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ENDOGENOUS IMMIGRATION, HUMAN AND PHYSICAL CAPITAL FORMATION, AND THE IMMIGRATION SURPLUS

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ABSTRACT

We evaluate the economic consequences of immigration in a two-country, two-skill, overlapping-generations framework, where immigration, population, human and physical capital formation, and economic growth are endogenous variables. We go beyond extant literature by integrating physical capital in our model. This enables the derivation of new insights about the induced-immigration effects of exogenous triggers, including pull and push factors and policy variables, on the dynamic evolution of the "immigration surplus" in the short run versus the long run, in destination vs. source countries and in the global economy. The policy shifts we analyze include the easing of constraints on potential migrants' labor and physical capital mobility, and the role of physical capital endowments. We also discuss the policy implications of asymmetries in the net benefits from immigration across destination and source countries.

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1. Introduction

The growing quantitative importance of immigration in the U.S. and throughout the world in the last half century has brought about renewed interest in the economic consequences of immigration, especially for receiving countries, where large immigration flows have brought about significant economic, demographic, and political challenges. The immigrant population stock has risen continuously worldwide, and has multiplied by about 3 times since 1970 from 84.5 million, or 2.3% of the world population, to 271.6 million, or 3.5% of the world population in 2019. In the U.S., which has been historically the largest immigration host country, immigration reached a peak of 14.8% as a percentage of the population in 1890, but had then continuously declined since about 1910, especially from 1929 to 1970. However, a modern new wave of immigration to the U.S. has also begun in that year, rising sharply from 9.6 million, or 4.7% of the U.S. population, to 40 million in 2010 or 12.9%, and to 44.8 million, or 13.7% of the population in 2018 (see Figure 1).[3]

Discreet changes in immigration laws[4] may explain some of the sharp turning points in immigration flows in Figure 1, but the varying trends in the pace of immigration in the U.S. and throughout the world require a deeper explanation. We ascribe them, more generally, to the role of major immigration triggers, or "pull" and "push" factors in destination and source countries, using a general (global) equilibrium analysis. These triggers can induce changes in human and physical capital formation and affect the volume and composition of immigration flows or waves, which generate added effects on the economy's equilibrium growth paths. We use this approach to asses both the growth, demographic, and distributional consequences of immigration triggers in the sending and receiving countries, as well as their impact on the net benefit from immigration to native populations in these countries – what is generally termed the "immigration surplus" (IS).

Our approach offers some new insights concerning the economic and policy implications of immigration. The bulk of the extant literature on these topics tends to focus on the outcomes for current generations of natives and immigrants in receiving countries. Much less attention has been paid to the long-term consequences of immigration on the outcomes for future generations of natives and immigrants in both destination (D) and source (S) countries and the global economy.

In the conventional literature, more immigration generally involves contrasting shifts in labor supply in the destination and source countries – the analysis largely abstracts from the possibility that immigrants can bring along not just their labor capacity but (claims for) physical capital as well. In that case, the upward shift in labor supply in D, for example, inevitably depresses the wage rate of native workers in D and thus raises the return to native owners of physical capital in D. Abstracting from any significant changes in human and physical capital and fertility, the short-term, or static IS generated by labor supply is always positive. The reason is that the returns on the economy's fixed capital stock, assumed to be exclusively owned by natives, necessarily outweighs the loss of wages to native workers due to the overall increase in output, which is now produced at lower wages and higher returns to capital for natives in D. However, this analysis misses a

[3] As per the Migration Policy Institute, *U.S. Immigrant Population and Share over Time, 1850-Present*. https://www.migrationpolicy.org/programs/data-hub/charts/immigrant-population-over-time.

[4] Such as the Immigration Act of 1903 and the Naturalization Act of 1906 that placed restrictions on admissible immigrants, and the Immigration and Naturalization Act of 1965 (the Hart-Celler Act) that relaxed many restrictions on immigrations.

critical aspect of migration by considering it an exogenous event rather than an endogenous choice variable, motivated by immigrants' desire for a better life for themselves and their offspring in the destination country. As we show in this paper, while immigration flows due to any external immigration trigger will generally (but not always) generate a positive IS for natives of country D in the short term, or what we call the "static" case, the longer-term surplus may turn negative, depending on the type of trigger that induces the immigration flow. Emigration flows in country S may generally (again, not always) generate the opposite effects.

A recent paper that addresses a number of these issues is Ehrlich and Kim [EK] (2015), which offered the basic approach used in this paper, treating migration as well as income and population growth as endogenous variables. One limitation of the EK model, however, is that it abstracts from the role of physical capital in production. The estimated net benefits from migration are therefore not directly comparable to those estimated in the conventional literature. This is because in the absence of physical capital, that model cannot assess the short, as well as long-term dynamic impacts of migration on factor prices, which is the channel through which the conventional immigration surplus is determined.

Our paper attempts to fill this gap. We expand and modify the latter model to allow for the role of physical capital as an essential factor of production as well as a reproducible (through saving) and *bequeathable* asset. Human capital remains our engine of growth, but production of goods requires both physical capital and effective labor, (augmented by human capital). Each agent (family head, worker) lives through two periods – childhood and parenthood. The model allows for heterogeneities within and across countries. Specifically, it recognizes two types of agents, high skilled and low skilled, who differ in their ability to produce human capital; two countries which differ in their development levels or technologies of producing both human capital and consumption goods; and two sectors producing two types of goods, high-tech and low-tech which employ exclusively high-skilled and low-skilled workers, respectively.[5] Finally, the decision makers are finitely lived parents who make all consumption, investment, and fertility decisions. Parents are altruistic toward their offspring and are assumed to derive altruistic benefits vicariously from both the value of the human capital stock they help produce in their offspring, and the value of the physical capital stock they bequeath to them. Fertility, thus population growth, is also an endogenous variable, along with savings and investment in children's human capital.

A distinct characteristic of the human capital production function in this model, as well as in the EK (2015) model, is that it allows for knowledge spillover effects across countries, as well as across different skill groups. In this context, however, both models consider two related versions. In the *benchmark model*, the analysis emphasizes the role of hierarchical knowledge spillover effects across the skill groups. Thus, the top skill group within each country produces knowledge spillover effect that augments the production functions of human capital of the lower skilled workers in D (S), respectively. The same hierarchical knowledge spillover effects are assumed to run from each skill group in D to its corresponding skill group in S. In this context, the top skill group in country D is the source of producing knowledge spillover effects both within and across countries. This pattern of knowledge spillover effects is essential for producing a balanced-growth equilibrium and income distribution within and across countries in our model. We also allow,

[5] The introduction of 2 skill groups in the model is necessary to allow for potential gains from immigration in the same way that we need to have 2 goods in each economy for potential gains from trade.

however, for an *extended model* version, which differs from the benchmark version by recognizing two-way spillover or "diversity effects" across immigrants and natives in the destination country (D). In this case, knowledge transfers can be two-sided, or interactive, as well as hierarchical.

To allow for numerical solutions of our complex model, we calibrate our model using the U.S. as our destination country and the weighted average of top 15 countries sending migrants to the U.S. as our source country. We then derive comparative dynamic effects of shifts in basic exogenous parameters of the model that capture the *total* effects of major shocks or immigration triggers on the balanced growth paths of the key control and state variables of the model. The latter include the skill composition of migrant flows, the fertility rates and population shares of natives and immigrants, the relative levels vs. growth rates of human and physical capital, and the level and distribution of income across different skill groups and countries.

A portion of these shocks reflects the specific effects of the immigration flows that are *induced* by the triggers on the individual market income of native populations, which is what the literature defines as the "immigration surplus".[6] In this context, we study the economic consequences of migration by exploring three related outcomes that the EK model could not address. First, we simulate the long-term dynamic path of the immigration surplus over the transition period, from its static value to its long-term equilibrium value, and determine the magnitude and direction of change of the corresponding values. Second, and related, we explore how *different* immigration triggers – demand pull and supply push factors – impact the IS dynamic path and the comparison between its static and long-term equilibrium values across D and S countries, as well as in the global economy. Third, we explore the implications of policies affecting both skilled labor and physical capital mobility at the individual migrant level, as well as the role of natural resources, or fixed capital endowments that affect both the incentive to migrate as well as the net welfare implications of immigration. This allows for a more comprehensive assessment of immigration flows and thus population shares across countries in different levels of development.

Policy implications: An advantage of our model is that we can use it to perform policy analyses concerning the impact of immigration policy shifts that can affect human and physical capital formation, and thus net per-capita income and income distribution within and across countries. Assuming free international mobility of labor and individual migrant's assets, and alternative pull and push factors, we find that in the majority of the cases, the immigration effects are asymmetrical within countries as well as across countries, which raises a question about the political stability of the equilibrium solutions we derive. This indicates the reasons why most countries invoke immigration policies that regulate specific migration flows via quotas, or apply selective requirements on immigrants based on educational attainments, occupation, health, and work experience, even in cases where immigration generates complementarities in innovation or the production of human capital across natives and immigrants.

The regulatory changes we model include hypothetical as well as actually enforced regulatory restrictions on labor and individual migrant's capital mobility by both destination and source countries. These include restrictions on the emigration of high-skilled workers by the source

[6] Our reliance on GDP per-capita, or market income, as a measure of the gains from migration deviates from that of EK (2015) which uses "full income" as a measure, which includes the opportunity costs of non-market activities. We focus on per-capita income, which is the conventional measure of the immigration surplus.

countries, to limit the "brain drain", or similar restrictions on the immigration of low-skilled workers in D. We also consider the impact of two types of changes involving physical capital. They include giving preference to immigrants who bring along with them more (claims to) physical capital and the impact of physical capital endowments, or natural resources, on immigration flows and the IS in D, S, and the global economy.

The structure of the paper is as follows: In section 2 we briefly review extant literature that has some bearing on our analysis. Section 3 introduces our benchmark and extended models of immigration in an open global economy. Section 4 derives the overall equilibrium effects of immigration triggers in our benchmark and extended models by simulating the comparative dynamic, macro-level outcomes of three types of triggers: pull factor shocks, push factor shocks and policy shocks and their equilibrium, steady state implications. Section 5 derives the transitional dynamic paths of the total outcomes of three major pull and push factors and the induced immigration effects that contribute to these outcomes. In section 6 we pull together the results of sections 3, 4 and 5 to derive the immigration surplus for our destination and source countries as well as the global economy. In section 7 we analyze the impact of policy interventions concerning labor and individual migrant's capital assets, and in section 8 we simulate a model extension where D acquires some capital endowment. In section 9 we discuss the asymmetries we find in the net benefits from immigration across D and S. We conclude with key takeaways in section 10.

2. Literature Review

As pointed out in the introduction, Ehrlich and Kim (2015) offers a model of endogenous immigration, which we follow in this paper as well, where human capital is the only capital asset. To our knowledge, however, this paper is the first attempt in the literature to treat immigration, both human and physical capital formation, population growth, and economic growth as endogenous variables in a global equilibrium setting. In this section, we discuss some earlier papers where the role of some of these variables is recognized and discussed.

The conventional literature has dealt with the economic costs and benefits of immigration in terms of its impact on the per capita GDP of natives in the destination country resulting from an exogenous rise in migration. In a static model, any rise in labor supply due to migration lowers labor wages, but increases the return to physical capital. The higher return to physical capital outweighs the fall in labor income due to the larger output generated through immigration. Consequently, the net effect on natives as a whole is positive. Borjas (1995) measures the immigration surplus in the U.S. in a static model where productivity, physical capital, and labor supply are all fixed, and finds that the immigration surplus is less than one percent of the U.S. GDP.

Ben-Gad (2004) examines the economic effects of exogenous immigration using a neoclassical growth model with physical capital accumulation and elastic labor supply. When capital and labor can adjust, the negative effects on wages and the positive effects on rate of return to physical capital are much smaller, and consequently the benefits from immigration are even more modest. Ben-Gad (2008) furthers expands this analysis in a neoclassical growth model by introducing capital-skill complementarities. Because of such complementarities, an increase in the number of skilled immigrants generates a much larger immigration surplus than that generated by an equal increase in the number of unskilled immigrants. Benhabib and Jovanovic (2012) analyze migration from the perspective of a world social planner, and argue that optimal migration that maximizes world welfare should be much higher than the level observed in reality. Storesletten (2000) studies the fiscal side of migration in an overlapping-generations model and finds that admitting middle-aged high-skilled immigrants is most beneficial fiscally.

These papers have either a static model or a neoclassical growth model, so the engine of per-capita income growth in these papers is exogenous, and these papers cannot account for the growth effects (whether positive or negative) due to migration. Several other papers do focus on endogenous growth, but treat migration as an exogenous variable.[7] For example, Lundborg and Segerstrom (2000) build an open-economy model with two trading countries that are similar in production technology (North-North) but have different population sizes. Firms in both countries develop new products by hiring workers in the R&D production. Therefore, there are efficiency gains from workers migrating from the more populated to the less populated country. Lundborg and Segerstrom (2002) develop a similar model where one country has a more advanced R&D production technology than the other (North-South). There is some efficiency gain when migrants move from South to North to engage in R&D.

Drinkwater et al. (2007) build an endogenous growth model with R&D production serving as the engine of growth. In their model, there are two types of workers, skilled and unskilled, and employment in R&D is relatively skill-intensive. The authors study the impact of an exogenous increase in migration. Their simulations show that the receiving country gains from migration of exclusively skilled migrants, because a larger volume of skilled workers creates greater incentives to engage in R&D production. But the receiving country loses if migration is just low skilled.

In a paper addressing the role of human capital in an endogenous growth context, Zak, Feng, and Kugler (2002) develop an overlapping-generations model where growth occurs through human capital formation. However, there is no investment in human capital in the model, and children's human capital increases if parents choose to lower fertility. Simulations of the model illustrate that an inflow of low-skilled migrants can cause middle-income countries to slide back into poverty, but such inflow to developed countries has only short run contraction effects. Overall, receiving countries are more likely to benefit from migrants with higher levels of human capital.

While the papers discussed in the preceding paragraphs deal with similar issues we explore in this paper and reach some similar conclusions, these papers neither treat immigration or population as endogenous nor address the distinct contributions of physical capital to the net benefits of immigration. We attempt to do so in the following sections.

[7] There is also a large literature on economic growth with either human capital or technological innovation serving as the engine of growth, but in a closed economy setting. For example, Lucas (1988), Stokey (1988), Becker, Murphy and Tamura (1990), Romer (1990), Ehrlich and Lui (1991), and Ehrlich and Kim (2007).

3. The Benchmark Model

Following EK (2015), our model adopts a two-country, two-skill, and two-sector overlapping generations model, where immigration and economic growth are the endogenous variables, investment in human capital is the engine of growth, and parents make investment decisions about the number and human-capital levels of their offspring, thus making population and human capital accumulation in each country endogenous variables as well. Knowledge spillover effects between workers of different *endowed* skill levels within and across countries are required to support the existence of a global dynamic equilibrium steady state. In addition, balanced global equilibrium requires that destination and source countries differ in their levels of technology in the productions of goods and human capital, and in their fertility rates. Unlike EK (2015), however, we allow for the role of physical capital as the second productive asset in the economy and specify the production functions in the economy's two sectors – the high-tech and low-tech sectors – to include both effective labor and physical capital. This allows us to recognize the essential roles of both human and physical capital in production, and their relevance for immigration dynamics, the measurement of the immigration surplus, and policies affecting labor and capital assets' mobility.

3.1 The Global Economic Environment

The global economy consists of two countries linked by migration: destination (D) and source (S) countries. Both countries experience persistent endogenous growth. Each country includes two types of agents, high skilled ($j = 1$) and low killed ($j = 2$), and two corresponding production sectors, high-tech and low-tech, employing exclusively both natives and immigrant workers of either high or low skill level ($i = d, s, m$). There are thus six distinct groups of agents in the global economy at each point in time: high-skilled and low-skilled in D; high-skilled and low-skilled in S; and high-skilled and low-skilled who migrate from S to D.[8] The model assumes that both D and S allow for labor and capital assets' mobility at the individual-migrant level, subject to corresponding transaction and friction costs. Our calibrated simulations consider, however, the impact of policies that lower such costs as well.

Agents live over two periods: childhood and adulthood. Adults make consumption, employment, fertility, investments in children's human capital, savings, and migration decisions. Only adults can migrate, and they bring their families along. Children's human capital is formed via parental investments. Because adulthood lasts one period, any savings turn into bequest, which offspring inherit when they become adults. Parents are thus necessarily altruistic in our model.

3.2 Human Capital Formation

The accumulation of human capital is the product of optimal parental investment decisions and is subject to three types of knowledge spillover effects: across generations, within countries, and across countries. The intergenerational spillover effects involve transmission of knowledge from parents to children. The within-country spillover effects result from social interaction between the

[8] As in EK (2015) the allowance for two exogenously determined skill types of agents in our model is a critical condition for the existence of any positive benefits from immigration to natives in D. This is because under a single skill-type agent, immigrants would always lower the average human capital level in the population, and thus per-capita income in D, regardless of the nature of the immigration trigger.

two skill, or distinct ability, population groups in each country and are hierarchical: they flow from higher to lower skill group. The cross-country spillover effects take place across similar skill groups in D and S and flow from D to S due to the former's technological advantage. By these assumptions, the high-skilled group in the destination country is the source of all spillover effects in the global economy.

