Do Migration Restrictions Matter?

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Abstract

Restrictions on the movement of labor across countries are widespread and severe. We assess the quantitative significance of these policies in an environment equipped with the essential features required for such an assessment. These are: (i) Total Factor Productivity differences across locations; (ii) production requires a fixed factor (land) which ensures that returns to capital and labor are jointly diminishing; (iii) capital is mobile and can be accumulated; (iv) individuals choose optimally whether and when to migrate. We first explore the main features of our framework. Then, we specialize it to perform a quantitative assessment of the likely effects of the upcoming enlargement of the European Union, and a hypothetical removal of migration restrictions to OECD countries. We find that lifting barriers to migration across regions leads to (i) large long–run movements of labor, in conjunction with large increases in total output and capital; (ii) slow transitions between steady states in relation to standard growth models; (iii) various welfare effects, with rich region young natives mostly losing and poor region natives mostly gaining from the removal of migration barriers. In the case of the enlargement of the European Union, we find that a lifting of immigration restrictions would raise European output by about 8 percent in the long run. Overall, our findings indicate that restrictions to labor movements have sizeable consequences on world output in the long run, and that abstracting from capital accumulation and capital mobility may seriously underestimate the consequences of labor mobility.

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1 Introduction

This paper is motivated by the following two observations. First, there are large differences in measured output per worker across countries. A substantial body of research indicates that differences in Total Factor Productivity (TFP) account for the bulk of these output per worker differences.[1] Second, barriers to labor mobility across countries are widespread, severe and have been in place for a long time; in most rich countries, since the 1920s.

We ask: in a world with exogenously given TFP differences, how significant are these barriers? We address this question by investigating the quantitative consequences, in terms of allocations and welfare, of lifting barriers to the movement of labor in a dynamic environment. The framework that we adopt to address this question is an open economy, life cycle model, where heterogeneous individuals choose when and whether to migrate given current and future wage differences. We first explore the main features of this framework. Then, we specialize it to perform a quantitative assessment of the likely effects of the upcoming enlargement of the European Union, and a hypothetical removal of migration barriers to OECD countries.

It is not easy to find a basis in standard economic theory for establishing obstacles to the movement of factors of production. Nevertheless, it is not immediately obvious how important the unrestricted mobility of labor is. Heckscher–Ohlin–Samuelson trade theory establishes that free trade can — in certain circumstances — be a perfect substitute for factor mobility. Moreover, with constant returns to scale and common technology across countries, capital mobility is a perfect substitute for labor mobility. In this paper, we consider empirically based circumstances under which labor mobility matters. In particular, we allow for differences in Total Factor Productivity (TFP) across regions, and the presence of an essential fixed factor of production (land).

We study an economy comprised of two locations (regions). Individuals have finite lives and are heterogeneous in terms of their age, skills, and the portability of their skills. There is a single

[1] See for instance Castro (2003), Hall and Jones (1999), Hendricks (2002), Gourinchas and Jeanne (2003) and Prescott (1998). See Jones (2002) for a textbook exposition of the importance of TFP in accounting for cross country output differences.

dated good, which is produced using three factors under constant returns: capital, labor and land. Capital moves costlessly across locations equating rates of return. Land is fixed. Labor is only *potentially* mobile; there are migration restrictions and individuals face migration costs. Moving from one location to the other entails a resource cost that individuals cannot borrow against future income to pay, and migration involves a loss of skills (skills are only imperfectly portable). In this environment, individuals decide how much to consume and save in the form of capital and land as well as when and whether to move.

The model economy has a number of features that make it an appropriate vehicle for the study of migration policy. First, the presence of land as a fixed factor avoids a degenerate distribution of population across locations when moving costs are zero. If returns to capital and labor jointly are constant, and total factor productivity (TFP) differs across countries, then costless mobility of capital and labor implies that the low TFP economy vanishes. Diminishing returns to capital and labor jointly allows for the survival of the low TFP economy. However, as we demonstrate later on, with a realistic (small) land share, some rather unpleasant arithmetic kicks in: even small differences in TFP imply large movements of labor in the long run if wages are to be nearly equal.

Second, our environment allows us to explore the consequences of labor mobility when capital is mobile *and* can be accumulated. Notice that in a static environment, when returns to capital and labor jointly are constant and total factor productivity is common to both countries, mobility of capital *or* labor is sufficient to equalize wages and returns on capital; in contrast, when there is a third factor in fixed supply and/or differences in TFP, capital *and* labor have to move to achieve an efficient allocation of resources. In a dynamic environment, we show that the output consequences of labor movements are magnified, as in the presence of TFP differences these labor movements lead to changes in the rate of return to capital in the short run. This in turn fosters capital accumulation and as a result, the world's capital stock is larger in the long run.

Finally, the model economy has appealing implications for the dynamic response to changes in migration policy. The fact that individuals have finite lives, when combined with migration costs and borrowing constraints, generates a *protracted* migration process over time that is broadly consistent with historical evidence on migration phenomena. As labor migrates, capital follows, both instantaneously and over time. Instantaneously, capital "chases" labor, since an increase in labor increases the marginal product of capital. Over time, the improved allocative efficiency resulting from migration increases the (common) world rate of return on capital, encouraging the accumulation of a larger world capital stock. The interaction of these effects determine smooth transitions for world output following the lifting of migration barriers.

Altogether, these features allow us to examine, quantitatively, the consequences of migration barriers on output and capital accumulation across steady states and over time. In welfare terms, we determine who gains, who loses, when, and how much. This latter point is of fundamental importance for understanding, from a positive standpoint, past and current migration policy as well as potential and actual reforms.

