_S \hat{\theta}_S (1-\phi)(1-\hat{n}_S - \hat{m}) - \frac{\mu_N (1-n_S)[\hat{m} + \phi(1-\hat{m}-\hat{n}_S)]}{1+\hat{m}+\phi(1-\hat{m}-\hat{n}_S)} \times$$
$$\times \frac{\chi(1-\alpha)(1-\lambda) A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{(1-\alpha-\eta)}{\eta}} \hat{n}_N^{\eta-1}}{1-(1-\chi)\mu_N} +$$
$$+ \frac{\phi \mu_N (1-\hat{m}-\hat{n}_S) \frac{\chi(1-\alpha)\lambda A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \hat{m}^{\eta-1}}{1-(1-\chi)\mu_N}}{1+\hat{m}+\phi(1-\hat{m}-\hat{n}_S)}$$

$$\hat{c}_N = A_N \hat{k}_N^{\alpha} \left[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}\right]^{(1-\alpha)/\eta} - \gamma_N \hat{\theta}_N \left[\phi(1-\hat{n}_S - \hat{m} + 1 - \hat{n}_N)\right] +$$
$$+ \frac{\mu_N (1-\hat{n}_S)[\hat{m} + \phi(1-\hat{n}_S - \hat{m})] \frac{\chi(1-\alpha)(1-\lambda) A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}]^{\frac{(1-\alpha-\eta)}{\eta}} \hat{n}_N^{\eta-1}}{1-(1-\chi)\mu_N}}{1+\hat{m}+\phi(1-\hat{m}-\hat{n}_S)} -$$
$$- \frac{\mu_N \phi (1-\hat{m}-\hat{n}_S) \frac{\chi(1-\alpha)\lambda A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta}+\lambda\hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \hat{m}^{\eta-1}}{1-(1-\chi)\mu_N}}{1+\hat{m}+\phi(1-\hat{m}-\hat{n}_S)} -$$
$$- \frac{\chi(1-\alpha)\lambda A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \hat{m}^{\eta}}{1-(1-\chi)\mu_N}$$

$$\hat{\tau}_S = \mu_S \frac{\chi A_S (1-\alpha)(1-\phi)(1-\hat{n}_S-\hat{m})}{[1-(1-\chi)\mu_S][1-\hat{m}-\phi(1-\hat{n}_S-\hat{m})]} \left(\frac{\hat{k}_S}{\hat{n}_S}\right)^{\alpha}$$

$$\hat{\tau}_N = \mu_N \chi (1-\alpha) A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}} \times$$
$$\times \left\{ \frac{(1-\hat{n}_N)(1-\lambda)\hat{n}_N^{\eta-1} + \phi(1-\hat{n}_S-\hat{m})\lambda \hat{m}^{\eta-1}}{[1-(1-\chi)\mu_N][1+\hat{m}+\phi(1-\hat{n}_S-\hat{m})]} \right\}$$

$$\hat{\Omega} = \frac{(1-\chi)(1-\mu_N)(1-\alpha) A_N \hat{k}_N^{\alpha}[(1-\lambda)\hat{n}_N^{\eta} + \lambda \hat{m}^{\eta}]^{\frac{1-\alpha-\eta}{\eta}}}{\left\{\alpha A_N \hat{k}_N^{-(1-\alpha)} \left[\lambda \hat{m}^{\eta} + (1-\lambda)\hat{n}_N^{\eta}\right]^{\frac{1-\alpha}{\eta}} + \delta_N \right\} [1-(1-\chi)\mu_S]} \times$$
$$\times \left[\lambda \hat{m}^{\eta-1} - (1-\lambda)\hat{n}_N^{\eta-1}\right],$$

which are always uniquely determined within $\hat{\theta}_N \in (0, \infty)$. That completes the proof of Proposition 1.■

B Sensitivity analysis on Southern replacement rate

This appendix provides results for the sensitivity analysis on the replacement rate in South, μ_S, for both the benchmark and extended versions of the model. In particular, we compare the benchmark parametrization ($\mu_S = 0.31$) with two extreme cases: (i) the case in which social protection for unemployed workers in South is absent ($\mu_S = 0$); (ii) the case in which the Southern government provides the same social protection scheme as in North by setting the same replacement rate ($\mu_S = 0.62$).

	Baseline			Extension		
Variable	$\mu_S = 0.31$	$\mu_S = 0$	$\mu_S = 0.62$	$\mu_S = 0.31$	$\mu_S = 0$	$\mu_S = 0.62$
c_N	0.54	0.48	0.65	0.44	0.39	0.54
c_S	0.51	0.57	0.45	-1.2	-1.12	-1.41
k_N	1.11	1	1.33	-0.11	-0.09	-0.15
k_S	-1.87	-2.5	-1.88	0.1	0.07	0.17
n_N	-0.02	-0.02	-0.02	-0.05	-0.04	-0.06
n_S	-1.87	-2.5	-1.88	0.1	0.07	0.17
m	10.59	10.93	9.82	-0.61	-0.54	-0.73
θ_N	-0.5	-0.44	-0.61	-1.41	-1.23	-1.8
θ_S	0	0	0	0	0	0
Y_N	1.11	1	1.33	-0.11	-0.09	-0.15
Y_S	-1.87	-2.5	-1.88	0.11	0.07	0.17
w_N	0.06	0.05	0.01	-0.	-0.	-0.
w_M	-0.45	-0.47	-0.4	-6.73	-6.73	-6.73
w_S	0	0	0	0	0	0
Π_N	1.11	1	1.33	-0.83	-0.71	-1.08
Π_S	-1.87	-1.5	-2.5	0.1	0.07	0.17
R	6.76	7.57	5.09	-20.11	-18.27	-24.42
$\mathcal{W}_N$	0.2	0.18	0.25	0.16	0.15	0.2
$\mathcal{W}_S$	0.35	0.4	0.29	-0.82	-0.79	-0.92

Table 6: Sensitivity analysis on μ_S – steady-state variations in percentage points.

Table 6 shows that the results obtained in Section 3 and 4 hold mostly unaffected: all steady-state variations preserve the same sign as in the benchmark parametrization, with modest differences in magnitudes across the three different cases.

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