The human capital formation functions are specified in continuous-time, (as in Lucas 1988), but augmented by the respective spillover effects as follows:

$$\begin{aligned} H_{t+1}^{d1} &= A^{d1} h_t^{d1} H_t^{d1} \\ H_{t+1}^{d2} &= A^{d2} h_t^{d2} H_t^{d2} \left(\Delta_t^{dd2}\right)^{\gamma^1} \\ H_{t+1}^{m1} &= A^{d1} h_t^{m1} H_t^{s1} \\ H_{t+1}^{m2} &= A^{d2} h_t^{m2} H_t^{s2} \left(\Delta_t^{dd2}\right)^{\gamma^1} \\ H_{t+1}^{s1} &= A^{s1} h_t^{s1} H_t^{s1} \left(\Delta_t^{ds1}\right)^{\gamma^2} \\ H_{t+1}^{s2} &= A^{s2} h_t^{s2} H_t^{s2} \left(\Delta_t^{ds2}\right)^{\gamma^2} (\Delta_t^{ss2})^{\gamma^1} \end{aligned} \quad (1)$$

where $\gamma^j < 1$ guarantees concave production functions of human capital. In all production functions, H_t^{ij} and H_{t+1}^{ij} ($i = d, s, m$; $j = 1, 2$), measure the level of human capital attained by parents' (t) and children's $(t+1)$ generations, and h_t^{ij} measures the share of earning capacity a parent in skill group j $(= 1, 2)$ in country i $(= d, s, m)$ invests in educating each of her children.[9] The productivity of these investments, denoted by A^{ij}, is influenced, however, by endowed elements of heterogeneity that are skill-specific as well as country-specific. We assume that the productivity of human capital investment is hierarchical, i.e., it is higher for the high-skilled relative to the low-skilled group within each country ($A^{i1} > A^{i2}$), and the productivity is also higher for each skill group in the more technologically-advanced destination country, D, relative to their skill counterparts in the less developed source country, S ($A^{dj} > A^{sj}$). These hierarchical assumptions are also part of the critical conditions for a balanced growth equilibrium to exist, as we show later in the analysis.

The knowledge spillover effects (Δ) in these human capital production functions are also hierarchical. The hierarchy implies that the knowledge spillover effect flows from the high-skilled in D or S ("teachers") to the low-skilled ("students") in the same country, and from skill j in D onto the corresponding skill j in S. Specifically, the spillover effects assume the following forms:

$$\begin{aligned} \Delta_t^{dd2} &= \frac{N_t^{d1} H_t^{d1} + M_t^1 H_t^{s1}}{N_t^{d2} H_t^{d2} + M_t^2 H_t^{s2}} \\ \Delta_t^{ss2} &= \frac{N_t^{s1} H_t^{s1} - M_t^1 H_t^{s1}}{N_t^{s2} H_t^{s2} - M_t^2 H_t^{s2}} \end{aligned} \quad (2)$$

[9] While we include physical capital in the goods production function (next subsection), we do not have physical capital augmenting human capital in knowledge production. This would require that households make optimal allocation of their physical capital into goods production and human capital production, which unnecessarily complicates our model. Our qualitative results would not be affected, however, as we show later, since physical capital grows at the same rate as human capital in the steady state.

$$\Delta_t^{ds1} = \frac{N_t^{d1} H_t^{d1} + M_t^1 H_t^{s1}}{N_t^{s1} H_t^{s1} - M_t^1 H_t^{s1}}$$
$$\Delta_t^{ds2} = \frac{N_t^{d2} H_t^{d2} + M_t^2 H_t^{s2}}{N_t^{s2} H_t^{s2} - M_t^2 H_t^{s2}}$$

where N_t^{ij} is the population size of natives with skill level j in country i, and M_t^j is the number of workers with skill level j who have migrated from country S to country D. The first two equations specify the within-country spillover terms within D and S, respectively, and last two equations specify the cross-country spillover terms. The idea is that the "effective teacher/student ratio" determines the intensity of the knowledge spillover. The larger the disparity between the levels of human capital and population sizes of the two linked groups, the greater the knowledge spillover effects. Examples of within-country knowledge spillover are social interaction among individuals living in the same location. Examples of cross-country knowledge spillover effects include technology transfers from both natives and immigrants in the destination country with counterparts of comparable skills and educational backgrounds in the source country through foreign direct investments, cross-country trade relations or various forms of social interaction.

3.3 Goods Production

Each country has two goods-producing sectors: high-tech and low-tech. For analytical simplicity, we treat the two sectors as segmented in terms of the skill-level of the worker-groups they employ: while both use physical capital, each employs exclusively high-skilled or low-skilled workers to produce their distinct consumption goods and to fund the physical capital inputs they employ. Consequently, the skill-index j $(= 1, 2)$ represents both the skill level of employees, their capital inputs, and the technology level of the goods they produce. The goods produced in each sector, however, are perfect substitutes in consumption, making trade in goods irrelevant in the model.

The rationale for having segmented production sectors is two-fold. It enables us to account fully for the role of skill, which is an exogenous variable, as opposed to acquired educational attainments at any skill category, which is endogenously determined. Furthermore, skill, or distinct ability, more naturally links with distinct production sectors, such as those producing high-tech and low-tech products. And since we model the sectors as segmented, we allow the rental rates of both human and physical capital to be determined within each production sector. The rental prices of human and physical capital may thus deviate across sectors following an external shock but they ultimately equalize in any balanced growth equilibrium steady state due to the balancing role of knowledge spillover effects.[10]

The production functions in sector j and country i are of the Cobb-Douglas, constant returns to scale form:

[10] We generally need to maintain both capital and labor markets segmented. Otherwise, the equalization of rates of return to physical capital across the two sectors implies that the rental prices of human capital are also equalized at all times, essentially defeating the distinction of two skills and thus the two production sectors. We have actually tried a version of our model that allows for a single capital market. We found out that under a skill-biased technological shock to the economy, which by definition affects only the high-skilled sector, the economy does not converge to a new steady state. This problem does not exist under shocks that do not generate a change in the skill composition of migrants.

$$Q_t^{ij} = \Gamma^{ij}\left(\mathcal{K}_t^{ij}\right)^{\alpha}\left(\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\right)^{1-\alpha} \tag{3}$$

where Γ^{ij} is the factor-neutral technology affecting productivity, $\mathcal{K}_t^{ij}$ is the aggregate physical capital, $\mathcal{H}_t^{ij}$ is the aggregate human capital and $\mathcal{L}_t^{ij}$ is the aggregate working hours, and $\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}$ is the aggregate effective working hours, in each country and sector. More specifically, the four relevant production functions are:

$$\begin{aligned}
Q_t^{d1} &= \Gamma^{d1}[N_t^{d1}K_t^{d1} + M_t^1 K_t^{m1}]^{\alpha}[N_t^{d1}H_t^{d1}L_t^{d1} + M_t^1 H_t^{s1}L_t^{m1}]^{1-\alpha} \\
Q_t^{d2} &= \Gamma^{d2}[N_t^{d2}K_t^{d2} + M_t^2 K_t^{m2}]^{\alpha}[N_t^{d2}H_t^{d2}L_t^{d2} + M_t^2 H_t^{s2}L_t^{m2}]^{1-\alpha} \\
Q_t^{s1} &= \Gamma^{s1}[(N_t^{s1} - M_t^1)K_t^{s1}]^{\alpha}[(N_t^{s1} - M_t^1)H_t^{s1}L_t^{s1}]^{1-\alpha} \\
Q_t^{s2} &= \Gamma^{s2}[(N_t^{s2} - M_t^2)K_t^{s2}]^{\alpha}[(N_t^{s2} - M_t^2)H_t^{s2}L_t^{s2}]^{1-\alpha}
\end{aligned} \tag{4}$$

where K_t^{dj}, K_t^{mj} and K_t^{sj} are the capital stocks supplied by natives and migrants in D and by natives in S, in each sector j, respectively, and L_t^{dj}, L_t^{mj} and L_t^{sj} are the working hours of natives and migrants in D, and natives in S in each sector j, respectively.

Labor, capital, and goods markets are competitive. Firms in each sector hire labor and rent capital to maximize profits,

$$\max \quad \Gamma^{ij}\left(\mathcal{K}_t^{ij}\right)^{\alpha}\left(\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\right)^{1-\alpha} - r_t^{ij}\mathcal{K}_t^{ij} - \omega_t^{ij}\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\,. \tag{5}$$

The rental rates, or shadow prices of physical and human capital are therefore given by:

$$\begin{aligned}
r_t^{ij} &= \alpha\Gamma^{ij}\left(\mathcal{K}_t^{ij}\right)^{\alpha-1}\left(\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\right)^{1-\alpha} \\
\omega_t^{ij} &= (1-\alpha)\Gamma^{ij}\left(\mathcal{K}_t^{ij}\right)^{\alpha}\left(\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\right)^{-\alpha}
\end{aligned} \tag{6}$$

so the wage rate per worker is $w_t^{ij} = \omega_t^{ij}H_t^{ij} = (1-\alpha)\Gamma^{ij}\left(\mathcal{K}_t^{ij}\right)^{\alpha}\left(\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\right)^{-\alpha}H_t^{ij}$.

3.4 Households Maximization

Parents are altruistic toward their children. For $i = \{d, s\}$ and $j = \{1, 2\}$, each adult parent maximizes utility from her own consumption and altruistic objectives. The maximization problem is thus

$$\max_{\{h_t, n_t, C_t, K_{t+1}\}} \quad \frac{\left(C_t^{ij}\right)^{1-\sigma}}{1-\sigma} + \delta\,\mathbb{E}\,\frac{\left(W_{t+1}^{ij}\right)^{1-\sigma}}{1-\sigma} \tag{7}$$

$s.t.$

$$C_t^{ij} + n_t^{ij}K_{t+1}^{ij} = r_t^{ij}K_t^{ij} + \left(1 - v^i n_t^{ij} - \theta^{ij}h_t^{ij}n_t^{ij}\right)\omega_t^{ij}H_t^{ij}$$
$$W_{t+1}^{ij} = B\left(n_t^{ij}\right)^{\beta}\left(\omega_{t+1}^{ij}H_{t+1}^{ij}\right)^{\eta}\left(r_{t+1}^{ij}K_{t+1}^{ij}\right)^{1-\eta}$$

where δ is the intergenerational discount factor; σ denotes the inverse intertemporal elasticity of substitution in consumption; n_t^{ij} is the number of children; v^i is the unit (time) cost of raising a child; and θ^{ij} is the unit (time) cost of financing a child's educational investment, h_t^{ij}. The total endowment of time, normalized as 1, is spent on child bearing and rearing ($v^i n_t^{ij}$), child education ($\theta^{ij} h_t^{ij} n_t^{ij}$), and parent's labor supply ($L_t^{ij} = 1 - v^i n_t^{ij} - \theta^{ij} h_t^{ij} n_t^{ij}$). Physical capital stock K_t^{ij} denotes the amount of inherited physical capital available to a generation-t parent.

The right-hand-side of the budget constraint in equation (7) thus represents income generated by parent's physical and human capital assets. The left-hand-side of the budget constraint, in turn, represents parental consumption spending, C_t^{ij}, and the total amount of savings left as bequest for children in generation $t+1$, $n_t^{ij} K_{t+1}^{ij}$, where K_{t+1}^{ij} thus represents bequest per child. We assume that parents use rational expectations to forecast children's future rate of return to physical and human capital of children in generation $t+1$, r_{t+1}^{ij} and ω_{t+1}^{ij}, respectively.

The parental altruism function is also specified as a general Cobb-Douglas function

$$W_{t+1}^{ij} = B\left(n_t^{ij}\right)^{\beta}\left(\omega_{t+1}^{ij} H_{t+1}^{ij}\right)^{\eta}\left(r_{t+1}^{ij} K_{t+1}^{ij}\right)^{1-\eta} \qquad (8)$$

where $\beta > 1$ and $0 < \eta < 1$. Parents value the quantity n_t^{ij} of children, and the potential labor and capital income each child will acquire. Labor income depends on the quality H_{t+1}^{ij} of the child, and capital income depends on the assets K_{t+1}^{ij} the child inherits. This altruism function includes two components: companionship (as in Ehrlich and Lui, 1991) and bequest. Companionship implies that parents derive the returns on the quantity and quality of offspring they have invested in raising and educating vicariously or through interaction with their offspring. Bequest is the altruistic value of the assets they bequeath to each child, as measured by the returns to capital. One of the benefits of adding physical capital to the model is that it allows us to recognize in a meaningful way the role of bequest in the growth dynamics. Since we model adulthood in equation (7) as a single period, bequest K_{t+1}^{ij} equals lifetime savings in the model. Note that it is necessary to have bequest in the model to ensure continuous physical capital accumulation across generations.

The altruism function distinguishes the offspring's labor income from income derived from physical capital, rather than combining the two, for two reasons. First, it reflects the distinct motives parents have for savings for, and investing in, the quantity and quality of children. For example, small business owners may be interested in leaving their businesses (physical capital) to their children as legacy. Similarly, farmers are often interested in leaving behind the family farm to their children. Second, our model is an endogenous growth model, and human capital is the engine of growth. We separate human and physical capital in the altruism function to highlight the parental benefits from investment in the distinct capital assets.

For immigrants with skill level $j = \{1, 2\}$, each adult solves the equivalent maximization problem

$$\max_{\{h_t, n_t, C_t, K_{t+1}\}} \quad \frac{\left(C_t^{mj}\right)^{1-\sigma}}{1-\sigma} + \delta\, \mathbb{E}\, \frac{\left(W_{t+1}^{mj}\right)^{1-\sigma}}{1-\sigma} \qquad (9)$$

$$s.t.$$

$$C_t^{mj} + n_t^{mj} K_{t+1}^{mj} = \left(1-\tau^{kj}\right) r_t^{dj} K_t^{sj} + \left(1 - v^s n_t^{mj} - \theta^{sj} h_t^{mj} n_t^{mj} - \tau^{hj}\right) \omega_t^{dj} H_t^{sj}$$

$$W_{t+1}^{mj} = B\left(n_t^{mj}\right)^{\beta} \left(\omega_{t+1}^{dj} H_{t+1}^{mj}\right)^{\eta} \left(r_{t+1}^{dj} K_{t+1}^{mj}\right)^{1-\eta}$$

Migrants are assumed to possess the physical and human capital attained by natives in their source country, S, but they also have to bear migration costs τ^{hj} and τ^{kj} in terms of foregone wage income, representing the time costs associated with migration, and foregone nonwage income, representing transaction costs associated with transferring their assets. Thus, individual migrants' labor supply is given by $L_t^{mj} = (1 - v^s n_t^{mj} - \theta^{sj} h_t^{mj} n_t^{mj} - \tau^{hj})$, and their net assets in D are given by $K_t^{mj} = \left(1-\tau^{kj}\right) K_t^{sj}$. Migrants are assumed to face the same time cost of raising (v^s) and educating (θ^{sj}) a child, as do their counterparts in country S, but they enjoy the same returns to human and physical capital as do their skill-counterparts in country D.

3.5 Optimality Conditions

The first-order conditions for fertility, n_t^{ij}, human capital investment, h_t^{ij}, and bequest K_{t+1}^{ij} for each skill group $j\ (=1,2)$ and country, or for migrants, $i\ (=d,s,m)$ are given respectively by

$$\left(C_t^{ij}\right)^{-\sigma} \left[\left(v^i + \theta^{ij} h_t^{ij}\right) \omega_t^{ij} H_t^{ij} + K_{t+1}^{ij}\right] = \delta \left(W_{t+1}^{ij}\right)^{-\sigma} B\beta \left(n_t^{ij}\right)^{\beta-1} \left(\omega_{t+1}^{ij} H_{t+1}^{ij}\right)^{\eta} \left(r_{t+1}^{ij} K_{t+1}^{ij}\right)^{1-\eta} \qquad (10a)$$

$$\left(C_t^{ij}\right)^{-\sigma} \theta^{ij} n_t^{ij} \omega_t^{ij} H_t^{ij} = \delta \left(W_{t+1}^{ij}\right)^{-\sigma} B\left(n_t^{ij}\right)^{\beta} \eta\, \omega_{t+1}^{ij} \frac{\partial H_{t+1}^{ij}}{\partial h_t^{ij}} \left(\omega_{t+1}^{ij} H_{t+1}^{ij}\right)^{\eta-1} \left(r_{t+1}^{ij} K_{t+1}^{ij}\right)^{1-\eta} \qquad (10b)$$

$$\left(C_t^{ij}\right)^{-\sigma} n_t^{ij} = \delta \left(W_{t+1}^{ij}\right)^{-\sigma} B\left(n_t^{ij}\right)^{\beta} (1-\eta) r_{t+1}^{ij} \left(\omega_{t+1}^{ij} H_{t+1}^{ij}\right)^{\eta} \left(r_{t+1}^{ij} K_{t+1}^{ij}\right)^{-\eta}. \qquad (10c)$$

Dividing each side of the first-order condition (FOC) for h_t (10b) by the corresponding sides of the FOC for K_{t+1} (10c), we obtain the analytical solutions for bequest:

$$K_{t+1}^{d1} = \frac{1-\eta}{\eta} \theta^{d1} h_t^{d1} \omega_t^{d1} H_t^{d1} \qquad (11)$$
$$K_{t+1}^{d2} = \frac{1-\eta}{\eta} \theta^{d2} h_t^{d2} \omega_t^{d2} H_t^{d2}$$
$$K_{t+1}^{s1} = \frac{1-\eta}{\eta} \theta^{s1} h_t^{s1} \omega_t^{s1} H_t^{s1}$$
$$K_{t+1}^{s2} = \frac{1-\eta}{\eta} \theta^{s2} h_t^{s2} \omega_t^{s2} H_t^{s2}$$
$$K_{t+1}^{m1} = \frac{1-\eta}{\eta} \theta^{s1} h_t^{m1} \omega_t^{d1} H_t^{s1}$$
$$K_{t+1}^{m2} = \frac{1-\eta}{\eta} \theta^{s2} h_t^{m2} \omega_t^{d2} H_t^{s2}$$

Similarly, dividing both sides of the FOC for n_t (10a) by the corresponding FOC for h_t and substituting K_{t+1} by its optimal value in equation (11), we obtain analytical solutions for human capital investments for the 6 groups in equation (12) as follows:

$$\begin{aligned} h_t^{d1} &= \frac{v^d \eta}{\theta^{d1}(\beta - 1)} \\ h_t^{d2} &= \frac{v^d \eta}{\theta^{d2}(\beta - 1)} \\ h_t^{s1} &= \frac{v^s \eta}{\theta^{s1}(\beta - 1)} \\ h_t^{s2} &= \frac{v^s \eta}{\theta^{s2}(\beta - 1)} \\ h_t^{m1} &= \frac{v^s \eta}{\theta^{s1}(\beta - 1)} \\ h_t^{m2} &= \frac{v^s \eta}{\theta^{s2}(\beta - 1)} \end{aligned} \quad (12)$$

Note that the optimal solutions for h are explicit solutions, which are independent of fertility n and the values of human and physical capital, H and K.