Our main findings are the following. With a realistic value for the land share, lifting barriers to migration leads to large long–run movements of labor, in conjunction with large increases in total output and capital; (ii) slow output transitions between steady states in relation to standard growth models; (iii) various welfare effects, with rich region young natives mostly losing, and rich location old natives and poor location natives mostly gaining from the removal of migration barriers. Overall, we find that abstracting from capital accumulation and capital mobility may result in a misleading picture of the consequences of labor mobility. For instance, when the output per worker ratio between locations is 2 in the absence of labor movements, at most about 38% of the total change in world output across steady states is due to labor movements alone; the residual is due to capital accumulation and changes in the allocation of the capital stock across locations.

Applying the model to the enlargement of the European Union, we find that a lifting of immigration restrictions would raise output by about 8% in the long run. But again, these output gains take several periods to materialize; when moving costs are the lowest level we consider, we find it would take about 50 years for European output to come half way toward the new steady state. When we consider the hypothetical removal of barriers between OECD and non-OECD countries, we find quite substantial consequences on world output in the long run (about 172% increase). This is not surprising given the large TFP differences between OECD and non-OECD countries implied by the data, and the fact that most of the world's labor force is currently concentrated in the second group of countries.

1.1 Related literature

This paper is closely connected with a number of papers which quantified the effects of migration policy.[2] Using simple static frameworks, Borjas (1995) and Hamilton and Whalley (1984) provided quantitative estimates of the effects of immigration. In a well cited paper, Borjas (1995) asked the question: how large are the benefits of immigration for *natives* of the United States? From estimates of aggregate labor demand price elasticities and the fraction of immigrants in the labor force, he calculated the area under the demand curve for labor corresponding to an exogenous increase in the labor force when the capital stock is given. He concluded that the presence of immigrants in the U.S. workforce gives rise to a surplus ranging from about 0.1 percent of GDP when workers are homogeneous, to values in excess of 1% of GDP when there are differences between skilled and unskilled workers. He also found a relatively large redistribution of income between workers and capital owners. This is not surprising, since the welfare measure (aggregate output net of the wage bill collected by migrants) can only go up relative to the situation in the absence of foreign workers, via a reduction in the wage rate and a corresponding increase in capital income.

Hamilton and Whalley (1984) calculated the effect on world output arising from the equalization of the marginal product of labor across regions. As in Borjas (1995), capital was assumed to be fixed and immobile across regions. Their results were striking; they found large output gains, in excess of a third of world income, as well as a significant reduction in the concentration of worldwide per capita income.

We differ from these exercises in a number of respects. First, we explicitly consider capital

[2] The literature on migration is too large and wide in scope to summarize here. See Borjas (1994) for a comprehensive survey.

accumulation and capital mobility across locations in our analysis. As we demonstrate in section 4, this is critical for an assessment of the effects of labor mobility on output; a large component of these effects hinge upon the consequences that the removal of the barriers have on the accumulation of world capital and its allocation across locations. Second, we explicitly cast the problem of migration barriers in the context of a dynamic environment, where individuals take savings and migration decisions. This allows us, among other things, to understand the welfare consequences of removing these barriers; who gains, who loses, when and how much.

A number of recent papers have used dynamic frameworks to quantitatively assess the consequences of immigration. In the context of growth model with overlapping dynasties, Ben-Gad (2003) also provided estimates of the welfare gain to natives from migration. He found that welfare gains, and changes in factor prices, are much smaller than in simple static exercises in the spirit of Borjas (1995). The reason for this is the endogenous response of capital accumulation to changes in the size of the labor input, and the explicit consideration of transitional dynamics. Storesletten (2000) also used a dynamic framework (a life-cycle growth model), but focused only on the consequences of immigration for U.S. fiscal policy. He found that expanding the number of skilled immigrants admitted can substantially help reducing the fiscal burden of unfunded programs (e.g. Social Security). In both of these papers the interactions between sending and receiving countries are not modeled. In particular, the migration choice is not modeled (migrants arrive exogenously at a specified rate), and there are no capital movements between the host country and the rest of the world.

In the closest paper to ours, Urrutia (1998) studied who migrates and the implications of migration policy on welfare in a two-country world populated by dynastic households where wage differences in the long run are due exclusively to TFP differences. He found negligible welfare costs associated with migration quotas for the host country. A critical feature of that paper is the assumption of costless capital mobility under constant returns to capital and labor jointly. In these circumstances, labor migration cannot reduce or eliminate differences in the marginal product of labor across countries. What it can do is to reduce the relative size of the low TFP country.

Urrutia's framework has the implication that poor locations disappear when moving costs are zero and there exist TFP differences across locations. This does not occur in our framework due to the presence of a fixed factor; thus, we can use it to study labor movements from poor countries (low TFP), where most of the world's labor force is concentrated, to rich (high TFP) countries. Nevertheless, the presence of a fixed factor has a small effect in the long run when TFP differences are large, and/or the share of the fixed factor in output is small. Unlike our model, Urrutia's model has the implication that all migration following the lifting of restrictions takes place within a very short period of time. This result is due to the dynastic structure of the model: if it is not worthwhile for a dynasty to move in an initial period, then it is typically never worthwhile.

The paper is organized as follows. In Section 2, we lay out the model environment. In Section 3, we describe our model in more detail and assign values to those parameters that will remain constant throughout our computational experiments. In Section 4, we explore the quantitative properties of our framework by discussing the results for a number of hypothetical cases. In Section 5 we discuss the actual case of the upcoming enlargement of the European Union. In Section 6 we discuss a possible case of removing barriers to immigration in the OECD. Section 7 concludes.

2 The Environment

Locations There are two locations where individuals can work and live, $x = \mathcal{R}$ and $x = \mathcal{P}$. These locations potentially differ in terms of Total Factor Productivity (TFP) and the quantities of land available. Location $\mathcal{R}$ has $F_{\mathcal{R}}$ units of land, and location $\mathcal{P}$ has $F_{\mathcal{P}}$ units of land. These units of land are by assumption fixed and immobile.