3.6 Labor Mobility – the Migration Decision

Our point of reference is that while labor is internationally mobile, it is also subject to migration costs, including regulatory costs. Agents have incentives to emigrate from S to D, as long as the lifetime utility of residing in D is higher than that in S. The equilibrium flow of migrants, M_t^j, is determined by the marginal worker in each skill group equalizing the utility levels from staying and migrating as follows:

$$\begin{aligned} \frac{(C_t^{s1})^{1-\sigma}}{1-\sigma} + \delta \frac{(W_{t+1}^{s1})^{1-\sigma}}{1-\sigma} &= \frac{(C_t^{m1})^{1-\sigma}}{1-\sigma} + \delta \frac{(W_{t+1}^{m1})^{1-\sigma}}{1-\sigma} \\ \frac{(C_t^{s2})^{1-\sigma}}{1-\sigma} + \delta \frac{(W_{t+1}^{s2})^{1-\sigma}}{1-\sigma} &= \frac{(C_t^{m2})^{1-\sigma}}{1-\sigma} + \delta \frac{(W_{t+1}^{m2})^{1-\sigma}}{1-\sigma} \end{aligned} \quad (13)$$

For interior solutions to exist along the balanced growth path, the productivity differences between D and S in human capital and goods production have to be large enough, $A^{dj} > A^{sj}$ and $\Gamma^{dj} > \Gamma^{sj}$, $j = \{1, 2\}$, and the fertility marginal shadow costs must also be larger in S relative to D, $v^s > v^d$. This is consistent with available data showing that developing countries with high fertility levels are predominantly source countries of immigration while developed countries with relatively low fertility levels are mostly destination countries for immigrants. It is also important to note that the migration costs τ^{kj} and τ^{hj} have to be of a moderate level for migration to have an interior solution.[11]

Note that while in reality many countries can have both immigrants and emigrants, the equilibrium flow of migrants in the model, M_t^j, refers to net migration. Furthermore, M_t^j may include temporary migrants.[12]

3.7 Population Growth

Both fertility and migration contribute to population growth. Native populations in D and S evolve as functions of their fertility rates and volume of migrants,

$$\begin{aligned} N_{t+1}^{d1} &= n_t^{d1} N_t^{d1} + n_t^{m1} M_t^1 \\ N_{t+1}^{d2} &= n_t^{d2} N_t^{d2} + n_t^{m2} M_t^2 \\ N_{t+1}^{s1} &= n_t^{s1}(N_t^{s1} - M_t^1) \\ N_{t+1}^{s2} &= n_t^{s2}(N_t^{s2} - M_t^2) \end{aligned} \quad (14)$$

One immediate proposition arising from equation (14) is that a balanced growth equilibrium in which population growth rates are equalized within and across countries for all skills groups may exist if, and only if, the steady state fertility rate in S exceeds that in D:

$$n_t^{sj} > n_t^{dj} \quad (15)$$

If equilibrium fertility rates were to equalize across countries, there would be no migration along the balanced growth paths. Put differently, as long as fertility rates are different, migration could persist in the balanced growth equilibrium steady state. It is for this reason that we have already placed a constraint on fertility costs in S vs. D in section 3.6.

3.8 Balanced Growth Paths

To allow for interior solutions for our model whereby D and S remain independent states we restrict our model's steady state equilibrium solutions to converge on balanced growth paths (BGP). This requires some specific parametric constraints. First, to make the model tractable and maintain our representative agent framework (in each sector of each country), we need to specify the process of immigrant assimilation. We assume that migrants' children fully assimilate within one generation – they attain the same human capital and physical capital as do natives' children. We recognize that the process may take longer than one generation and could allow for a longer period of assimilation. But in a perpetual growth equilibrium, migrants must ultimately assimilate, and allowing for longer lags would not change our results qualitatively.

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[11] As S has a higher fertility rate than D, we need to have some migrants flowing from S to D to maintain a constant population ratio along the balanced growth path. If migration costs are too high, there will be too few migrants and over time population in D will shrink to zero relative to population in S, and vice versa if migration costs are too low.

[12] Temporary migrants refer to those migrants who work and live in the destination country for several years before they go back to their home countries.

Second, we have already placed constraints on the relative magnitudes of a few parameter values concerning the productivity of investment in knowledge ($A^{dj} > A^{sj}$), the technology of goods production ($\Gamma^{dj} > \Gamma^{sj}$) and the shadow costs of fertility ($v^d > v^s$) in section 3.6 to assure interior solutions in these variables across sectors and countries. The conditions assuring a balanced growth path further require the following conditions:

1. A threshold level of parental investments in offspring's human capital in D, $\left(h_t^{d1}\right)^*$, to guarantee that the optimal level of investment in offspring human capital is sufficiently large to assure a positive growth rate of human capital in D, ($g^* > 0$),

$$\frac{\partial H_{t+1}^{ij}}{\partial H_t^{ij}} = A^{d1}\left(h_t^{d1}\right)^* = \frac{A^{d1}}{\theta^{d1}}\frac{v^d\eta}{\beta - 1} = 1 + g^* > 1 \;\; or \;\; (h^{d1})^* > \frac{1}{A^{d1}} \qquad (16)$$

2. Equal relative efficiency (A/θ) of producing human capital across agents with different skill levels within and across countries:

$$(A^{d1}/\theta^{d1})/(A^{d2}/\theta^{d2}) = (A^{s1}/\theta^{s1})/(A^{s2}/\theta^{s2}) \qquad (17)$$

3. Equal relative endowed productivity levels in goods production in D and S:

$$\Gamma^{d1}/\Gamma^{d2} = \Gamma^{s1}/\Gamma^{s2} \qquad (18)$$

While condition 1 is guaranteed by the magnitude of the coefficients representing the explicit solution concerning human capital accumulation in equation (16), conditions 2 and 3 are parameter restrictions that are required to guarantee the existence of a balanced growth equilibrium steady state, linking the destination and source countries, D and S.

Subject to these conditions, we derive a balanced global growth equilibrium with the following properties:[13]

The steady-state growth rates of population (N), human capital (H), and physical capital (K) are constant and equal across skill groups within and across countries. This is illustrated in equation (19) below, where X stands for N, H, and K, respectively:

$$\frac{X_{t+1}^{d1}}{X_t^{d1}} = \frac{X_{t+1}^{d2}}{X_t^{d2}} = \frac{X_{t+1}^{s1}}{X_t^{s1}} = \frac{X_{t+1}^{s2}}{X_t^{s2}} \qquad (19)$$

Physical capital and human capital growth rates are equalized for $i = \{d, s\}$ and $j = \{1, 2\}$:

$$\frac{K_{t+1}^{ij}}{K_t^{ij}} = \frac{H_{t+1}^{ij}}{H_t^{ij}} \qquad (20)$$

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[13] To derive balanced-growth equilibrium paths, both D and S must be in a growth regime, in the sense defined in (Ehrlich and Lui 1991). This does not mean that this is a North-North model. Most of the immigration-source countries for which data exist are developing countries, but having per-capita income significantly below destination countries.

Relative human capital and physical capital are equalized across skill groups and across countries:

$$\frac{H_t^{d1}}{H_t^{s1}} = \frac{H_t^{d2}}{H_t^{s2}} \quad and \quad \frac{K_t^{d1}}{K_t^{s1}} = \frac{K_t^{d2}}{K_t^{s2}} \qquad (21)$$

A constant fraction of each skill group in S migrate to D:

$$\frac{M_t^{1}}{N_t^{d1}} = \frac{M_t^{2}}{N_t^{d2}} \quad and \quad \frac{M_t^{1}}{N_t^{s1}} = \frac{M_t^{2}}{N_t^{s2}} \qquad (22)$$

Relative rental rates of human capital and rates of returns to physical capital are equalized across groups and across countries:

$$\frac{\omega_t^{d1}}{\omega_t^{s1}} = \frac{\omega_t^{d2}}{\omega_t^{s2}} \quad and \quad \frac{r_t^{d1}}{r_t^{s1}} = \frac{r_t^{d2}}{r_t^{s2}} \qquad (23)$$

3.9 Extended Model – Diversity Effects

Equilibrium growth paths in the benchmark model were assured by hierarchic one-sided knowledge spillover effects flowing from the top skill group in D and S onto the lower skill group in D and S and from both skill groups in D onto their counterparts in S. But knowledge spillover effects could also be two-sided. This idea was already implemented in Ehrlich and Kim (2015). We briefly expound on this possibility in this section in order to reassess its implications on the net benefits from immigration in the context of our current model by similarly allowing for two-sided interactions between natives and migrants in the production of knowledge in country D, which we refer to as "diversity effects". Such interactions may have an independent effect on the net welfare effects of immigration in both D and S, under the various immigration triggers we consider in this paper, which is what this extension is designed to focus on.[14]

To incorporate the possible effects of diversity, we allow the productivity of knowledge generation to be an increasing and concave function of a simple measure of diversity involving natives and migrants. Specifically, for $j = \{1, 2\}$, the productivity of human capital production in D is modified to be

$$\bar{A}^{dj}(d^j) = A^{dj}\left(1 + d^j\right)^{\rho}, \qquad (24)$$

where d^j is the diversity measure of population in skill group j, defined as

$$d^j = \frac{M^j}{N^{dj}+M^j}, \qquad (25)$$

[14] There is literature documenting the existence of complementarities between natives and migrants in production and innovation. For example, Alesina, Harnoss and Rapoport (2016) indicates that birthplace diversity has a net positive effect on productivity growth. Additional studies include Peri (2007), and Greenwood and Hunt (1995).

and $0 \leq \rho \leq 1$, making the diversity effect increasing and concave in d^j. The diversity measure d^j, in turn, is increasing in the ratio of migrants in the population, $M^j/(N^{dj} + M^j)$. Note that the benchmark model is a special case of the extended model, where $\rho = 0$.

4. Solving the Comprehensive Model

In this section, we implement the dynamic implications of the benchmark and extended models by pursuing balanced growth equilibrium solutions for both. We first describe how we calibrate the structural parameters of the model in section 4.1. We then explore the behavioral properties of the model by exerting external shocks to its basic parameters, or immigration triggers, representing pull, push, and policy factors through comparative and transitional dynamic analyses from which we derive the total economic effects and the induced immigration effects of the external shocks. Since the dynamic analyses are constrained by the objective to derive balanced growth paths, the bulk of the comparative dynamic effects of the triggers in section 4.2, and the transitional dynamic paths showing the total and induced-immigration effects of the triggers in section 5 are derived in the form of *ratios* of the relevant outcome variables within and across countries. It is only in section 6 where we can translate the induced immigration effects of the various triggers into measures of the net changes in the average per-capita income of the native populations (i.e., the immigration surplus levels) in D and S, and thus in the global economy.

4.1 Calibration

We calibrate the key parameters of the model by matching the basic moments of the model's balanced growth paths – the growth rates of GDP per capita and fertility rates driving the population growth – with the corresponding moments in the U.S., which serves as the migration destination country in our model, over the period 1960 to 2017. We similarly calibrate the source country as a composite country, based on the weighted average moments of the top 15 source countries of immigration to the U.S., and with weights of individual countries computed as the shares of the stock of immigrants from each country to the total stock of immigrants from all 15 countries.[15]

We calibrate the following parameters as follows: We set the inverse intertemporal elasticity of substitution at $\sigma = 0.9$, the intergenerational discount factor at $\delta = 0.7$, the scale parameter at $B = 1$, the exponent of fertility in the altruism function at $\beta = 1.3$, and the human capital spillover parameters at $\gamma^1 = \gamma^2 = 0.4$, all taken from EK (2015). The capital share α, set at $1/3$, in the Cobb-Douglas production function is a common value used in the literature. We set $\eta = 2/3$, so the labor income share in the altruism function is the same as that in the goods production function.

The relative productivity parameters in the goods production function Γ^{dj}/Γ^{sj} affect the incentives to migrate. We normalize Γ^{d1} and Γ^{d2} to 10, and calibrate Γ^{s1} and Γ^{s2} to 8.377 in order to match

[15] The top 15 countries of origins, ranked in descending number of migrants to the U.S., are Mexico, China, India, the Philippines, Puerto Rico, Vietnam, El Salvador, Cuba, South Korea, Dominican Republic, Guatemala, Canada, Jamaica, Colombia, and the United Kingdom. See United Nations (2017), https://www.un.org/en/development/desa/population/migration/data/estimates2/estimates17.asp.

the immigrant share of the population, $(M^1 + M^2)/(N^{d1} + M^1 + N^{d2} + M^2)$ in D. In the benchmark model, there is free international migration, but in reality, there are also many restrictions imposed on the volume of immigration and emigration in the form of quotas by especially destination countries. To mimic this aspect of immigration we have therefore imposed an immigration target ratio of 15%, which is an upper bound of the U.S. historic immigrant share of the population, as seen in Figure 1.

Human capital formation is the engine of growth in the model and is mostly affected by the relative efficiency of human capital production, A^{ij}/θ^{ij}, which reflects the ratio of the endowed productivity of human capital production to the unit cost of investment in human capital by agents of different skill levels in different countries. We normalize the productivity parameters of the model as follows: $A^{d1} = 10$, $A^{d2} = 5$, $A^{s1} = 8$ and $A^{s2} = 4$, and calibrate θ^{ij} at the value 1.675 in order to match the annual growth rate of GDP per capita in D and S at 2%, which is the average annual growth rate of GDP per capita in the U.S.[16]. One generation implicitly lasts 30 years in our model, so the targeted growth rate per capita over a generation is $1.02^{30} = 1.81$.

The unit cost of production capacity (time) devoted to raising a child in countries D and S, v^d and v^s, are set to be 0.1365 and 0.0853 respectively. This allows us to target the fertility rates to be around 1.07 in D and around 1.74 in S. Since agents in the model are unisex, this calibration allows us to match the total fertility rates of 2.14 in the U.S. and 3.48 in the 15 source countries.[17] Costs of migration in terms of time, τ^{h1} and τ^{h2}, are set to be 0.062, in order to target the fertility rate of migrants to be around 1.33 in the model, an intermediate value between the natives in the destination and source countries. We set the transaction costs to migrants for moving physical capital from S to D at $\tau^{k1} = \tau^{k2} = 0.5$ to reflect the fact that while migrants are generally poor relative to the natives, they do bring some positive capital assets with them, commensurate with the levels they had in S. We will further relax this assumption in section 7.2 of the paper.

4.2 Comparative Dynamics under the Benchmark and Extended Models

We start with the *benchmark model*. To derive numerically the model's basic properties, we conduct a series of simulations that are summarized in their respective rows in Table 1. We first derive the model's equilibrium balanced growth steady state solutions, using the calibrated parameters specified in the previous subsection. These are shown in row 1. The solutions indicate that the fertility in S is higher than that of both migrants and of natives in D ($n^s > n^m > n^d$); the physical to human capital ratio ($K^d/H^d > K^s/H^s$) and rental price of human capital ($\omega^d > \omega^s$) are higher in D relative to S, while the rates of return to physical capital ($r^d < r^s$) are higher in S relative to D. All are consistent with the generally observed empirical evidence concerning destination and source countries. We then introduce external shocks in the model's basic parameters representing pull and push factors, policy instruments, and structural parameters, and study the resulting impacts of the shocks on the model's endogenous variables in their new steady states.

[16] See World Bank (2019), https://data.worldbank.org/indicator/ny.gdp.pcap.cd.
[17] See World Bank (2019), https://data.worldbank.org/indicator/sp.dyn.tfrt.in.

It is important to note that Table 1 summarizes the *total* impact of these exogenous shocks, not the differential impacts of the *induced migration* arising from the shocks, which are the focus of our analysis in the next section. To save on notation in the following descriptions, we omit the superscripts $i = \{d, s\}$ and $j = \{1, 2\}$ as long as they are not needed for clarification.

Row 2 presents the steady-state effects of a *pull factor* shock, which we term skill-biased technological shock (SBTS). It is illustrated through an equi-proportional rise of 20% in the endowed productivity of human capital, or knowledge production, of the top skill groups in countries D and S, A^{d1} and A^{s1}, respectively. As the Table shows, the shock raises the global growth rate of human and physical capital (H and K), and thus income and parents' desired fertility level (n). It also raises the skill composition of migration, $M^1/(M^1 + M^2)$, and the population share of migrants relative to natives in D, (M/N^d), but lowers the population share of emigrants in S (M/N^s), as N^s rises faster. This result is consistent with the secular increase in the skill composition of migrants in major destination countries, including the U.S. since the 1970s, when the digital revolution picked up steam, as documented in EK (2015). The shock also lowers the steady state levels of the physical to human capital ratio (K/H) in both D and S, essentially because of the rise in the average level of human capital per capita in the new steady state equilibrium. The shock also raises the ratios of human and physical capital across skill groups (H^{i1}/H^{i2} and K^{i1}/K^{i2}) and across countries (H^{dj}/H^{sj} and K^{dj}/K^{sj}), and thus income disparity within skill groups in D and S as well as across countries.[18] This pattern fits closely the evidence concerning the impact of the digital revolution in the U.S. since the early 1970s.