Technology A single good is produced in each location, using a CRS production function that uses capital (K), labor (L) and land given by

$$Y_x(t) = G(K_x(t), L_x(t), F_x; A_x) = A_x K_x^{\lambda}(t) L_x(t)^{\eta} F_x^{1-\lambda-\eta}$$

for $x = \mathcal{O}, \mathcal{N}$, where A_x stands for TFP in location x. Capital depreciates at the rate $\delta \in [0, 1]$.

Preferences, Endowments and Demographics Time is discrete. A continuum of individuals are born at the beginning of each period t in each location, in proportion to the prior population of this location. A person's age j belongs to the set $\mathcal{J} = \{1, 2, \ldots, J\}$, where J denotes the maximum possible age. Denote consumption in period s by a person of age j by $c_s(j)$. Notice that a person whose first period of life is in period t has age j in period $t + j - 1$. The objective of a person born in t in location x is to maximize

$$\sum_{j=1}^{J} \beta^{j-1} u\left(c_{t+j}(j)\right).$$

The function $u(.)$ is continuous, strictly increasing and strictly concave. Individuals are born with no assets and are endowed with birthplace–dependent efficiency units of labor $e(j, x)$ where $x \in \{\mathcal{R}, \mathcal{P}\}$ and $j \in \mathcal{J}$. The dependence of the function e on individuals' birthplace allows for differences in labor quality across regions.

Migration Within a cohort, individuals are heterogeneous. Their type, i, belongs to the unit interval $\mathcal{I} = [0, 1]$. The type of a given person is realized at birth and does not change as the person gets older. The distribution of types is described by a density $\alpha(i)$.[3] Being of type i implies a permanent loss of a fraction $\theta(i)$ of one's efficiency units of labor after having moved to a new location.

Hence, if a person moves, her effective endowment is $e(j, x)(1 - \theta(i))$ for all $j \geq j_0$, where j_0 is the age of arrival to the new location. Otherwise, it equals $e(j, x)$.[4]

People can move from one location to another by paying a fixed cost m. Paying m in period t entitles the individual to start period $t + 1$ in the other location. Individuals are allowed to

[3] It is actually important that this distribution have a density; otherwise there might easily not exist an equilibrium in the absence of randomization. The point is that small differences in wages across regions should give rise to small changes in the mass of people deciding to move.

[4] Note that this assumption implies that the the loss of efficiency units associated with migration for an individual is *permanent*. For a discussion and empirical support for our assumption, see Baker and Benjamin (1994).

change locations (move) only once in their lives (i.e. "return" migration is not allowed).[5]

Individuals are unrestricted in their choice of asset position except when they are about to die or have decided to move, in which case their asset choice must be non–negative. Thus, in the latter case, the fixed cost m cannot exceed individual's labor income plus the gross return on their asset holdings.

Markets Individuals supply labor services in competitive markets. Denoting birthplace by $y \in \{\mathcal{R}, \mathcal{P}\}$, if $y = x$ (i.e. the individual was born in location x), labor income equals $w_x(t)e(j,x)$, and if $y \neq x$, it equals $w_x(t)e(j,y)(1-\theta(i))$, where $w_x(t)$ stands for the wage rate at time t in location x.

Individuals can accumulate two risk-free assets, capital (k) and land (f), which pay competitive rates of return. Both capital and land are perfectly divisible. Purchasing land in period t entitles the buyer to the proceeds from renting it out in periods $t+1, t+2, \ldots$. Individuals are allowed to buy and sell land from both locations.

Capital moves costessly across locations. Thus, $r^k(t)$ is the common "world" rate of return on capital. In equilibrium, since capital and land are *identical* assets from the perspective of an individual, the two types of land also have this rate of return in the following sense. Let $p_x(t)$ be the price of land in region x in period t. Let $R_x(t)$ be the rental rate on (equal to the marginal product of) land in region x in period t. Then

$$\frac{p_x(t) + R_x(t)}{p_x(t-1)} \equiv 1 + r_x^f(t) = 1 + r^k(t) = 1 + r(t)$$

for all $x \in \{\mathcal{R}, \mathcal{P}\}$ and all t. Thus, the previous no arbitrage relationship implies that, in the absence of any speculative bubble, the current prices of land will equal the present discounted value of land rental rates, accruing from tomorrow on. That is, for all $x \in \{\mathcal{R}, \mathcal{P}\}$,

$$p_x(t) = \sum_{s=1}^{\infty} Q_{t,s} R_x(t+s)$$

where $Q_{t,s} = \prod_{i=1}^{s} (1 + r(t+i))^{-1}$.

[5] This assumption is helpful in simplifying the individual's decision problem and computing the solution of the model. It is not restrictive, however, as there are no incentives for individuals to return to the location of origin.

Decision Problem We now describe an individual's decision problem recursively. Relevant for this decision will be wages in the two locations as well as world interest rates. The time-dependence of these objects will translate into the time-dependence of decision rules and value functions.

We argue first that given common rates of return on land and capital, the asset position of an individual is summarized by a single state variable (e.g. there is not a portfolio decision and thus, what matters is the total value of assets, properly defined). Consider the budget constraint of an individual of type i at age j and time t in location x, who (for instance) has not moved in the past. He/she enters the period with capital and land holdings k_j and $f_{x,j}$ respectively. He/she faces a rate of return on capital holdings $r(t)$ and a land rental rate $R_x^f(t)$. He can buy and sell land at the end of the period at the price $p_x(t)$ as well as accumulate capital for the next period. Hence, his budget constraint reads

$$c_j + k_{j+1} + \sum_{x \in \{\mathcal{R},\mathcal{P}\}} p_x(t) f_{x,j+1} + \varphi_j m =$$

$$(1 + r(t))k_j + \sum_{x \in \{\mathcal{R},\mathcal{P}\}} (R_x(t) + p_x(t)) f_{x,j} + w_x(t) e(j, x)$$

where φ_j takes the value of 1 if chooses to start next period in the other location, and 0 otherwise. Since, for $x \in \{\mathcal{R}, \mathcal{P}\}$, $R_x(t) + p_x(t) = (1 + r(t))p_x(t-1)$ by no arbitrage, we can write the budget constraint as

$$c_j + k_{j+1} + \sum_{x \in \{\mathcal{R},\mathcal{P}\}} p_x(t) f_{x,j+1} + \varphi_j m = (1 + r(t)) \left[k_j + \sum_{x \in \{\mathcal{R},\mathcal{P}\}} p_x(t-1) f_{x,j} \right] + w_x(t) e(j, x)$$

Therefore, defining current assets as $a_j \equiv k_j + \sum_{x \in \{\mathcal{R},\mathcal{P}\}} p_x(t-1) f_{x,j}$ and desired assets for the next period as $a_{j+1} \equiv k_{j+1} + \sum_{x \in \{\mathcal{R},\mathcal{P}\}} p_x(t) f_{x,j+1}$, the budget constraint becomes

$$c_j + a_{j+1} + \varphi_j m = (1 + r(t))a_j + w_x(t) e(j, x)$$

The above arguments determine that the state of an individual of is summarized by the vector $z = (a, i, j, x, y)$, where x, as before, denotes the location where he/she is currently living and

y denotes the location where the individual was born. Let $-x$ denote the "other" location so that $-\mathcal{R} = \mathcal{P}$ and vice versa.

The value function $v_t(z)$ obeys the following recursions. If $x \neq y$ (i.e. the individual has migrated in the past and migration is not feasible)

$$v_t(a, i, j, x, -x) = \max_{(a', c)} \{u(c) + \beta v_{t+1}(a', i, j+1, x, -x)\}$$

subject to

$$c + a' \leq a(1 + r(t)) + (1 - \theta(i)) w_x(t) e(j, -x),$$

$$a' \geq 0, \quad \text{for} \quad j = J$$

$$v_t(a, i, J+1, x, -x) \equiv 0.$$

If $x = y$ (i.e. migration is feasible)

$$v_t(a, i, j, x, x) = \max_{(a', c, \varphi)} \{u(c) + \beta [\varphi v_{t+1}(a', i, j+1, -x, x) + (1 - \varphi) v_{t+1}(a', i, j+1, x, x)]\}$$

subject to

$$\varphi \in \{0, 1\}$$

$$c + a' + \varphi m \leq a(1 + r(t)) + w_x(t) e(j, x),$$

$$\varphi \cdot a' \geq 0$$

$$a' \geq 0, \quad \text{for} \quad j = J$$

$$v_t(a, i, J+1, -x, x) \equiv 0.$$

$$v_t(a, i, J+1, x, x) \equiv 0.$$

Abusing the notation somewhat, denote the optimal decision rules for assets by $a'_t(z)$, the optimal consumption function by $c_t(z)$ and the optimal moving function by $\varphi_t(z)$.

Equilibrium law of motion For aggregation purposes, it is necessary to describe the position of individuals across states. Let $\psi_t(B, I; j, x, y)$ be the mass of people with asset position $a \in B$, type $i \in I$, age j in location x in period t and born in location y. The function (measure) ψ_t is defined for all B in $\mathcal{B}$, the class of Borel subsets of $\mathbb{R}$, all Borel subsets $I \subset \mathcal{I} = [0, 1]$, all $j \in \mathcal{J}$ and all x and y in $\{\mathcal{R}, \mathcal{P}\}$. The dynamic evolution of ψ_t is as follows.

We begin with the newborns; they arrive according to

$$\psi_{t+1}(B, I; 1, x, y) = \begin{cases} N_x(t) \displaystyle\int_I \alpha(i)di & \text{if } 0 \in B \text{ and } x = y \\ \\ 0 \text{ otherwise.} \end{cases}$$

where $N_x(t)$ stands for the population of location x at t.[6] Notice that we take for granted that a newborn did not move in the previous period.

Since everyone dies at age J, we have

$$\psi_{t+1}(B, I; J + 1, x, y) = 0.$$

For $1 < j \leq J$, ψ obeys the following recursions. If $x' = x = y$, we have

$$\psi_{t+1}(B, I, j, x, x) = \int_{\mathbb{R}\times I} (1 - \varphi_t(a, i, j-1, x, x))\, I\{a'_t(a, i, j-1, x, x) \in B\} d\psi_t(a, i; j-1, x, x) \tag{1}$$

In words, the mass of individuals in the next period located at x who were born also at x are those who were born at x and located at x the current period and decided *not* to move.

[6] Thus the number of newborns in a region is proportional to the total number of people in that region. Alternatively, one could assume that the number of newborns in a region is proportional to the number of people in a certain age range.

In similar fashion, the number of individuals at location x next period but who were *not* born at x includes *i)* those who were born *and* are located at $-x$ in the current period and decided to move; *ii)* those who were born at $-x$ and are already at location x in the current period. Formally,

$$\psi_{t+1}(B, I; j, x, -x) =$$

$$\underbrace{\int\limits_{\mathbb{R}\times I} \varphi_t(a, i, j-1, -x, -x) I\{a_t'(a, i, j-1, -x, -x) \in B\} d\psi_t(a, i; j-1, -x, -x)}_{\text{Natives of } -x \text{ who arrive to } x \text{ at } t+1} +$$

$$\underbrace{\int\limits_{\mathbb{R}\times I} I\{a_t'(a, i, j-1, x, -x) \in B\} d\psi_t(a, i; j-1, x, -x)}_{\text{Past arrivals from } -x}$$