Row 3 presents the steady-state effects of another *pull factor* shock: a rise in the opportunity costs of fertility, v^d by 5% in D. This shock produces some different consequences relative to those of the SBTS. The rise in v^d generates a shift in parental demand for quantity toward "quality" of children, thus lowering the fertility rate in D and increases investment (h) in the human capital of each child, which, in turn, raises the global growth rate of human and physical capital formation. The fertility cost increase in D also raises the share of migrants in the population of country D, M/N^d, due to the fall in natives' fertility. But unlike the SBTS shock, this pull factor raises slightly the physical to human capital ratio in D, K^{dj}/H^{dj}. Although the fall in fertility induces a higher investment in human capital, which raises the average human capital attainments of the skill groups in D, it also raises the accumulated level of physical capital, as indicated by equation (11), which ultimately raises K^{dj}/H^{dj}. The faster growth of human capital in D leads to a *rise* in wage and income disparities between D and S. These consequences seem to be consistent with the consequences of migration to Germany after the fall of the Berlin Wall.

Row 4 presents the steady-state effects of a *push factor* shock: a fall in the productivity of goods production in both sectors in country S, Γ^{s1} and Γ^{s2}, by 0.02 (or 0.2%).[19] In the new steady state, country D ends up with a larger population, so, although more people migrate from S to D, the ratio of migrants in the population of the destination country, M/N^d, ultimately falls as the preceding stocks of immigrants become natives. The higher population in D relative to S generates

[18] The per-capita income level in each country is measured as $I = rK + \omega HL$.

[19] The model is somewhat sensitive to changes in the relative productivity Γ^{dj}/Γ^{sj}. The reason is relative productivity represents the income difference between D and S, which determines the incentives to migrate. A small but permanent change in productivity can cause a large change in migration, disrupting the balanced population growth in D and S.

stronger knowledge spillover effects from the skill groups in D on the corresponding groups in S, so H^{dj}/H^{sj} and K^{dj}/K^{sj} decrease in the new steady state. These effects ultimately lead to a *reduction* in the relative wage and income gaps between D and S.

Row 5 presents the steady-state effects of a *policy factor* shock: a fall in the transaction cost of moving capital assets for all migrants who bring (claims of) physical capital to D, τ^{k1} and τ^{k2}, by 5%. This shock increases the migration of people with more physical capital from S to D. The shock also decreases the ratio of migrants relative to the population in D, M/N^d, because of the rising total native population in D as migrants assimilate over time. In other words, the rise in N^d is larger than the rise in M in the steady state. The average levels of human and physical capital in D, however, fall relative to those in S, because of the relatively lower levels of human and physical capital of migrants to D and also of the stronger knowledge spillover effects on the formation of H^{sj} emanating from the larger population in D. In the steady state, both H^{dj}/H^{sj} and K^{dj}/K^{sj} fall as a result, lowering the income disparity between D and S.

Row 6 presents a *preference factor* shock: the steady state outcome of a fall in the weight of labor income relative to capital income in the altruism function, η, by 5%. This shock represents a rise in parents' preferences to bequeath their capital assets to their offspring. Not surprisingly, such shock increases the steady state physical to human capital ratio, K/H, in both D and S due to the parents' greater preference for bequest. This effect lowers the optimal level of parental investment in human capital (h) which, in turn, lowers the growth rate of human capital, physical capital and income. At the same time, the relative stocks of both human and physical capital, H^{dj}/H^{sj} and K^{dj}/K^{sj}, as well as the relative income gap between D and S rise largely because the lower investment in human capital in D lowers the spillover effect of knowledge from D to S.

Finally, row 7 presents the steady-state effects of a *knowledge spillover factor* shock: a rise in the magnitude of the knowledge spillover effects across groups and across countries, γ^1 and γ^2, by 5%. Stronger spillover effects across groups reduce within-country inequality in both D and S (H^{i1}/H^{i2} and K^{i1}/K^{i2}) as lower-skilled groups benefit from faster growth rates in income. Although this effect is also present across countries, stronger spillover effects across countries reduce potential migrants' incentives to migrate, since they can stay in their home country and enjoy knowledge transfer. Overall, stronger cross-country knowledge spillover leads to a smaller population in D relative to S and reduces total spillover effects. Therefore cross-country inequality (H^{dj}/H^{sj} and K^{dj}/K^{sj}) increases.

Table 2 similarly presents the comparative dynamics of our *extended model*, which allows for positive diversity effects, i.e., interactions between natives and migrants in the production of human capital. To permit a comparison between the impact of shocks in the extended, relative to the benchmark model (where ρ is implicitly 0), we set $\rho = 0.2$ and keep all the other parameters equal to those in Table 1. As the results indicate, the complementary relations between natives and migrants in the extended model lead to higher growth rates of both human and physical capital, and thus income. In turn, fertility rates also become higher in both destination and source countries due to the wealth effect on the demand for children. The effects of all shocks (pull factor, push factor, policy factor, preference factor and spillover factor) in Table 2 (rows 2-7) relative to the initial steady state (row 1) are qualitatively the same as those in Table 1.

5. Transitional Dynamics: Total and Induced Immigration Effects

The comparative dynamics analysis in section 4 indicates the total impact of various external shocks on the steady state values of the key control variables of the model. These include fertility decisions, investment in human and physical capital, and the *relative* magnitudes of the state and co-state variables of the model across skill groups within and across the destination (D) and source (S) countries. In this section, we trace numerically the transitional dynamic paths generated by some of these shocks on the values of the same or related key variables of interest in both D and S. We pursue the transitional dynamics analysis in two parts: in the first part, we trace numerically the *total effect* of the external shocks on the transitional dynamic and balanced growth paths (BGP) of these variables. In the second part, we trace numerically the transitional dynamic paths generated by the *distinct component* of the total effect of the external shock that can be ascribed to the immigration flows *induced* by the external shocks, or immigration triggers, which we term the *induced immigration effect*.

We first present the results of two pull factors – a skill-biased technological shock (SBTS), and an adverse fertility shock in the destination country.[20] We also depict the effects of a principal push – a negative supply shock generated by a fall in the productivity of goods production in the source country.[21] We plot the total effects of these three shocks in Figure 2, and the induced immigration effects in Figure 3. We pursue these cases below, in the context of the benchmark model. The transitional dynamics under the extended model are qualitatively the same, so we omit them here. We compare the quantitative impacts of the benchmark and extended models, however, in the context of the immigration surplus analysis in sections 6 and 7.

5.1 Pull Factor: A Skill-Biased Technological Shock

We focus here on the transitional dynamic paths generated by a demand pull factor resulting from a skilled-biased technological shock, such as the digital revolution starting in the early 1970s. We assume that the economies in D and S are initially at an equilibrium steady state under the benchmark model. We then apply an upward productivity shock to the technology governing knowledge formation by the higher skill groups in both countries, A^{d1} and A^{s1}, which we raise simultaneously by 20% while holding constant the corresponding parameters associated with low-skilled workers, A^{d2} and A^{s2}. Panel (a) in Figure 2 illustrates the main impacts of the SBTS. The shock affects the skill composition of migrants and the income distributions across the two skill groups and across countries. First, the skill composition of migrants increases over time since the rise in the technological parameter A^{d1} increases the incentive of high-skilled workers to immigrate from S to D.[22] Second, income inequality across groups within country increases,

[20] The SBTS trigger was already covered in EK (2015) in the context of an economy where human capital is the only asset in the economy.

[21] We analyze additional triggers originating from government policies concerning labor and migrants' asset mobility, as well as physical capital endowments in sections 7 and 8.

[22] There is an initial dip in both the migration flow and the skill composition of migrants. Migration flow decreases initially because S receives a positive shock, benefitting the high skilled directly but also benefitting the low skilled indirectly through the knowledge spillover effects. Skill composition decreases because in the very first period of the SBTS, the high skilled group in S benefits immediately from it, while the low-skilled group has to wait until the next period to enjoy the higher spillover effects. Hence, the incentives to migrate is lower for the high-skilled group relative to the low-skilled group in S, leading to a small initial decline in the migrants' skill composition.

because high-skilled groups in both countries benefit more from the SBTS. Third, income inequality across countries also increases, as more high-skilled migrants migrate from S to D over the transition phase as well as along the balanced growth paths (BGP).

5.1.1 Isolating the Effects of Induced Migration under SBTS

The total impact of the SBTS includes the added migration effects it induces. But what are the net economic effects of the induced migration effects in D and S? To answer this question, we decompose the total SBTS effect into: (1) the component that would exist without the increased migration; and (2) the component generated by the rise in the skill composition of migrants that the SBTS has induced. To isolate the latter, we simulate the dynamic paths under two scenarios. First, the skill composition of migrant flows $M^1/(M^1 + M^2)$ and the share of migrants to natives M^1/N^{d1} are restricted to be frozen at their initial steady state equilibrium values. Second, immigration remains unrestricted, and thus exhibits the total SBTS effect. The difference between the two scenarios indicates the impact of induced migration, as shown in Panel (a) of Figure 3.

In country D, immigration raises the population share of skilled workers. This raises the average human and physical capital levels, thus the income per worker. Country D as a whole benefits. But there is a difference across groups. Wage income of high-skilled workers falls in D, as the larger number of skilled migrants increases the supply of skilled workers in the unrestricted case. The impact on low-skilled workers in D goes in the opposite direction: they gain, because the larger share of skilled workers in the population raises the knowledge spillover effect on their human capital level. Thus, induced immigration under SBTS lowers income inequality in D.

In country S, in contrast, unrestricted immigration under SBTS is a loss to S as a whole because there are more skilled migrants emigrating (a "brain drain"), and this lowers knowledge spillover effects on the lower-skilled group members, raising income inequality within S. This is the chief adverse result of the brain drain in the source country. Moreover, since unrestricted migration raises income in D and lowers income in S, it increases income inequality across D and S.

5.2 Pull Factor: A Downward Fertility Shock in *D*

We now consider the transitional dynamics paths generated by another pull factor resulting from an assumed downward fertility shock in D. We identify the exogenous factor contributing to the shock heuristically as an upward shift in the opportunity costs of bearing children, due to the rise in the age of marriage and the rise in the labor market opportunities for females in the more developed Western countries, relative to the less developed countries in Asia and Africa in recent decades. Technically, we raise the fertility cost parameter in our model, v^d, by 5%. We then simulate the transitional dynamic evolution in both D and S, tracing it from the initial steady state.

Panel (b) in Figure 2 illustrates the results. As the shock applies to both skill types, there is no change in the skill composition of migration. But the shock attracts more migrants, so the ratio of migrants to natives rises in country D. Since the shock is symmetric across sectors and there is no change in the skill composition of migration, income inequality does not change across the skill groups within countries. But income inequality between D and S rises, as a higher fertility cost in D leads to a lower fertility and a greater investment in human capital, which in turn raises the growth rates of physical capital and income in D, as well as the level of migration flows along the transitional dynamic paths.

5.2.1 Isolating the Effects of Induced Migration under the Fertility Shock

As in section 5.1.1, to isolate the induced immigration effect of this shock, we simulate the dynamic paths under two scenarios. In the first, the migrant to native ratios M^1/N^{d1} and M^2/N^{d2} are restricted to be frozen at their initial steady state equilibrium values. In the second, immigration is left unrestricted, which represents the total effect of the shock. The difference between the two scenarios indicates the impact of induced migration, as shown in Panel (b) of Figure 3.

The adverse fertility shock in D generates induced migration from S. Since migrants' average human capital is lower than that of the natives in D, the induced migration lowers the average human and physical capital, and thus income, in D. Hence, country D experiences a loss from the rise in migration. At the same time, the latter increases the population in D relative to S, so the knowledge spillover effects from D to S become stronger, benefitting human capital formation in S. Therefore, country S gains. The net effect of immigration induced by the decline in the fertility rate in D thus also lowers income inequality between D and S.

5.3 Push Factor: A One-Period Adverse Productivity Shock in *S*

We focus here on the transitional dynamics of an adverse productivity shock, specific to country S, such as a decline in the productivity parameters associated with high-tech and low-tech goods. The trigger could be a radical change in government policies, or a natural disaster that lowers the demand for workers and induces more of them to migrate to country D. One example is the Syrian civil war that launched the immigration of millions of refugees to neighboring countries in the Middle East and Europe between 2011 and 2016. In the simulations, we implement the adverse shock by lowering the parameters Γ^{s1} and Γ^{s2} in equation (4) by 5%. We limit the negative shock to last just a single period (generation) since such shocks are reversible. We then simulate the transitional dynamic evolution in both D and S, tracing it from the initial steady state of balanced growth. Panel (c) of Figure 2 illustrates the results. As the shock occurs in both production sectors, there is no change in the skill composition of migration. We obtain this result since we are not upsetting any balanced growth condition in this experiment – the relative productivity ratio Γ^{s1}/Γ^{s2} remains constant. During the period of the shock, the migrant population rises relative to native population in country D. However, when the shock is reversed, the population share of migrants relative to natives eventually gets back to its pre-shock level.

Since the shock is symmetric across sectors and there is no change in the skill composition of migration, income inequality does not change across the skill groups within countries. It does change, however, in a non-monotonic pattern between D and S. Specifically, the cross-country inequality first rises, as the negative productivity shock results in a loss of production and income in S. It then continuously falls, because (1) S recovers from the negative shock, and (2) S benefits from higher knowledge spillover effects from D since the increased migration from S to D brings about a larger population in D relative to S. Eventually, however, the cross-country income inequality rises back again when migration from S to D returns to the original steady state, so population in S rises and the knowledge spillover effects slow down relative to their original magnitude.

5.3.1 Isolating the Effects of Induced Migration under the Productivity Shock

Following the same methodology as in section 5.2.1, we again isolate the effects of the induced migration under the negative productivity shock in S, and the results are illustrated in Panel (c) of Figure 3. The adverse productivity shock in S induces migration to rise in D. Since there is no change in the skill composition of migration due to this shock, and migrants' average human capital is lower than that of the natives in D, the induced migration lowers the average human and physical capital, and thus income, in D. At the same time, the rise in migration increases the population in D relative to S, so the knowledge spillover effects from D to S become stronger, benefitting human capital formation and the thus the income level in S. While induced migration brings about a decline in income inequality across countries, D would gain and S would lose from restricting immigration. However, there is no change in the skill composition of migration within the two countries, so income inequality across skill groups remains unchanged.

6. The Immigration Surplus

Following the comprehensive simulation analyses in section 5, we can now compute a critical indicator of the reported results by assessing the *net* economic benefits to natives in both destination and source countries resulting from the induced changes in migration due to their relevant triggers. Our assessment of the net benefits is based on the conventional "immigration surplus", but we evaluate it in both static and dynamic forms.

The conventional approach for measuring immigration surplus is based on a static or neo-classical framework where technology is invariant, and per-capita physical capital (as well as human capital stock, if any) are fixed. As the demand for labor is downward sloping, any rise in labor supply due to migration, assuming that migrants do not bring any physical capital, lowers the wage rate due to the diminishing returns to labor. At the same time, however, the rate of return to physical capital increases, and the rise in capital income outweighs the fall in labor income. Hence, the overall net effect on natives in the destination country is positive. By the converse logic, emigration surplus in the source country is negative.

In our dynamic model, a discrete period represents a whole generation. But we can mimic the conventional approach by estimating a static version of the immigration surplus. We do that by allowing a specific external immigration trigger to effect an endogenous change in migration flows under the restriction that the flows affect only the wage rate and the rate of return to capital in the destination (source) country, leaving all other endogenous variables constant. We can then compute the corresponding change in income due to these factor price changes. More specifically, taking the destination country D as an example, we denote the weighted average per-capita income (Inc) in D before the change in migration (time 0) as

$$Inc^{d,0} = \frac{N^{d1,0} I^{d1,0} + N^{d2,0} I^{d2,0}}{N^{d1,0} + N^{d2,0}},$$

where $I^{d1,0} = r^{d1,0}K^{d1,0} + \omega^{d1,0}H^{d1,0}L^{d1,0}$ is the income per capita of the high-skilled group and $I^{d2,0} = r^{d2,0}K^{d2,0} + \omega^{d2,0}H^{d2,0}L^{d2,0}$ is the income per capita of the low-skilled group. We weigh each group by its population, $N^{d1,0}$ and $N^{d2,0}$ respectively, to get the weighted average income per capita. Similarly, we denote the per-capita income after the change in migration (time 1) as

$$Inc^{d,1} = \frac{N^{d1,0}I^{d1,1} + N^{d2,0}I^{d2,1}}{N^{d1,0} + N^{d2,0}},$$

where $I^{d1,1} = r^{d1,1}K^{d1,0} + \omega^{d1,1}H^{d1,0}L^{d1,0}$, and $I^{d2,1} = r^{d2,1}K^{d2,0} + \omega^{d2,1}H^{d2,0}L^{d2,0}$. Note that we allow only the factor prices r and ω to change, while all other endogenous variables – population (N), physical capital (K), human capital (H), and labor (L) – remain fixed. The static immigration surplus, $IS^{d,static}$ in D, is the percentage change in income due to immigration:

$$IS^{d,static} = 100 \times \frac{Inc^{d,1} - Inc^{d,0}}{Inc^{d,0}}.$$

Our static immigration surplus measure is thus similar to the conventional measure in that the change it represents is due to factor price movements, which is caused by the change in aggregate labor supply due to migration. The difference, however, is that in our case, migration is an endogenous outcome of what has triggered it, while in the conventional approach migration is strictly an exogenous event. Another difference is that in our model migrants bring some capital as well, which further affects factor prices. The formula is identical for computing the static IS in the source country if the superscript d is replaced by s, and the population N^{dj} is replaced by $N^{sj} - M^j$. The global IS measure is similarly computed as the percentage change in the weighted average of per capita income in the global population, which includes natives in D and S and migrants.

More importantly, we implement a dynamic version of the immigration surplus measure to assess the net benefits of a change in the migration flow, from its initial, static value to its dynamic evolution over the transitional dynamic path, leading to the balanced growth equilibrium path. In our dynamic equilibrium context**,** we need to measure the immigration surplus by separating from the total economic effects of an external shock, or trigger, its *induced immigration effects* – i.e., the effects brought about strictly by the immigration changes induced by that trigger. To do so, we restrict the skill composition of migrants or migrants to natives shares to stay unchanged and compute the percentage changes in key determinants of the IS across the unrestricted and restricted cases.