Aggregates We now illustrate how a number of aggregates and prices can be calculated given ψ_t.[7] Given ψ_t, we can write labor input in location x as

$$L_x(t) = \sum_{j=1}^{J} \psi_t(\mathbb{R}, \mathcal{I}; j, x, x) \cdot e(j, x) + \sum_{j=1}^{J} \int\limits_{\mathbb{R}\times\mathcal{I}} (1 - \theta(i)) \cdot e(j, -x) d\psi_t(a, i; j, x, -x)$$

and population in location x as

$$N_x(t) = \sum_{j=1}^{J} \psi_t(\mathbb{R}, \mathcal{I}; j, x, x) + \sum_{j=1}^{J} \psi_t(\mathbb{R}, \mathcal{I}; j, x, -x)$$

Similarly, total world's assets at time t, $A(t)$, are given by

$$A(t) = \sum_{x \in \{\mathcal{R}, \mathcal{P}\}} \left\{ \sum_{j=1}^{J} \int\limits_{\mathbb{R}\times\mathcal{I}} a \, d\psi_t(a, i; j, x, x) + \sum_{j=1}^{J} \int\limits_{\mathbb{R}\times\mathcal{I}} a \, d\psi_t(a, i; j, x, -x) \right\}$$

Suppose that we know the past price of land in each location. Then we easily back out the world capital stock from the following equilibrium relation, which expresses the idea that everything

[7] In Appendix I we present a formal definition of equilibrium.

is owned by someone:

$$A(t) = K(t) + p_{\mathcal{R}}(t-1)F_{\mathcal{R}} + p_{\mathcal{P}}(t-1)F_{\mathcal{P}}.$$

Meanwhile, all capital is somewhere, so

$$K(t) = K_{\mathcal{R}}(t) + K_{\mathcal{P}}(t).$$

Knowing aggregate labor in each location, we know how world's capital is divided: since in equilibrium rates of return equal the marginal product of capital net of depreciation, and rates of return are equalized across locations, we have

$$G_1(K_{\mathcal{R}}(t), L_{\mathcal{R}}(t), F_{\mathcal{R}}; A_{\mathcal{R}}) = G_1(K(t) - K_{\mathcal{R}}(t), L_{\mathcal{P}}(t), F_{\mathcal{P}}; A_{\mathcal{P}})$$

The above implies we also know wages rates and rental rates of land as they are given by the respective marginal products. This procedure can be repeated at all points in time. As a result, there is an implied sequence of land prices as these are given by the discounted value of land rental rates. Altogether, these principles constitute the basis for an algorithm to compute equilibria, which we describe in detail in Appendix II.

2.1 Discussion

We now elaborate briefly on the implications of a number of features of the model. First, in the absence of migration, all individuals within a cohort in each location are identical in terms of their earnings and their decisions. Their type i is irrelevant since it only affects what happens to people who move.

On the other hand, when migration is allowed, a cohort in a given location is potentially quite diverse. Some members are natives, others are new immigrants, others may have arrived in the more distant past. Migrants will differ from each other and from natives with respect to earnings because of their type–specific skill losses $\theta(i)$. Moreover, immigrants as a group may earn more or less than natives because they were endowed with more or skills in their region of birth as described by the dependence on x of the function $e(j, x)$. Of course, asset holdings within a cohort will differ as well.

Second, migration will be a *gradual* process. That is, not only is convergence to the new steady state not instantaneous because of gradual capital accumulation, the movement of people does not end after one period either. There are three distinct but perhaps related reasons for this. All of them are more or less closely tied to the life cycle structure of the economy, and in particular, to the lack of intergenerational altruism.

In the first place, some people will be relatively old when the barriers are removed. Since these people do not have many years left to live and they do not care about their children, it is not worthwhile for them to pay a moving cost in return for a small period of time with higher earnings.

Secondly, moving is expensive, and individuals cannot borrow to pay for it. Thus, they need time to accumulate assets sufficient to cover the moving cost.

Finally, it is the high–portability (i.e. low $\theta(i)$) types that tend to move. In the presence of a moving cost, every generation will contain a certain mass of high $\theta(i)$ types who will not move even if the wage gap is very large, and the next generation will contain a mass of low $\theta(i)$ types that will move even if the wage gap is not so large.

This gradualness is a desireable property of any model of migration, since gradualness is a striking feature of migration experiences in the past.[8] For example, about a third of Sweden's population emigrated to the United States during the period 1870-1920. In no year did the migration rate exceed 1.1 percent.

Another desireable feature of our model is that people do not move in their first period of life. Again, this is what we observe both currently and in the past. Migrants tend to be concentrated in their 30s and early 40's. For instance, currently in the United States the mean age of immigrants is of about 41 years.[9]

Lastly, we note that when only movements of capital can take place, output per worker can

[8] See Hatton and Williamson (1998) and O'Rourke and Williamson (1999) for ample evidence on the mass migration process of the 19th century and early 20th century.

[9] Our calculation from INS data for 1990-2000. Individuals considered are 20 years or older. If individuals 15 years or older are considered, the mean age is about 38 years.

differ in a steady state because of three factors: differences in land stocks per worker, differences in efficiency units per worker, and differences in Total Factor Productivity. More explicitly,

$$(y_{\mathcal{R}}/y_{\mathcal{P}}) = (A_{\mathcal{R}}/A_{\mathcal{P}})^{(1/(1-\lambda))} \times (\tilde{L}_{\mathcal{R}}/\tilde{L}_{\mathcal{P}})^{\eta/(1-\lambda)} \times (z_{\mathcal{R}}/z_{\mathcal{P}})^{(1-\lambda-\eta)/(1-\lambda)}$$

where y_x and z_x stand for output per worker and land per worker in location x respectively, and $\tilde{L}_x$ are average labor efficiency units per worker. This obviously differs from more standard analyses as land is a now determinant of output per worker differences. Nevertheless, unless the land share is large,[10] land differences will play at best a secondary role in accounting for the large observed differences in output per worker across countries. To illustrate this point, suppose, counterfactually, that both the capital and land shares equal 1/3. This determines that the land per worker should be raised only to a factor of 1/2. So only if there are rather large disparities in land per worker across countries will land play a significant role. In the data (see Section 3) however, land per worker does *not* differ systematically across countries.

3 Parameterization

In this Section, we describe the model in more detail and assign precise parameter values wherever those values are held constant in all our computational exercises.

The length of a period is assumed to be 5 years. Based on this choice, parameter values are selected as follows.

Demographics Agents enter the model at age 20 and live for a maximum of 79 years. This implies that the total number of periods a person lives is 12. Lifespans are independent of where individuals are born and population growth rates are zero (as described above). These assumptions imply that the initial distribution of the population (in the absence of migration) coincides with the initial distribution of the labor force.

[10] Evidence on land shares indicate that they are relatively small; never in excess of $0.2 - 0.3$.

Technology We assume that the labor share in the production technology is the same across locations, an assumption that is supported by the findings of Gollin (2002). The shares corresponding to capital and land, however, might differ.

For all cases except one (see below), we assume capital and labor shares to be the same across regions and we use US data to pin down their values. To do this, we begin by following Cooley and Prescott (1995) in using the sum of income from capital and land services, the ratio of the sum of capital and land to output and the ratio of gross investment to output to obtain an average for the US of about 0.37 of the share of output accruing to capital and land, a depreciation rate of capital of about 0.081 and also a rate of return on capital.[11]

After this, it remains to disentangle income from capital and income from land. We do this indirectly by using theory and data on the total value of land as a share of output. Since in a steady state, the marginal product of land equals the interest rate times the price of land, the land share equals $r \times v$, where v is the value of land as a share of total output. Using the interest rate obtained in the previous step, we obtain a land share of about 0.051. Together with the previous calculations, this implies a share of capital of 0.317. This figure is quite similar to the value of 0.06 estimated by Caselli and Coleman (2001) for the US non-agricultural sector, which accounts for nearly 98% of total output. Based on these considerations, we set $\lambda = 0.317$ and $\eta = 0.632$.

For some readers, the value of the land share for the poor location might seem low. To understand the quantitative significance of this possibility, we conduct sensitivity analysis where we increase the land share in the poor location; see Section 4.

Preferences We assume a CRRA period utility function with parameter σ. We set σ equal to 2. This value is in the range of estimates reviewed by Auerbach and Kotlikoff (1987) and other authors.

When land and capital shares are equal across locations, capital to output ratios are the same

[11] The period considered is 1959-1990 and we use the same data sources of Cooley and Prescott (1995). The notion of physical assets include capital equipment, structures, residences, inventories, consumer durables and land.

in each location. Then, for each assumed case of land per worker, we set the discount factor β so as to generate a capital to annual output ratio equal to 2.18, which is consistent with the calibration of the capital share. This implies a world rate of return equal to about 6.7% on an annual basis. The resulting value for β is 0.976.

Efficiency Units The profile of efficiency units is parameterized so that

$$e(j,x) = \tilde{e}(j) \times h_x, \quad x \in \{\mathcal{R}, \mathcal{P}\}$$

The function $\tilde{e}(j)$ is common to both locations, and set equal to the age-profile for U.S. males estimated by Hansen (1993). The parameter h_x controls the human capital endowment and shifts the age–efficiency profile in a multiplicative fashion. Later, we will pin down the ratio $h_{\mathcal{R}}/h_{\mathcal{P}}$ using measured differences in educational attainment across the two groups of countries that we are considering; see Sections 4, 5 and 6.

Land Stocks and Relative Total Factor Productivity Except in one case (see Section 4), we set the stocks of land per worker equal to 1 in both locations. This assumption is supported by the evidence in Rao (1993), which indicates there is no strong empirical association between the stock of land per worker and GDP per worker. For instance: in 1990, arable land per worker was about 1.1 Hectares in OECD economies and about 0.97 Hectares in non-OECD countries.

Skill losses of Migrants We assume that skill losses $\theta(i)$ are uniformly distributed in the interval $[0, 1]$. Since this distribution is not directly observable, we will discuss how the implications of these choices relate to available data; see Sections 4, 5 and 6.

4 Removing Migration Barriers: Exploring the Framework

In this Section, we explore the model framework by considering a number of hypothetical economies and investigate the consequences of removing barriers to migration. More specifically, the excercise we conduct in all cases is the following: departing from a steady state in which individuals are not allowed to move, we allow them *unexpectedly* to do so. It is important to mention here that we restrict our attention to the transitional dynamics that ensues under the (realistic) portfolio assumption that in the initial steady state, *all* of the land stock in each location is held exclusively by residents of that location.

We proceed by first comparing steady states and then we examine transitions between these steady states. Finally, we look at welfare effects.

4.1 Steady State Effects

We begin by dividing the world's labor force equally across locations, and then proceed to discuss the quantitative implications of the model for a number of cases. In our first group of results, there are no differences in labor quality between natives of $\mathcal{P}$ and $\mathcal{R}$, so $h_{\mathcal{R}}/h_{\mathcal{P}} = 1$. In the second group, labor quality of natives of $\mathcal{R}$ is 50% higher than labor quality of natives of $\mathcal{P}$, which implies $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$. We then report results for two values of the moving cost, $m = m_L$ and $m = m_H$. The low value (m_L) is equal to a value of 1 annual GDP per worker in the poor region in the initial situation, while the high value (m_H) is equal to a value of 2 $\times$ annual GDP per worker of the poor region in the initial situation.