Formally, the dynamic immigration surplus in D, $IS_t^{d,dyn}$, is calculated as the percentage change in per capita income, which is used to measure the benefits or losses brought about by an external shock – a pull or push factor – to the economy, as follows:

$$IS_t^{d,dyn} = 100 \times \frac{Inc_t^{d,b} - Inc_t^{d,e}}{Inc_t^{d,b}},$$

where $Inc_t^{d,b}$ stands for per capita income in country D at time t under free immigration and $Inc_t^{d,e}$ stands for per capita income under an experiment where we hold constant either the skill composition of migrants (in the case of a SBTS shock) or migrants to natives ratio (in the case of a downward fertility shock in D, or an adverse productivity shock in S). In both the unrestricted and restricted migration cases, all endogenous variables adjust along the dynamic paths. The formula is identical for computing the dynamic IS in the source country if the superscript d is replaced by s, with the population measured as $N^{sj} - M^j$ in group j. The global IS measure is also the percentage change in per capita income in the global population, which includes natives in D, natives in S and migrants.

6.1. Migration Induced IS Changes due to Alternative Triggers

In Table 3, Panel (a) summarizes the immigration surplus (IS) in the benchmark model, and Panel (b) summarizes the IS in the extended model that allows for diversity effects. In both Panels, positive values indicate a *loss* from a restrictive policy change, hence a *gain* in the IS due to unrestricted migration. In addition to the IS, which we compute based on income per capita, we also compute in Table 3 the percentage changes in other related endogenous variables: per-capita values of human capital and physical capital. While the literature generally focuses only on the destination country, we evaluate the IS for three groups: the natives in the destination country, the natives in the source country, and the entire global economy. We calculate both the static and dynamic immigration surplus along the transitional paths for the natives in both the destination and source countries to determine if they are compatible or conflicting, as this may determine their political stability. The reason for considering the global economy is that our model is also suitable for studying internal migration within a country, and the welfare in the global economy can be mapped to the welfare in a country with internal migration.[23]

In Panel (a) of Table 3, the effects of immigration changes on the IS are summarized by the triggers that induced these changes. We consider three triggers: a skill-biased technological shock (SBTS) in both D and S, a downward fertility shock in D, and an adverse productivity shock in S. The static IS for country D, measured in terms of income per capita, is negative under SBTS, and positive under the other two triggers. The reason is that there is a small, but temporary, decline in migration under SBTS in the static case, as explained in footnote 19 and shown by the values of M^j/N^{dj} ($j = 1, 2$) in Table 3 relative to their initial, steady-state values in Table 1 (0.1772). In contrast, there is a rise in migration under the downward fertility shock or the adverse productivity shock relative to their initial steady state values in Table 1. Consistent with the conventional measure, our static IS in D is positive (negative) when migration increases (decreases). Note that alternative welfare indicators, including human and physical capital per capita, are zero because both capital stocks are invariant in the short-term.[24]

[23] For example, we can use our model to study rural (S) to urban (D) migration within a country and evaluate the welfare impact on the whole country due to various migration policies.

[24] EK (2015) computes the immigration surplus just in the case of SBTS, based on the net changes in "full income", rather than market income per capita, which produces different quantitative results, since full income includes the opportunity cost of time spent in non-market activities and is invariant to changes in physical capital and work time, L.

The static IS for country S is positive under SBTS, because having less high-skilled workers emigrating increases their proportion in the population and generates an immediate, but very small rise in per-capita income in S – just 0.01 of 1%. But the static IS for S is zero under the downward fertility shock in D or the adverse productivity shock in S. This is because in our analysis these two shocks induce an equal change in high-skilled and low-skilled migration, and migrants also bring their physical capital when they migrate, so the capital-to-labor ratio is maintained in S, and per-capita income is not affected. Note that this results contrasts with the conventional literature, since it assumes that immigration involves exclusively just a pure labor transfer.

Turning now to the dynamic effects of immigration triggers on the IS, we report these effects only after 3, 5, and 10 generations following the shock. Table 3 Panel (a) shows that under SBTS the long-term IS rises modestly in D in terms of the change in per-capita income – from only 0.05 of 1% after 3 generations to only 1.16% after 10 generations – and falls *significantly* in S - by 12.8% after 10 generations. This is because SBTS induces a rise in the skill composition of migrants, so the skilled workers' population share, and average human and physical capital, and thus income per capita in D increase. But as S experiences a "brain drain", its average human and physical capital decrease, and thus per capita income continuously falls. The loss to S outweighs the gain to D, as reflected by the value of the global IS, essentially because the marginal addition by the skilled migrants to average human and physical capital-rich D is modest, relative to the significant loss in the capital assets-poor S country.

Under a downward fertility shock in D or an adverse productivity shock in S, the IS falls in D and rises significantly in S – by over 40% in the long term under both shocks. This is because under these shocks, the migration volume increases without an increase in its skill composition. Immigration to D lowers the average human capital level in D. But the higher population in D raises the intensity of the knowledge spillover effects, which increase the average human capital in S. As the gain in S is significantly larger than the loss in D, the global IS increases. Panel (a) thus indicates that the changes in the IS for D and S as a result of migration triggers are generally asymmetric. We discuss the underlying source of these asymmetries in section 9.

Panel (b) reports the immigration surplus for the extended model where the IS is augmented by diversity effects. Allowing immigration to generate complementarities in knowledge production between migrants and natives alters the predicted total and induced immigration effects due to the three triggers. Under all three triggers, there is a rise in the growth rates of human and physical capital, and thus in per capita income. The faster growth rate in D, in turn, increases uniformly the rates of growth of income per capita in S due to the knowledge spillover from D to S. However, the changes in the IS due to the migration changes induced by the three triggers are again not uniform, as discussed below.

The asymmetric welfare effects on D and S remain unchanged in the extended model under the SBTS shock: while the IS gain becomes larger in D (1.28% after 10 periods, relative to 1.16% in the benchmark model), the IS loss in S persists though at a slightly lower level, as in the benchmark model. However, under a downward fertility shock in D, the IS change now turns to be positive, rather than being negative in D, as was the impact in the benchmark model, while continuing to be positive in S. This is a *win-win* outcome due to the allowance for diversity effects in knowledge generation. Also, under an adverse productivity shock in S, the IS change turns positive in D for three periods, but then slides down in a negative direction. The initial gain in D is due to the interaction effects between natives and immigrants, but the ultimate loss in D is due to the fact that the migrants' population ratio M^j/N^{dj} falls as the native population in D rises over time when older immigrant cohorts become native, and the resulting diversity effects become smaller. Since there is no such loss in S, the IS continues to be positive in S, as in the benchmark model. For all three triggers, the global IS remains the same as in the benchmark model: negative under SBTS and positive under the other two shocks.

7. Impact of Policy Interventions

We apply the same methodology used to assess the impact of external shocks, or immigration triggers, to assess the net benefits of immigration policy changes that affect human capital, or the *skill composition* of immigrants, and their capital asset mobility. As in Table 3, we compute the immigration surplus for both the benchmark and the extended models. These experiments produce insights about both the static and the long-term consequences of specific immigration policies, as well as the political stability of unconstrained immigration in view of the asymmetric consequences that affect natives in both destination and source countries.

7.1 Immigration Policies Limiting High and Low-Skilled Migration

Our analysis in sections 5 and 6 indicates that the skill composition of migration turns out to have a significant impact on the immigration surplus when immigration is triggered by an SBTS shock. In the following experiments, we attempt to highlight the net welfare effects of high-skilled and low-skilled migration restrictions on natives in D and S.

The first experiment is a hypothetical policy intervention whereby country S disallows all emigration of high-skilled workers from S.[25] Table 4 shows that the static effects of this restriction on the IS turn out to be a very small loss to D (0.03 of 1%) and a positive gain (5%) to S, as would be expected under the conventional case. The dynamic outcomes, however, turn out to be *symmetrical* for both D and S. Table 4 shows that in this case both D and S lose a very high share of their potential long-term per-capita income from the policy restriction, regardless of the type of the external shocks (SBTS, fertility shock, or productivity shock) that trigger the change in the induced migration. D is losing due to the loss of high-skilled migrants who can raise the average human capital level in the population, and thus income per capita. Although S no longer experiences a "brain drain", S also loses because the knowledge spillover effects it obtains from D become quite modest. In other words, allowing for some high-skilled migration from S to D not only benefits D, but also benefits S, because it exerts a beneficial effect on a still relatively large group of high-skilled workers in S, which also generates a significant spillover effect on low-skilled workers in S. Allowing free high-skilled migration, relative to none, which is what Table 4 shows, turns out to be a win-win situation for both D and S, and therefore the global economy under all three triggers.

[25] This experiment as well as the following one in Table 5 have been offered originally in EK (2015) using just SBTS as the immigration trigger and relying on just human capital as a productive asset. The qualitative results we derive are nevertheless similar, although the quantitative effects are somewhat different in our case where we compute the IS based on GDP, or market income, rather than "full income" per-capita.

The second experiment is the opposite hypothetical experiment whereby country D disallows all low-skilled immigration from S to D. Table 5 indicates that, except for the static case where both D and S lose from the restriction, over time the dynamic outcomes become *asymmetric* for the two countries: D gains whereas S loses from the policy restriction, regardless of the external shock that triggers the induced migration. The gain in D occurs because by disallowing low-skilled migrants, thus assimilating only high-skilled migrants, the long-term average human and physical capital, and therefore income per capita rise over time. In contrast, S loses because by remaining with a large low-skilled population, average human and physical capital, and thus income per capita in S fall over time. Furthermore, knowledge spillover effects from D to S and from high-skilled to low-skilled in S become weaker, which increase the loss in S. And since the loss in S exceeds the gain in D, the global economy loses from a full restriction on low-skilled immigration. Unrestricted low-skilled migration is thus a gain to S and the global economy, but a loss to D.

The IS outcomes of bans on either high-skilled or low-skilled migration that are reported in Panel (a) in Tables 4 and 5 under the benchmark model are reconsidered using the extended model that allows for complementarities between natives and immigrants in knowledge production. Panel (b) in Tables 4 and 5 reports the changes in the immigration surplus when high-skilled and low-skilled migration are disallowed, respectively. Compared to Table 4 Panel (a), the results are identical qualitatively in Panel (b), but the magnitudes of the net gains from unrestricted high-skilled migration are larger quantitatively in the extended, relative to the benchmark model. This is because the complementarity between natives and migrants increases the growth rates in both D and S, which strengthens the conclusion that allowing for some positive high-skilled migration is beneficial to both D and S. This may explain why some less developed countries send students to get educated in developed countries, despite the fact that many choose to become immigrants in D: The spillover effects on their counterparts in S is an advantage to S. But the outcomes in Table 5 Panel (b) remain conflicting concerning the allowance for positive low-skilled migration, which are negative in D and positive in S, although somewhat less harsh quantitatively.

7.2 Immigration Policies Motivating Migrants to Bring Physical Capital Assets

Our model allows us to extend our policy experiments to deal with regulations affecting the mobility of individual assets, which generate distinct changes in migration flows and thus in the net benefits to natives in D and S. In this subsection, we consider a policy shift that encourages migrants to bring more physical capital by decreasing their transaction costs of moving physical capital from S to D, which are captured in our model as reductions in the parameters τ^{k1} and τ^{k2} (see equation 9). Table 6 shows the corresponding welfare effects of reducing τ^{k1} and τ^{k2} by 5% relative to their initial steady state values. In Panels (a) and (b) we report the consequences under the benchmark and the extended models. We also plot the transitional dynamics of the total and induced migration effects of these changes in Panel (a) of Figures 4 and 5, respectively.

In assessing the impact of the lowered transaction cost of migrants' capital mobility, we consider three welfare measures, all expressed in percentage terms. The first measure is the total impact of the policy shift, relative to the original equilibrium under the benchmark or extended models, where there are no restrictions on migration and no accompanying shocks (row 1 of Tables 1 and 2). Since the policy in this subsection is nonrestrictive, as it involves a reduction in the costs of moving capital, positive values continue to denote the welfare gains from relaxing a restrictive policy. The second measure involves the immigration surplus, as in section 6, which captures the per-capita income change due to the induced immigration effect of the policy shift. The third measure is the isolated effect of the change in the flow of *physical capital* induced by the policy, which is independent of the change in migration flows. This effect is assessed by constraining the *migrants-to-natives* ratios to remain at the same level as in the original equilibrium. This mimics a quota system, which the government can achieve by giving preference to immigrants with more capital without changing the total quota of immigrants.

Under no migration restrictions, the total effect of the policy shift leads to a small static income gain to D due to larger migration flows. But in the long run, there is a small income loss to D, but a large gain to S. Although a larger inflow of physical capital increases aggregate production in D, the larger inflow of migrants lowers the average level of human capital in D since the policy does not affect the skill composition of migrants who have a lower level of human capital relative to natives. The rise in the population ratio of D relative to S, partly due to the wealth effects of higher wages, and partly due to migrants becoming assimilated, increases the knowledge spillover effects from D to S. Hence, there is a significant rise in the net benefits to S from emigration, and global welfare increases as well. There is no change in the income distribution across skills since the policy shift does not change the skill distribution of migrants. The change in the immigration surplus in this case indicates the same effect as that the total effect of the policy shift, although the loss of income in D is slightly higher. The reason is that the immigration surplus does not capture the small benefits to D from having more capital.

In the extended model (see Panel (b) of Table 6), when there are no restrictions on migration, the rise in migration increases the diversity level and thus the growth rates in D, and leads to an increase in income per capita through the 5th generation. But as the population in D continues to rise relative to S, the migration ratio M^j/N^{dj} eventually falls and the diversity effects become weaker, resulting in a loss in per capita income in D in the 10th generation.

Under the restriction that the migrants-to-natives ratios remain constant, which can be effected by imposing a fixed migration quota with preference awarded to those bringing more capital, the direct effects of facilitating the rise in physical capital in D is shown to yield a small static income loss to D. Although this “migrant direct investment” increases aggregate production, income per capita among natives decreases, because while more capital means both a lesser decline in the wage rate and a smaller rise in rate of return to physical capital, the gain in wage income cannot fully offset the loss in capital income. The overall effect is a very tiny income loss to D, as the beneficiaries from the output increase are the immigrants. This effect is consistent with the static immigration surplus analysis in the literature. However, in the longer term, this constrained policy leads to a win-win situation: both D and S gain. The reason is that in this scenario, the negative effects on human capital are eliminated when immigration is constrained, so D gains, while S also gains due to knowledge spillover effects. These effects apply equally to the benchmark and extended models.

There is yet an additional policy scenario that can make the policy shift discussed in this subsection more potent: raising potential immigrants’ incentive to bring more physical capital to D when they migrate can also attract wealthier immigrants with an entrepreneurial proclivity, who could bring about new process and product innovations. In this case, the net effect on the IS would turn into a win-win situation even when there are no restrictions on immigration. This effect is equivalent to inducing more high-skilled migrants, who are wealthier than the less-skilled immigrants. In that case, increasing the individual incentive to bring more capital assets would also trigger an increase in the skill composition of migrants, and thus bring about an increase in the average level of human capital in the population, as in the case of a skill-biased technological shock.

8. Capital Endowment

Our theoretical model has so far recognized just one fundamental difference between destination and source countries – their predetermined technological development levels in producing both knowledge and goods, and thus their income levels and fertility choices. Both countries are otherwise assumed to share identical competitive economic environments. In reality, however, there are differences in natural resources that may also separate D and S, one of which is physical capital endowments in the form of land or natural resources. An advantage of having physical capital in the model is that it allows us to study the implications of such heterogeneous capital endowments on immigration. In this section, we extend the structure of the benchmark model by adding a fixed capital endowment $\bar{K}$ as a factor affecting the production functions of goods and exploring its impact on immigration flows and the resulting immigration surplus. We motivate this analysis by linking the simulated experiment with historical and stylized examples illustrating the impact of the discovery of resource endowments on immigration.

We assume that country D receives a physical capital endowment such as land that is rich in natural resources and good climate, which can be thought of as a special form of capital that augments the productivity of effective labor and capital, and thus enhances the technology of goods production. Specifically, the goods production functions associated with sector $j = \{1, 2\}$, can be specified as follows:

$$Q^{dj} = \Gamma^{dj}\left(\bar{K}^{dj}\right)^{\alpha}\left(\mathcal{K}_t^{ij}\right)^{\alpha}\left(\mathcal{H}_t^{ij}\mathcal{L}_t^{ij}\right)^{1-\alpha} \qquad (26)$$

Equation (26) has the same specification as equation (3) except that $\bar{K}^{dj} = 1$ in the benchmark model. Note that an increase in $\bar{K}^{dj}$ raises overall factor productivity, and thus the wage rate and the rate of return on physical capital.

In the simulation experiment, we raise $\bar{K}^{dj}$, by 1%, to 1.01. We plot the transitional dynamics of total and induced migration effects of the endowment shock in Panel (b) of Figures 4 and 5, respectively. In Panels (a) and (b) of Table 7 we also assess quantitatively the total effect of the endowment shock and the dynamic evolution of the immigration surplus due to the induced immigration triggered by the shock, under both the benchmark and extended models, respectively.[26] In so far as the total endowment effect on the economy is concerned, the increased endowment and the enhanced productivity it generates are a windfall for D, so income per capita

[26] The total effect and the immigration surplus measures are calculated in the same way as in section 7. Recall that immigration surplus shows the impact of the induced immigration effect of the shock, which is only a small part of the total impact of the shock.

rises in D. The higher productivity level in D also attracts more immigrants to move from S to D, and this increases the knowledge spillover effects generated by D, benefitting S as well. The capital endowment shock in D is thus beneficial to both D and S (see Panels a and b in Table 7).

In so far as the impact on the immigration surplus is concerned, however, the capital endowment effect is similar to the one we obtained in section 7.2 when providing an incentive to immigrants to bring more capital. A higher migration leads to a small static gain in income per capita in D. But over the long run, the higher immigration volume lowers the average human capital level and decreases income per capita in D, starting after the third generation. The higher immigration also raises the population level of D relative to S, so that the knowledge spillover effects from D to S become much stronger. This raises the IS in S and the global IS.[27]

In the extended model, higher migration initially increases the diversity effect in D, which increases the growth rates of human capital, physical capital and income. So the IS turns positive through the 5th generation (see Panel b of Table 7). But as migrants become assimilated, the population in D rises, so the migrants-to-natives ratio declines, causing a decline in diversity and a loss in IS in the 10th generation.

To some extent, this exercise sheds some light on the Louisiana Purchase by the U.S. in 1803 and the Homestead Act of 1862. The fertile land endowment encouraged westward population expansion and settlement, as well as a significant increase in foreign migration, which is similar qualitatively to the rise in migration over a few generations generated by our simulation. Our results also provide a possible explanation for why the U.S. placed restrictions on immigration in the late 19th century (e.g., via the Chinese Exclusion Act of 1882) and the early 20th century (via the Immigration Act of 1903 and the Naturalization Act of 1906). This may be explained by our simulation exercise, which indicates that the initially positive effects generated by the endowment shock on D's IS last through a few generations, but then start diminishing going forward.

9. Cross-Country Asymmetries in the Immigration Surplus

Our simulation exercises allow us to draw several policy inferences concerning the dynamic economic consequences of immigration. First, while the rise in migration is always beneficial to the destination country and harmful to the source country in the conventional short term or static case, the long-term dynamic implications can be very different, depending on the immigration triggers that induce the change in migration. In our simulations based on the benchmark model, the only external shock that leads to long-term benefits to the destination country is the SBTS, which raises the skill composition of migration. The long-term benefits in this case take place because immigration flows that have a higher share of skilled immigrants raise the average human

[27] Another way of modeling is that the capital endowment extends the existing capital stock as, $Q^{dj} = \Gamma^{dj}(\bar{K}^{dj} + K^{dj})^{\alpha}(H^{dj}L^{dj})^{1-\alpha}$, where $\bar{K}^{dj} = 0$ in the benchmark model. Such is the situation in Norway with the discovery of oil. In this case, D faces a positive increase in static IS along with higher migration, but IS turns negative in the long run. Note that in this subsection, we are using D as a receiver of the endowment. If S receives the capital endowment, the results are opposite: IS increases in D and decreases in S.

capital of all workers in D over time.[28] Under immigration triggers that produce no increase in the skill composition of migrants, D loses in the long term despite a short-term gain, as migrants have lower average human capital, while S gains from the spillover knowledge effects conferred by a rise in the population shares of D relative to S due to perpetual migration. We emphasize the role of perpetual migration since over time past migrants become natives – by our simplifying assumption after only one generation – the asymmetry in educational attainments persists between new flows of immigrants and natives.

Second, the induced migration effects tend to be asymmetrical in the destination and source countries, not just in the short run, but in the long run as well. Based on our immigration surplus analysis as summarized in Tables 3-7, the only two long-term win-win situations for the destination and source countries in the benchmark model occur if S does not disallow skilled migration and if D restricts the migration ratio to remain constant when migrants are induced to bring in more physical capital. In the extended model, which allows for diversity effects, the additional win-win equilibrium occurs when a negative fertility shock in D induces additional migration. In all other cases, including the capital endowment case, there is a long-term gain to one country but a long-term loss to the other country from the added migration induced by an external shock or a policy change.

The underlying reason for the asymmetrical welfare effects is that free migration may inevitably impose negative externalities on natives in either the destination or source countries, since individual decisions to migrate do not consider any adverse impact on natives in either D or S. Thus, while there exists a balanced growth equilibrium under unrestricted migration, it may be unstable politically. Note that in this paper we consider only the economic consequences of migration, and ignore the fiscal consequences of immigration in D. The latter have been estimated to worsen the IS for natives in D in the short term (see NAS 2017). This asymmetry in the net welfare effects of immigration helps rationalize the fact that most countries have intervention policies regulating the migration of labor or even the transfer of capital assets. It also explains why countries often resort to bilateral diplomacy to reach bargaining solutions concerning the flow of immigration.[29]

A superior market solution is to internalize the externalities by pricing and compensation a la Coase (1960). Specifically, as migrants impose costs on the destination and/or source countries, governments can make migrants pay for these costs and redistribute the revenue to individuals who are adversely affected. This approach would be a Pareto improvement, as it assures that natives in D and S are not adversely affected while migrants become better off in terms of the impact on their individual incomes due to migration. For example, Becker (2011) argues that charging immigrants a fee, say $50,000 per person, would be a more efficient system than the quota system existing in many developed countries. Another superior approach is to promote economic growth in the source countries. One example is to make more investments in human

[28] In this context, it is worth noting that the channels of net benefits of migration in a destination country are very different in the short term versus the long term. In the short term, benefits are derived from changes in prices, i.e., the decrease in wage rate and the increase in rate of return to capital. However, in the long term, benefits come about when average human capital increases.

[29] An example is the U.S. aid to the Northern Triangle states of Central America (Guatemala, Honduras, and El Salvador) since 2014, when immigration waves by children were triggered by adverse economic shocks in these countries, which brought immigration from these countries to its lowest level in 2017.

capital in S, especially in education by reducing the financial cost of investment in human capital, which in turn reduces the incentive to emigrate. But this solution may require public investment in higher education as well as a conducive economic environment that provides an adequate rate of return to investment in higher education.[30] Another strategy for both D and S is to lower the economic and political risks associated with capital inflows from D to S in the form of foreign direct investment, which tends to enhance productivity and technology transfers and lower income inequality between the destination and source countries.

10. Conclusion

This paper is closely related to an earlier paper by EK (2015), where immigration, population growth, and income growth and distribution are treated as endogenous variables in an overlapping generations, balanced growth global equilibrium setting, with human capital serving as an engine of growth in both destination (D) and source (S) countries. Both papers recognize two distinct groups of workers – high and low skill – who are employed exclusively in high-tech and low-tech sectors, and allow for knowledge spillover effects across the skill groups within and across countries. Both papers also develop the analysis using two models – a benchmark model where knowledge spillover effects are hierarchical, and an extended model allowing for complementarities, or diversity effects, between natives and migrants in knowledge production. EK (2015) recognized human capital, however, as the sole factor of goods production.

The main innovation of our paper is the inclusion of physical capital as a complementary factor of goods production, and an asset that immigrants can bring along with them as they move from S to D. Residents of each country can thus invest their accumulated physical capital in either their own economy or the economy of the other country, and leave it as bequest to their offspring, as our model emphasizes. Having two distinct assets in the economy has also enabled us to add new insights concerning the economic consequences of immigration. The first is the ability to offer a more complete assessment of the net benefits from immigration, or the "immigration surplus" to the native populations in D and S, and thus to the global economy (G). More specifically, we assess the immigration surplus under both "static" conditions, as does the conventional literature, as well as over the transition phase leading to a new balanced growth steady state. While our estimated IS is always positive in country D in the short term, whenever D receives more immigrants, this is not necessarily the case in the long run, where the value of the IS may turn negative along the transitional growth paths. Conversely, while the IS often assumes a zero value in S initially due to the rise in emigration, its ultimate long-run value may turn positive. This depends largely on the type of external shock that induces changes in the flow and skill composition of immigration. For example, a downward fertility shock in D or an adverse productivity shock in S increases migration from S to D, which initially generates a positive IS in D and a zero IS in S. But in the long-run IS turns negative in D and positive in S. In general, we obtain positive IS for D in the long run only if the average levels of human and physical capital eventually rise.

[30] Ehrlich, Cook and Yin (2018) show that the Morrill Act, which pioneered the establishment of public higher education had been successful in raising productivity growth rates in the U.S. relative to the UK, which did not have such a public system until the first decade of the 20th century.

A fair question that is worth discussing in connection with the dynamic effects of endogenous immigration reported in Tables 3-7, which document the long-term effects of pull and push factors, is that they are estimated over many generations into the future, so the policy implications we have discussed in sections 6-9 apply only in the very distant future. But as Tables 3-7 indicate, the dynamic implications of the long-term effects are detected within 3 to 5 generations as well and remain consistent into the distant future, so the direction of change they manifest may be relevant for the development of immigration policies that apply in the near and intermediate terms as well.

A critical inference underscored in the paper is that the treatment of immigration as an endogenous variable highlights the role of external shocks that are behind the observed migration flows. This implies that the total economic effect of an immigration trigger is often incompatible with the welfare benefits of the added migration induced by the trigger. For example, an SBTS increases the growth rates of per-capita income in both D and S but also the flow and skill composition of new immigrants from S to D. Consequently, the long-term induced immigration effects on per-capita income and the IS are positive in D but significantly negative in S. While the long-term total effects of SBTS raise income inequality both within and across countries, the induced immigration effects diminish income inequality within D, but increase it within S as well as across D and S. Likewise, the total effects of a downward fertility shock in D are positive in D and S in the long term, but the long-term induced immigration effects are positive only under the extended model due to diversity effects. And while the total effects of the fertility shock increase income inequality across D and S, its induced immigration effects decrease the cross-country inequality. In contrast, the total economic effects of an adverse productivity shock in S are negative in both D and S, but their long-term induced immigration effects have adverse effects in D but beneficial effects in S. However, both the total and the induced immigration effects lower the cross-country inequality, due to the knowledge spillover effects on S generated by the rise in migration flows. Neither the fertility shock in D nor the adverse productivity shock in S, however, affect within-country inequalities, as they do not generate any changes in the skill composition of migrants.

Physical capital also plays a distinct role in this context. The conditions for a balanced growth equilibrium require that the physical to human capital ratios remain constant across the high-tech and low-tech production sectors within each country. However, these ratios can change as a result of external shocks representing different pull or push factors, or as a result of government policies that favor immigrants who may bring along with them physical capital, or ‘immigrant investment funds”. Our analysis shows that a reduction in high transaction costs of physical capital, which results in more (claims to) capital brought along by migrants, will also attract a higher immigration from S to D. Such induced migration may have a neutral effect on the skill composition in the destination economy, in which case the initial IS would be positive but the long-term effect of the induced immigration will turn negative because the added migration lowers the average level of human capital in the economy. In the long term, then, both average human and physical capital per capita would fall, reducing income per capita and the immigration surplus.[31] Lastly, our capital

[31] While we focus on the per-capita terms in the paper in evaluating the immigration surplus, it is also important to point out that in reality, many policies emphasize consequences of immigration that apply to aggregate GDP, not per-capita GDP. One potential reason is that there may be some social externalities from having a bigger sized economy. For example, a larger GDP may imply a greater international influence, both economically and politically. If this is indeed the case, then there are additional benefits from having more migrants or attracting migrants with more capital, both of which increase aggregate GDP.

endowment experiment illustrates the distinct relevance of physical capital for immigration. When country D receives a physical capital endowment, it increases output and the wage rate in D and attracts more migrants from S. However, the induced migration effect is negative for D, as migrants have lower average human capital, while it is positive for S, as knowledge spillover effects become stronger.

A critical feature of the global equilibrium analysis we derive in this paper is that in the majority of the long-term equilibrium consequences of immigration, the immigration surplus is asymmetric across D and S. This is the case in both our benchmark model and the extended model where we allow for complementarity in knowledge production between natives and immigrants of similar skills, which produces higher net benefits to natives in D, but still negative benefits to those in S. This asymmetry indicates that although our model helps explain the existence of a locally stable balanced growth steady state equilibria, such equilibria may not be politically stable and require government intervention. This may explain why virtually all sovereign nations do not allow free labor mobility and constrain immigration through varied immigration policies.

Finally, while we have tried to emphasize the general applicability of our model in assessing the consequences of different external shocks and alternative public policies, we need to emphasize some of its limitations as well. The balanced-growth equilibrium and segmented production sectors under which the model is developed is intended to eliminate corner solutions in which immigration triggers can lead to the absorption of source countries into their destination targets. At the same time, these constraints limit the degree to which we can vary some key parameters of the model and fully assess the quantitative benefits from immigration that may apply to just one country or one sector of the economy. The dynamic estimates of the immigration surplus are limited also because they apply just to their impact on the per-capita income of natives. This leaves out benefits to the immigrants who derive psychic benefits from extended family unification, which takes place when close relatives of natives are given preference under quota systems. The same applies to other non-economic benefits from providing asylum to victims of dictatorial and authoritarian regimes. Furthermore, while we allow for the production of both high-tech and low-tech goods, we abstract from their distinct consumption benefits, which rules out any consideration of the impact of immigration on international trade in goods. In addition, our analysis of the economic effects of immigration does not address the fiscal consequences of immigration. An integrated model that combines international trade in goods with international labor and capital mobility or the economic and fiscal consequences of immigration, however, are way beyond the scope of this paper and are left for future work.

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Table 1. Comparative Dynamics under the Benchmark Model

Parameter Shift	$n^{d1} = n^{d2}$	$n^{s1} = n^{s2}$	$n^{m1} = n^{m2}$	$h^{d1} = h^{d2}$	$h^{s1} = h^{s2}$	$h^{m1} = h^{m2}$	$H_{t+1}^{ij}/H_t^{ij} = K_{t+1}^{ij}/K_t^{ij}$	$\Delta^{dd2} = \Delta^{ss2}$	$\Delta^{ds1} = \Delta^{ds2}$	$M^1/(M^1+M^2)$
1. Initial steady state	1.0680	1.7401	1.3308	0.1811	0.1132	0.1132	1.8109	5.6569	5.6589	0.5
2. $A^{d1} = 12, A^{s1} = 9.6$	1.0759	1.7546	1.3432	0.1811	0.1132	0.1132	2.1731	8.9234	5.6589	0.5188
3. $v^d = 0.1433$	1.0145	1.7440	1.3247	0.1901	0.1132	0.1132	1.9015	5.6569	6.3930	0.5
4. $\Gamma^{s1} = \Gamma^{s2} = 8.357$	1.0713	1.7401	1.3323	0.1811	0.1132	0.1132	1.8109	5.6569	5.6589	0.5
5. $\tau^{k1} = \tau^{k2} = 0.475$	1.0711	1.7401	1.3363	0.1811	0.1132	0.1132	1.8109	5.6569	5.6589	0.5
6. $\eta = 0.6333$	1.0669	1.7429	1.3251	0.1720	0.1075	0.1075	1.7204	5.6569	5.6589	0.5
7. $\gamma^1 = \gamma^2 = 0.42$	1.0680	1.7401	1.3308	0.1811	0.1132	0.1132	1.8109	5.2088	5.2106	0.5

Parameter Shift	$M^1/N^{d1} = M^2/N^{d2}$	$M^1/N^{s1} = M^2/N^{s2}$	$K^{d1}/H^{d1} = K^{d2}/H^{d2}$	$K^{s1}/H^{s1} = K^{s2}/H^{s2}$	$H^{d1}/H^{s1} = H^{d2}/H^{s2}$	$K^{d1}/K^{s1} = K^{d2}/K^{s2}$	$\omega^{d1}/\omega^{s1} = \omega^{d2}/\omega^{s2}$	$r^{d1}/r^{s1} = r^{d2}/r^{s2}$	$H^{d1}/H^{d2} = H^{s1}/H^{s2}$	$K^{d1}/K^{d2} = K^{s1}/K^{s2}$
1. Initial steady state	0.1772	0.2507	0.5578	0.2188	2.8194	7.1892	1.5935	0.6700	5.6569	5.6569
2. $A^{d1} = 12, A^{s1} = 9.6$	0.2057	0.2294	0.4270	0.1671	3.7053	9.4712	1.5973	0.6667	8.2770	8.2770
3. $v^d = 0.1433$	0.2411	0.2351	0.5598	0.2035	4.7746	13.1326	1.6370	0.6348	5.6569	5.6569
4. $\Gamma^{s1} = \Gamma^{s2} = 8.357$	0.1100	0.3001	0.5543	0.2180	1.3421	3.4126	1.5890	0.6786	5.6569	5.6569
5. $\tau^{k1} = \tau^{k2} = 0.475$	0.1093	0.3005	0.5545	0.2188	1.3311	3.3736	1.5839	0.6781	5.6569	5.6569
6. $\eta = 0.6333$	0.2425	0.2035	0.6889	0.2685	5.1294	13.1576	1.6030	0.6620	5.6569	5.6569
7. $\gamma^1 = \gamma^2 = 0.42$	0.1971	0.2355	0.5578	0.2188	3.1353	7.9947	1.5935	0.6700	5.2088	5.2088

Benchmark parameters: $\sigma = 0.9$, $\delta = 0.7$, $B = 1$, $\beta = 1.3$, $\alpha = 1/3$, $\eta = 2/3$, $\gamma^1 = \gamma^2 = 0.4$, $\Gamma^{d1} = \Gamma^{d2} = 10$, $\Gamma^{s1} = \Gamma^{s2} = 8.377$, $A^{d1} = 10$, $A^{d2} = 5$, $A^{s1} = 8$, $A^{s2} = 4$, $\theta^{d1} = \theta^{d2} = \theta^{s1} = \theta^{s2} = 1.675$, $v^d = 0.1365$, $v^s = 0.0853$, $\tau^{h1} = \tau^{h2} = 0.062$, $\tau^{k1} = \tau^{k2} = 0.5$.