For every case of labor quality differences, we find the corresponding TFP ratio that reproduces an output per worker ratio of 2 in the absence of labor movements. Note that when there are no differences in labor quality, all output per worker differences are due to TFP; when $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$, TFP contributes to ouptut per worker differences by a factor of about 1.37.[12]

[12] As we discuss below, when labor quality differences are identified using educational attainment data, a

The key results for steady states are summarized in Tables 1 and 2. The most striking result that emerges from these calculations is the large movements of labor across steady states that the removal of restrictions implies, and the simultaneous large effects on world output. When $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$, between approximately 78% and 92.5% of the world's labor force chooses to live and work in the high TFP region in the new steady state (a 56% and 85% increase respectively), while world output increases by between 16 and 24 percent as a result. When there are no differences in skills of natives of $\mathcal{P}$ and $\mathcal{R}$, nearly the whole world's labor force is located in the new steady state in the high TFP location, and the output increase amounts to about 27%. These long run output changes are sizeable by the standards of policy analysis in applied general equilibrium modelling; they take, however, a large number of periods to materialize, a critical property of the environment we discuss below.

To understand why even rather modest TFP differences lead to sizeable movements of labor across steady states, note that although returns to labor and capital jointly are not very far from constant. The presence of the fixed factor means that returns are diminishing, so that not all capital and land needs to move to the high TFP region in order to equalize returns. But because the land share is not very big, returns do not diminish very fast. This is perhaps seen most clearly in an environment without moving costs; there, labor moves until wage rates are equalized. Thus in this case, both wages and capital rental rates are equalized, and we have

$$L_{\mathcal{R}}/L_{\mathcal{P}} = (A_{\mathcal{R}}/A_{\mathcal{P}})^{1/(1-\lambda-\eta)} \times (F_{\mathcal{R}}/F_{\mathcal{P}})$$

This equation says that the ratio of labor input across the two locations is proportional to the TFP ratio raised to a power given by the reciprocal of the land share. In our case, to a value in excess of $1/0.06 \approx 16.6$. This simple calculation implies that for TFP levels leading to a output per worker ratio of 2 and $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$, about 98% of the world population should be located in the rich location in order for wages to be equalized.

value of $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$ corresponds roughly to a OECD vs non–OECD partition of the world's population, while $h_{\mathcal{R}}/h_{\mathcal{P}} = 1$ approximates the case of the enlargement of the European Union.

Table 1: Percentage Change of Key Variables

Economy	World Capital	World Output	Pop. ($\mathcal{R}$)	Output per worker ($\mathcal{R}$)	Output per worker ($\mathcal{P}$)
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$					
$m = m_H$	+27%	+27%	+99%	-5%	+90%
$m = m_L$	+27%	+27%	+99%	-5%	+90%
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$					
$m = m_H$	+16%	+16%	+56%	-3%	+6%
$m = m_L$	+24%	+24%	+85%	-4%	+15%

To account for the changes in output in Table 1, it is important to note that world capital increases across steady states and that capital 'chases' labor, as the high TFP location receives a higher fraction of the world capital stock. These two effects result in that world capital to output ratios are invariant across steady states (i.e. the world's capital stock increases by the same factor than world output). These phenomena are accounted for by the fact that labor movements in the presence of TFP differences lead to an increase in the marginal product of capital. This determines in turn, both higher capital accumulation, as well as reallocation of capital in favor of the high TFP location until the rate of return to capital returns to its original level.

Table 2: Decomposition of World's Output Changes

Economy	Only Labor Movements (1)	Labor Movements-New Division of K (2)	Total Change (3)	(1)/(3) (%)
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$				
$m = m_H$	+3.7%	+17.5%	+26.6%	11.6%
$m = m_L$	+3.5%	+17.5%	+26.6%	11.0%
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$				
$m = m_H$	+8.1%	+10.8%	+16.1%	38.4%
$m = m_L$	+8.3%	+15.6%	+23.7%	28.7%

To assess the quantitative importance of capital movements and capital accumulation for the results in Table 1, we calculate a number of auxiliary statistics presented in Table 2. The table shows (i) the increase in world output due exclusively to movements of labor (i.e for a *given* world capital stock and a given division between locations); (ii) the increase in world output due to the movement of labor, for the old capital stock under its *new* division; (iii) the total increase in world output. Under this decomposition, at most 38% of the increase in world output is accounted for labor movements. This implies that the residual, about 62%, correspond to changes in the stock of capital and its distribution. This clearly demonstrates that abstracting from capital accumulation may provide a misleading picture of the effects of migration for the world's economy.

The Importance of Land Since the assumption of a common land share may suggest that the value of the land share is relatively low for the low TFP location, we investigate the effects of different values of this parameter across locations. One key motivation for this exercise are observations that indicate that the share of land in total output varies inversely with the level of development, and that cross-country estimates of the land share in agriculture are in the range of 0.15 - 0.20.[13]

Specifically, we present results below for an extreme case: we leave the labor share in both locations as before, but reduce the capital share in the poor location only so that the land share *triples* in relation to the benchmark case. This implies $\lambda_{\mathcal{R}} = 0.317$ and $\lambda_{\mathcal{P}} = 0.215$, with a corresponding land share in the low TFP location of 0.153. As previously, we calculate for each value of assumed labor quality the TFP value that reproduce an output per worker ratio of 2.

[13] See Mundlak (2001) for a review of evidence on land shares in agriculture.

Table 3: Importance of Land Share (Percentage Change of Key Variables)

Economy	World Capital	World Output	Pop. ($\mathcal{R}$)	Output per worker ($\mathcal{R}$)	Output per worker ($\mathcal{P}$)
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$					
$m = m_H$	+16%	+11%	+32%	-2%	+8%
$m = m_L$	+28%	+18%	+56%	-3%	+18%

Now the effects on population movements and world output are smaller than in the benchmark case; 11% vs 16%, and 18% vs 23%. This is not surprising; intuitively, as the returns to labor and capital jointly diminish much faster, a smaller reallocation of labor is required to make individuals indifferent in terms of moving decisions. Thus, smaller movements of labor take place, and a smaller amount of capital is accumulated across steady states. Quantitatively however, the effects on world output are still rather large: it increases at least by about 11% in relation to the original steady state.