Table 2. Comparative Dynamics under the Extended Model with Diversity Effects

Parameter Shift	$n^{d1} = n^{d2}$	$n^{s1} = n^{s2}$	$n^{m1} = n^{m2}$	$h^{d1} = h^{d2}$	$h^{s1} = h^{s2}$	$h^{m1} = h^{m2}$	$H_{t+1}^{ij}/H_t^{ij} = K_{t+1}^{ij}/K_t^{ij}$	$\Delta^{dd2} = \Delta^{ss2}$	$\Delta^{ds1} = \Delta^{ds2}$	$M^1/(M^1+M^2)$
1. Initial steady state	1.0691	1.7422	1.3326	0.1811	0.1132	0.1132	1.8595	5.6569	6.0461	0.5
2. $A^{d1} = 12, A^{s1} = 9.6$	1.0771	1.7569	1.3453	0.1811	0.1132	0.1132	2.2393	8.9234	6.0997	0.5190
3. $v^d = 0.1433$	1.0159	1.7467	1.3270	0.1901	0.1132	0.1132	1.9673	5.6569	6.9608	0.5
4. $\Gamma^{s1} = \Gamma^{s2} = 8.357$	1.0720	1.7415	1.3335	0.1811	0.1132	0.1132	1.8428	5.6569	5.9112	0.5
5. $\tau^{k1} = \tau^{k2} = 0.475$	1.0718	1.7415	1.3375	0.1811	0.1132	0.1132	1.8427	5.6569	5.9100	0.5
6. $\eta = 0.6333$	1.0684	1.7456	1.3274	0.1720	0.1075	0.1075	1.7805	5.6569	6.1664	0.5
7. $\gamma^1 = \gamma^2 = 0.42$	1.0692	1.7424	1.3328	0.1811	0.1132	0.1132	1.8642	5.2088	5.5831	0.5

Parameter Shift	$M^1/N^{d1} = M^2/N^{d2}$	$M^1/N^{s1} = M^2/N^{s2}$	$K^{d1}/H^{d1} = K^{d2}/H^{d2}$	$K^{s1}/H^{s1} = K^{s2}/H^{s2}$	$H^{d1}/H^{s1} = H^{d2}/H^{s2}$	$K^{d1}/K^{s1} = K^{d2}/K^{s2}$	$\omega^{d1}/\omega^{s1} = \omega^{d2}/\omega^{s2}$	$r^{d1}/r^{s1} = r^{d2}/r^{s2}$	$H^{d1}/H^{d2} = H^{s1}/H^{s2}$	$K^{d1}/K^{d2} = K^{s1}/K^{s2}$
1. Initial steady state	0.1648	0.2603	0.5366	0.2104	2.6678	6.8051	1.5940	0.6695	5.6569	5.6569
2. $A^{d1} = 12, A^{s1} = 9.6$	0.1931	0.2391	0.4087	0.1598	3.5557	9.0925	1.5980	0.6662	8.2686	8.2686
3. $v^d = 0.1433$	0.2278	0.2453	0.5326	0.1935	4.6493	12.7947	1.6378	0.6342	5.6569	5.6569
4. $\Gamma^{s1} = \Gamma^{s2} = 8.357$	0.1003	0.3076	0.5403	0.2124	1.2239	3.1382	1.5893	0.6783	5.6569	5.6569
5. $\tau^{k1} = \tau^{k2} = 0.475$	0.0998	0.3079	0.5405	0.2132	1.2257	3.1072	1.5842	0.6778	5.6569	5.6569
6. $\eta = 0.6333$	0.2306	0.2126	0.6550	0.2552	5.0358	12.9240	1.6038	0.6614	5.6569	5.6569
7. $\gamma^1 = \gamma^2 = 0.42$	0.1849	0.2449	0.5346	0.2096	2.9973	7.6457	1.5941	0.6694	5.2088	5.2088

Parameters: $\rho = 0.2$; the other parameters are the same as in the benchmark model.

Table 3. Immigration Surplus due to Induced Free Migration by Triggers

(a) Benchmark Model		Destination D			Source S		Global	
Trigger	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Skill-biased technological shock in *D* and *S*								
Income	-0.0006	0.05	0.26	1.16	0.01	-12.84	-0.009	-3.40
Human Capital	0	0.03	0.25	1.16	0.01	-13.04	0	-3.46
Physical Capital	0	0.05	0.26	1.13	0.01	-12.45	0.01	-3.35
M^1/N^{i1}	0.1755	0.1763	0.1781	0.1847	0.2463	0.2354		
M^2/N^{i2}	0.1764	0.1763	0.1770	0.1818	0.2486	0.2378		
2. Downward fertility shock in *D*								
Income	0.001	-0.08	-0.19	-0.62	0	45.52	0.02	42.03
Human Capital	0	0	0	0	0	49.91	0	41.64
Physical Capital	0	-0.09	-0.25	-0.95	0	36.54	-0.03	41.14
M^j/N^{ij}	0.1813	0.1923	0.2030	0.2270	0.2462	0.2264		
3. Adverse productivity shock in *S*								
Income	0.05	-0.12	-0.19	-0.28	0	41.85	0.65	17.41
Human Capital	0	0	0	0	0	42.74	0	17.74
Physical Capital	0	-0.05	-0.28	-0.46	0	40.14	-0.70	16.65
M^j/N^{ij}	0.2858	0.1684	0.1433	0.1240	0.4044	0.2917		

(b) Extended Model		Destination D			Source S		Global	
Trigger	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Skill-biased technological shock in *D* and *S*								
Income	-0.0004	0.02	0.21	1.28	0.002	-12.63	-0.007	-2.58
Human Capital	0	0.001	0.20	1.34	0.002	-12.60	0	-2.63
Physical Capital	0	0.05	0.21	1.18	0.002	-12.66	0.008	-2.63
M^1/N^{i1}	0.1636	0.1643	0.1660	0.1722	0.2561	0.2452		
M^2/N^{i2}	0.1644	0.1642	0.1649	0.1695	0.2583	0.2475		
2. Downward fertility shock in *D*								
Income	0.002	0.05	0.31	1.84	0	49.20	0.02	45.01
Human Capital	0	0.19	0.62	2.71	0	53.69	0	44.74
Physical Capital	0	-0.05	0.04	1.02	0	39.90	-0.03	43.88
M^j/N^{ij}	0.1696	0.1797	0.1897	0.2125	0.2568	0.2375		
3. Adverse productivity shock in *S*								
Income	0.05	0.43	-0.04	-2.82	0	40.86	0.68	14.27
Human Capital	0	0.40	-0.04	-2.88	0	41.62	0	14.39
Physical Capital	0	0.90	0.23	-2.38	0	39.40	-0.72	13.98
M^j/N^{ij}	0.2708	0.1662	0.1345	0.1146	0.4275	0.2995		

Notes: Values for "Income", "Human Capital", and "Physical Capital" are percentage changes in income, human capital, and physical capital per capita. Our measures of the changes in the immigration surplus are based on the per-capita income changes. Positive values mean loss from restricting migration, hence gain from unrestricted migration. The ratio M^j/N^{ij} denotes the evolving population ratio of migrants to natives of each skill group in D or S when migration is unrestricted. As the table shows, these ratios evolve differently for the two skill groups under SBTS, but their evolution is the same in the case of the other two shocks.

Table 4. Immigration Surplus due to Allowing High-Skilled Migration by Triggers

(a) Benchmark Model	Destination D				Source S		Global	
Trigger	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Skill-biased technological shock in *D* and *S*								
Income	0.03	11.15	30.93	73.63	-5.00	92.93	0.84	93.45
Human Capital	0	12.55	32.49	74.45	-5.00	94.37	0	93.51
Physical Capital	0	9.64	28.65	72.25	-5.00	89.23	-1.01	92.78
2. Downward fertility shock in *D*								
Income	0.03	11.33	31.97	77.91	-5.09	93.57	0.85	94.86
Human Capital	0	12.63	33.73	78.90	-5.09	94.91	0	94.95
Physical Capital	0	10.00	29.23	75.94	-5.09	90.08	-1.03	94.24
3. Adverse productivity shock in *S*								
Income	0.07	13.37	32.57	70.93	-8.62	95.88	1.60	94.28
Human Capital	0	14.90	34.43	71.95	-8.60	96.76	0	94.35
Physical Capital	0	11.79	29.76	69.22	-8.60	93.56	-1.65	93.65

(b) Extended Model	Destination D				Source S		Global	
Trigger	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Skill-biased technological shock in *D* and *S*								
Income	0.03	13.58	34.97	77.04	-4.87	93.99	0.83	94.34
Human Capital	0	15.84	37.21	78.04	-4.87	95.28	0	94.45
Physical Capital	0	10.39	31.32	75.23	-4.87	90.63	-1.00	93.62
2. Downward fertility shock in *D*								
Income	0.03	13.76	35.96	80.87	-4.96	94.61	0.84	95.64
Human Capital	0	15.92	38.38	82.01	-4.96	95.80	0	95.77
Physical Capital	0	10.76	31.89	78.57	-4.96	91.46	-1.02	94.99
3. Adverse productivity shock in *S*								
Income	0.07	15.81	36.16	73.89	-8.79	96.45	1.62	94.86
Human Capital	0	18.03	38.53	75.05	-8.78	97.24	0	94.96
Physical Capital	0	12.97	32.31	71.85	-8.78	94.34	-1.67	94.20

Notes: Values for "Income", "Human Capital", and "Physical Capital" are percentage changes in income, human capital, and physical capital per capita. Our measures of the changes in the immigration surplus are based on the per-capita income changes. Positive values mean loss from restricting migration, hence gain from unrestricted migration. M^1/N^{i1} is restricted to be 0 under the policy restriction here.

Table 5. Immigration Surplus due to Allowing Low-Skilled Migration by Triggers

(a) Benchmark Model		Destination D			Source S		Global	
Trigger	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Skill-biased technological shock in *D* and *S*								
Income	0.005	-16.28	-32.94	-63.68	10.99	86.63	0.14	67.00
Human Capital	0	-16.75	-33.69	-64.64	11.03	86.84	0	66.82
Physical Capital	0	-15.21	-31.44	-62.00	11.03	86.15	-0.17	67.23
2. Downward fertility shock in *D*								
Income	0.005	-16.28	-33.21	-65.09	11.10	85.81	0.14	69.85
Human Capital	0	-16.64	-34.16	-66.69	11.12	86.11	0	69.57
Physical Capital	0	-15.50	-31.49	-62.43	11.12	85.13	-0.17	70.22
3. Adverse productivity shock in *S*								
Income	0.01	-17.87	-32.47	-59.17	21.47	93.93	0.26	77.15
Human Capital	0	-18.38	-33.41	-60.36	21.55	94.13	0	77.02
Physical Capital	0	-16.80	-30.69	-56.88	21.55	93.47	-0.28	77.32

(b) Extended Model		Destination D			Source S		Global	
Trigger	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Skill-biased technological shock in *D* and *S*								
Income	0.005	-15.05	-30.78	-60.89	11.51	88.06	0.14	68.32
Human Capital	0	-15.40	-31.43	-61.73	11.55	88.26	0	68.16
Physical Capital	0	-14.19	-29.46	-59.37	11.55	87.61	-0.17	68.51
2. Downward fertility shock in *D*								
Income	0.005	-15.00	-30.97	-62.42	11.63	87.49	0.14	71.50
Human Capital	0	-15.22	-31.77	-63.82	11.66	87.77	0	71.26
Physical Capital	0	-14.48	-29.50	-60.04	11.66	86.84	-0.17	71.81
3. Adverse productivity shock in *S*								
Income	0.01	-16.06	-29.92	-55.88	23.39	94.58	0.26	77.84
Human Capital	0	-16.46	-30.73	-56.94	23.49	94.76	0	77.72
Physical Capital	0	-15.17	-28.35	-53.81	23.49	94.14	-0.28	77.99

Notes: Values for "Income", "Human Capital", and "Physical Capital" are percentage changes in income, human capital, and physical capital per capita. Our measures of the changes in the immigration surplus are based on the per-capita income changes. Positive values mean loss from restricting migration, hence gain from unrestricted migration. M^2/N^{i2} is restricted to be 0 under the policy restriction here.

Table 6. Welfare Change due to Migrants Bringing More Physical Capital (decreasing τ^k)

(a) Benchmark Model	Destination D				Source S		Global	
Policy restriction	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Total impact of the shock								
Income	0.003	-0.03	-0.05	-0.13	0	23.03	0.07	9.63
Human Capital	0	0	0	0	0	25.22	0	9.61
Physical Capital	0	-0.03	-0.08	-0.21	0	19.11	-0.007	9.26
M^j/N^{ij}	0.1877	0.1805	0.1751	0.1581	0.2656	0.2885		
2. Immigration surplus due to induced migration								
Income	0.004	-0.05	-0.07	-0.14	0	18.05	0.05	8.31
Human Capital	0	0	0	0	0	19.37	0	8.33
Physical Capital	0	-0.06	-0.10	-0.22	0	15.54	-0.06	7.96
3. Impact of the shock when migration ratio is restricted to remain constant								
Income	-0.0007	0.02	0.02	0.007	0	0.83	0.02	0.52
Human Capital	0	0	0	0	0	0.96	0	0.48
Physical Capital	0	0.03	0.03	0.02	0	0.59	0.06	0.56

(b) Extended Model	Destination D				Source S		Global	
Policy restriction	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Total impact of the shock								
Income	0.003	0.09	0.12	-0.43	0	22.82	0.08	8.59
Human Capital	0	0.13	0.17	-0.39	0	24.92	0	8.49
Physical Capital	0	0.07	0.10	-0.33	0	19.06	-0.01	8.41
M^j/N^{ij}	0.1745	0.1685	0.1626	0.1463	0.2769	0.2971		
2. Immigration surplus due to induced migration								
Income	0.004	0.08	0.10	-0.43	0	17.92	0.06	7.46
Human Capital	0	0.14	0.17	-0.40	0	19.19	0	7.42
Physical Capital	0	0.04	0.07	-0.34	0	15.52	-0.07	7.27
3. Impact of the shock when migration ratio is restricted to remain constant								
Income	-0.0007	0.02	0.02	0.007	0	0.82	0.02	0.49
Human Capital	0	0	0	0	0	0.95	0	0.44
Physical Capital	0	0.03	0.03	0.02	0	0.58	0.06	0.52

Notes: Values for “Income”, “Human Capital”, and “Physical Capital” are percentage changes in income, human capital, and physical capital per capita. Our measures of the changes in the immigration surplus are based on the per-capita income changes. The ratio M^j/N^{ij} denotes the evolving population ratio of migrants to natives of each skill group in D or S when migration is unrestricted. The evolution of the ratios is the same for the two skill groups here.

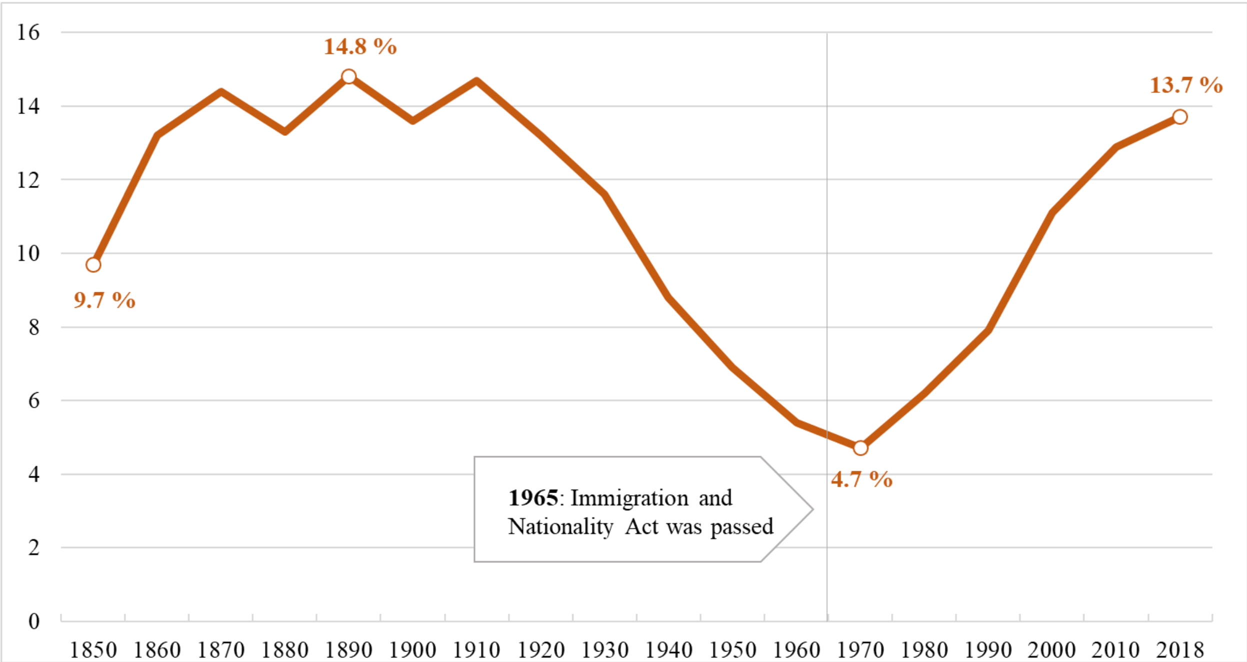
Table 7. Welfare Change due to Increasing Capital Endowment in *D*

(a) Benchmark Model	Destination D				Source S		Global	
Policy restriction	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Total impact of the shock								
Income	0.34	0.41	0.40	0.28	0	33.40	0.36	13.75
Human Capital	0	0	0	0	0	36.85	0	13.23
Physical Capital	0	0.35	0.34	0.16	0	27.29	-0.08	13.13
M^j/N^{ij}	0.1895	0.1821	0.1750	0.1509	0.2682	0.3051		
2. Immigration surplus due to induced migration								
Income	0.004	-0.07	-0.10	-0.21	0	25.04	0.06	11.70
Human Capital	0	0	0	0	0	26.93	0	11.69
Physical Capital	0	-0.09	-0.15	-0.34	0	21.44	-0.08	11.21

(b) Extended Model	Destination D				Source S		Global	
Policy restriction	Static	3rd generation after a shock	5th generation after a shock	10th generation after a shock	Static	10th generation after a shock	Static	10th generation after a shock
1. Total impact of the shock								
Income	0.34	0.58	0.64	-0.09	0	33.26	0.37	12.35
Human Capital	0	0.19	0.25	-0.51	0	36.59	0	11.73
Physical Capital	0	0.48	0.58	0.03	0	27.35	-0.08	12.00
M^j/N^{ij}	0.1772	0.1698	0.1623	0.1392	0.2798	0.3135		
2. Immigration surplus due to induced migration								
Income	0.005	0.10	0.15	-0.58	0	24.96	0.07	10.60
Human Capital	0	0.19	0.25	-0.51	0	26.79	0	10.50
Physical Capital	0	0.03	0.09	-0.47	0	21.48	-0.08	10.31

Notes: Values for "Income", "Human Capital", and "Physical Capital" are percentage changes in income, human capital, and physical capital per capita. Our measures of the changes in the immigration surplus are based on the per-capita income changes. The ratio M^j/N^{ij} denotes the evolving population ratio of migrants to natives of each skill group in D or S when migration is unrestricted. The evolution of the ratios is the same for the two skill groups here.

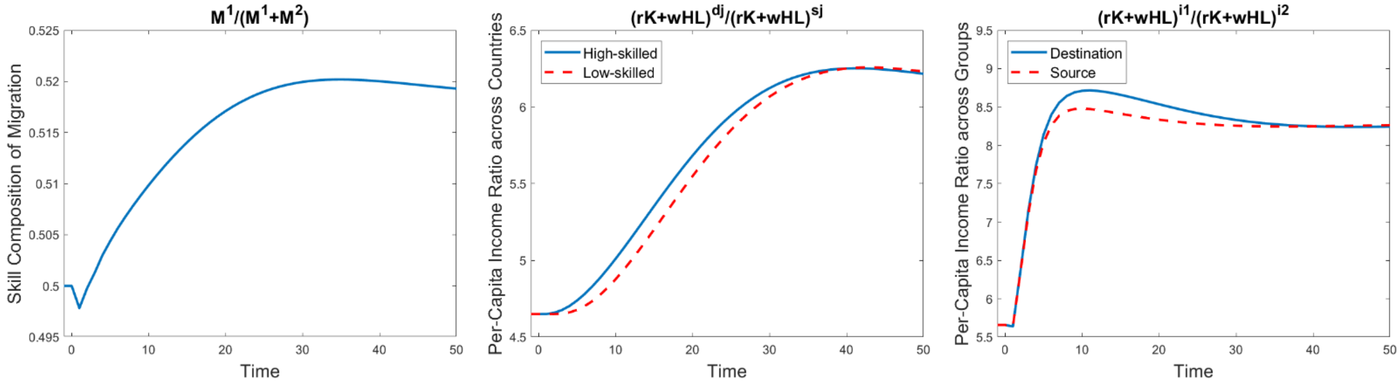
Figure 1. Immigrants Share of the United States Population, 1850-2018
(% of the United States population that is foreign born)



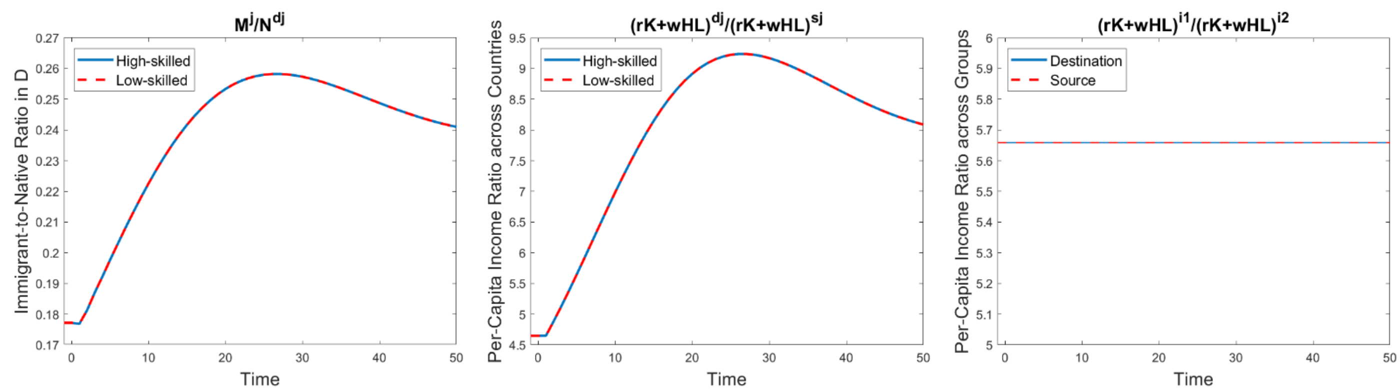
Source: The United States Census Bureau, "Historical Census Statistics on the Foreign-Born Population of the United States: 1850-2000" and Pew Research Center tabulation of 2010 and 2018 American Community Survey (IPUMS).

Figure 2. Transitional Dynamics by Immigration Triggers

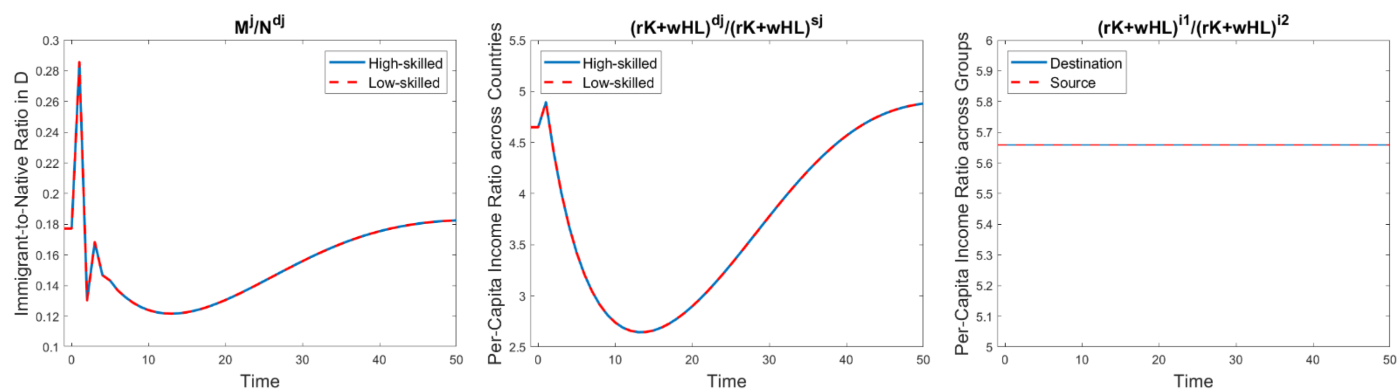
(a) Skill-Biased Technological Shock



(b) Downward Fertility Shock in *D*



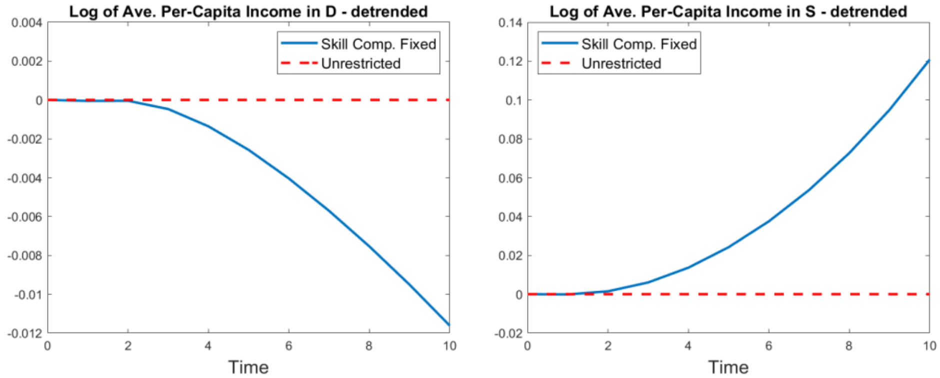
(c) One Period Adverse Productivity Shock in *S*



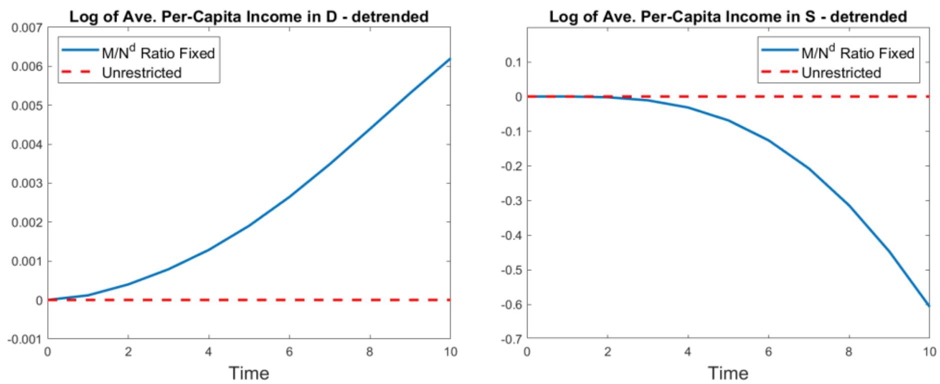
Notes: In panels (b) and (c), we plot the transitional dynamic paths of migrant-to-native population ratios, the ratio of per-capita income in *D* relative to *S*, and the ratio of per-capita income in the high-tech sector relative to the low-tech sector following the adverse fertility and productivity shocks, respectively. In panel (a) we plot similar transitional paths following an SBTS shock, except that we exhibit the transitional dynamic path of the skill composition of migration rather than the migrant-to-native population ratio, which exhibits a very similar dynamic pattern. We chose to do so since this is the only case where the shock affects the skill composition of migration.

Figure 3. Impact of Induced Migration by Immigration Triggers

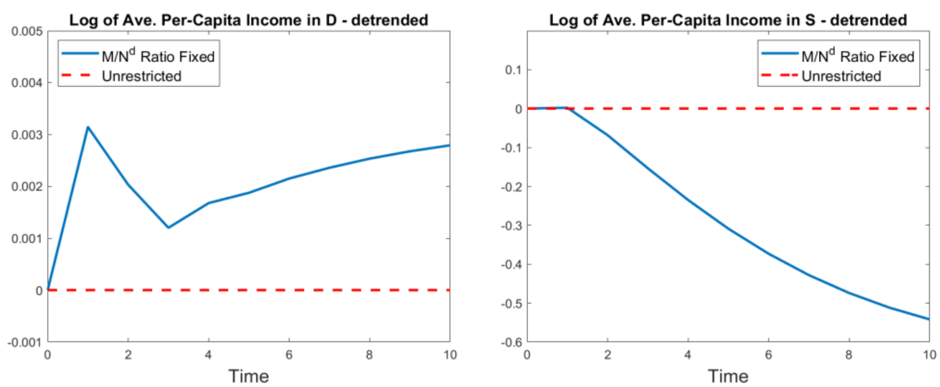
(a) Skill-Biased Technological Shock



(b) Downward Fertility Shock in *D*



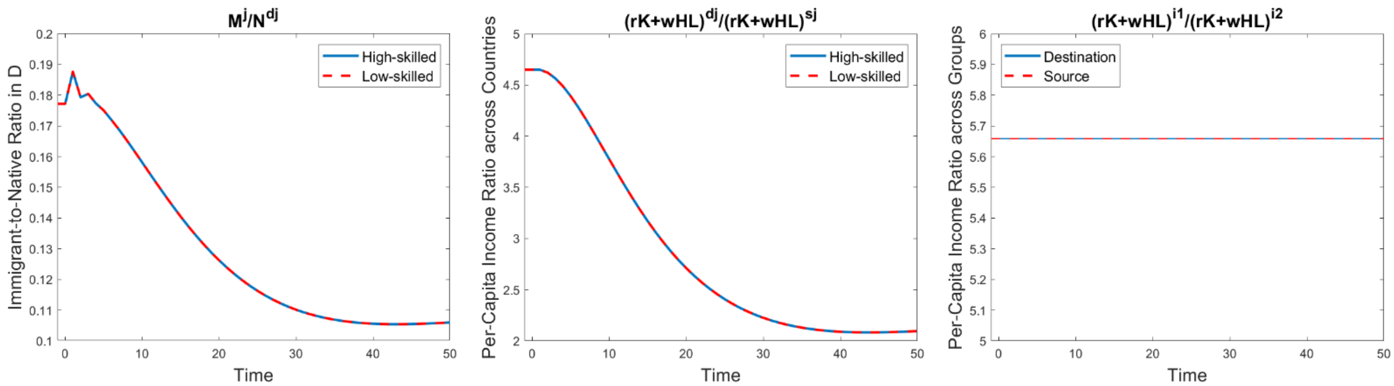
(c) One Period Adverse Productivity Shock in *S*



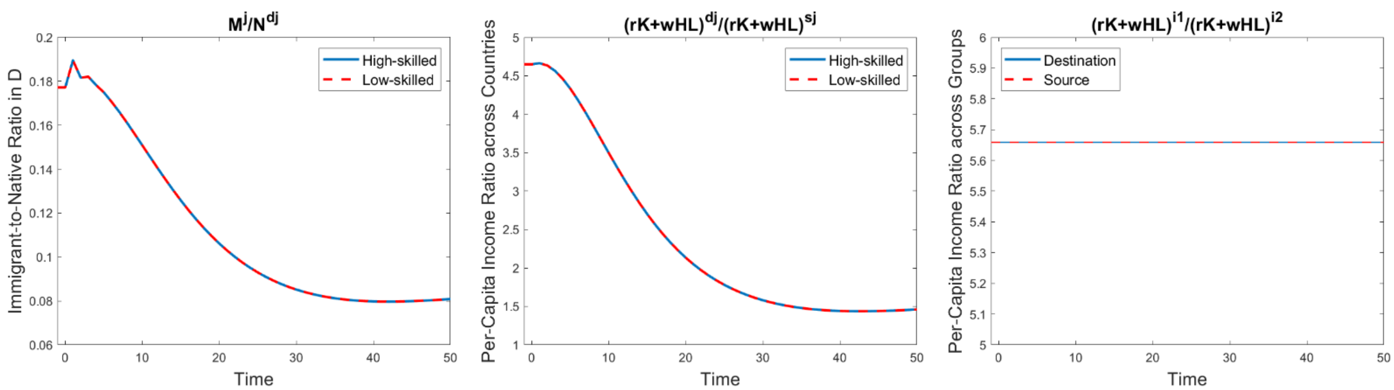
Notes: We plot the simulated time paths of average per-capita income in *D* and average per-capita income in *S* when either the skill composition of migration (SBTS, panel a) or the migrant-to-native ratio (adverse fertility and productivity shocks, panels b and c) are held constant, relative to the case when migration is unrestricted.

Figure 4. Transitional Dynamics Paths of Policies Affecting the Role of Physical Capital

(a) Motivating Migrants to Bring More Capital to *D*



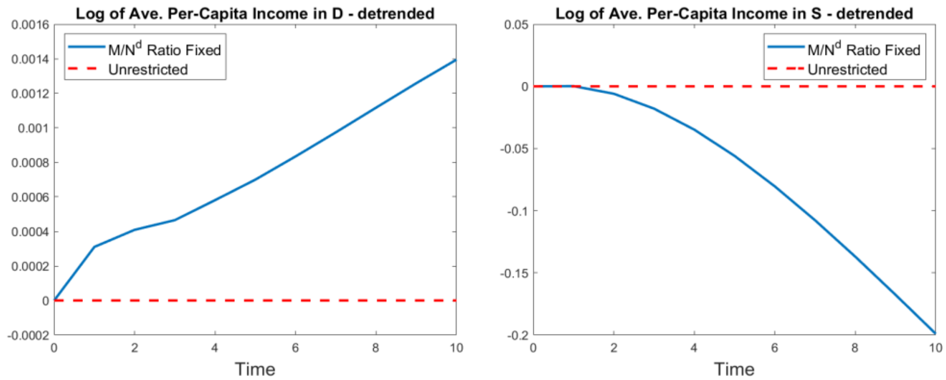
(b) Expanding the Economy's Capital Endowment in *D*



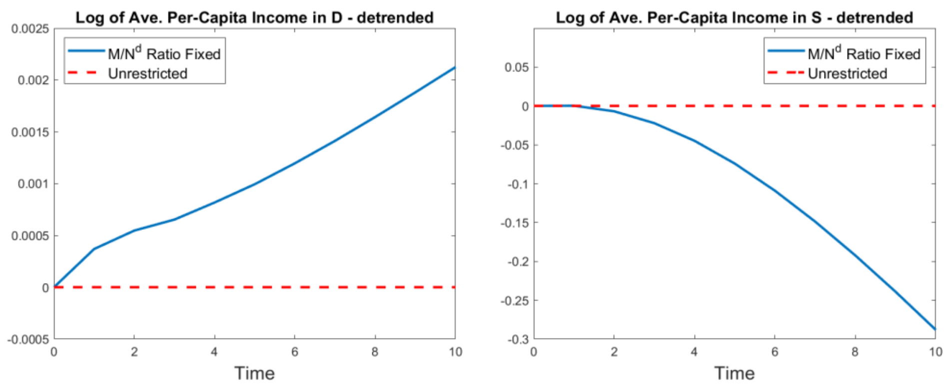
Notes: We plot the transitional dynamic paths of migrant-to-native population ratios, the ratio of per-capita income in D relative to S, and the ratio of per-capita income in the high-tech sector relative to the low-tech sector, following the policy change motivating migrants to bring more capital to D (panel a), and the shock expanding the economy's capital endowment in D (panel b).

Figure 5. Impact of Induced Migration of Policies Affecting the Role of Physical Capital

(a) Motivating Migrants to Bring More Capital to *D*



(b) Expanding the Economy's Capital Endowment in *D*



Notes: We plot the simulated time paths of average per-capita income in *D* and average per-capita income in *S* when migrant-to-native ratio is held constant, relative to the case when migration is unrestricted, following the policy change motivating migrants to bring more capital to *D* (panel a), and the shock expanding capital endowment in *D* (panel b).