4.2 Transitions Between Steady States

The removal of migration restrictions leads both to large changes *and* a protracted transition for world output, as Table 4 demonstrates. The speed of convergence to the new steady state of the model economies, as measured by the half-life for world output ranges from 65 years to 270 years, depending of TFP differences and fixed migration costs. It is worth noticing that this result stands in sharp contrast with the quantitative properties of standard growth models, which predict rapid convergence to the steady state with a half–life of about 5 years for a capital share around 1/3.[14] Figure 1 displays the transitional dynamics for world's output when $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$. From these findings, it is clear that the model has the ability to deliver gradual transitions, not only qualitatively, but also quantitatively.

[14] Barro and Sala–i–Martin (1999), chapter 2, for a textbook discussion of speed of convergence in the one sector neoclassical growth model.

Table 4: World Output

(Percentage increase with respect to the initial steady state)

Economy	10 years	25 years	50 years	Half-life in years (approx.)
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$				
$m = m_H$	+1%	+3%	+8%	90
$m = m_L$	+2%	+4%	+11%	65
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$				
$m = m_H$	+0%	+2%	+7%	270
$m = m_L$	+2%	+4%	+11%	65

Table 5 shows the corresponding transitional changes in the population of the rich location. Quantitatively, migration is, as output, a gradual process. When the skill ratio is 1.0, the model implies annual migration rates of about 1% and 1.5% for the first 10 years of the transition to the new steady state; when the skill ratio is 1.5, the corresponding annual rates are about 0.1% and 0.5%.[15]

[15] The fact that transitions for output and population tend to be faster under a skill ratio of 1.5 than under a ratio of 1.0 should not be surprising. In the latter case, all differences in output per worker are due to TFP. This translates into an initially higher wage gap between locations, and as a result, into larger incentives to move.

Figure 1: Transition when $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$.

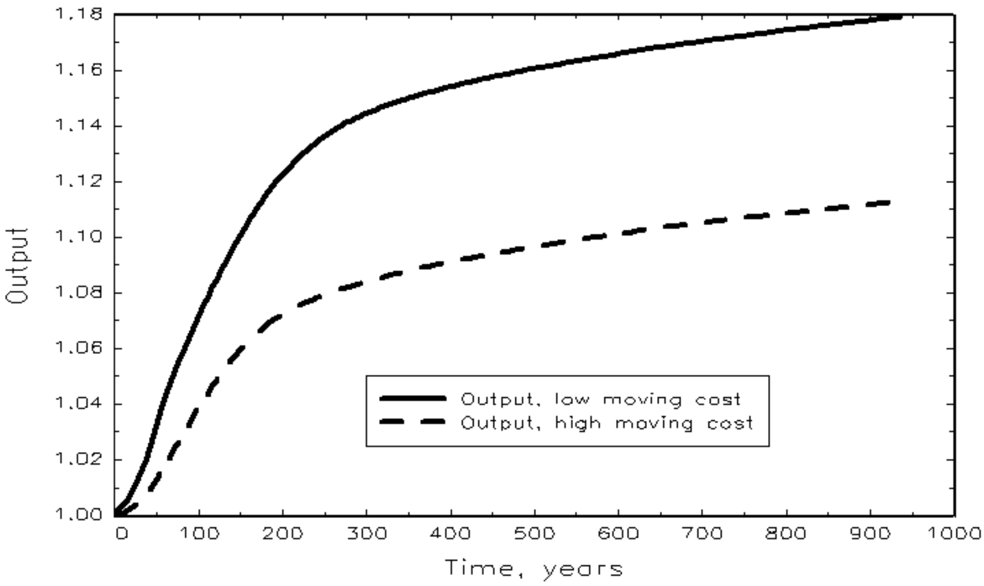

Table 5: Population of $\mathcal{R}$

(Percentage increase with respect to the initial steady state)

Economy	10 years	25 years	50 years	∞
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$				
$m = m_H$	+10%	+22%	+35%	+99%
$m = m_L$	+16%	+32%	+45%	+99%
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$				
$m = m_H$	+1%	+4%	+8%	+56%
$m = m_L$	+5%	+12%	+17%	+85%

The protracted nature of output changes and population movements is accompanied by small changes in rates of return over the transitional period. This is displayed in Table 6. The results indicate that the rate of return to capital is never more than 2 percentage points above its steady state value in annual terms, despite the magnitude of output changes and labor movements.

The economic forces at work that account for the transition patterns are simple. As we mentioned before, finite lives and fixed migration costs in conjunction with borrowing constraints, lead to gradualness in population movements; that is, only a fraction of the population of the relatively poor location moves at a point in time. More labor in the high TFP location determines that the marginal product of capital increases. This in turn triggers both accumulation of capital, and an increasing share that the high TFP location gets of the world's capital stock (e.g. capital 'chases' labor). The net result is the relatively smooth pattern of rates of return, gradual movements of population and gradual increases in world's output that are summarized the tables.

Table 6: Annualized Rates of Return (%)

Economy	10 years	25 years	50 years
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$			
$m = m_H$	7.0%	7.0%	6.9%
$m = m_L$	6.9%	7.0%	6.8%
$h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$			
$m = m_H$	6.7%	6.7%	6.7%
$m = m_L$	6.7%	6.8%	6.8%

4.3 Welfare

In this section, we report the welfare consequences of lifting barriers to migration. We proceed as follows. For each type i, we calculate the percentage increase in consumption that is required in each period in order to make individuals indifferent between a world without migration barriers, and the status quo. The average of this consumption compensation across individuals of a given cohort is the welfare gain that we report in Table 7. To understand the results in the Table, recall that individuals live for 12 periods. Then, generation 1 is the generation whose last period of life takes place when migration barriers are lifted, say t_0. Similarly, generation 12 is the one that is born at date t_0. Generation "∞" corresponds to individuals who are born in the new steady state.

Table 7: Welfare Gains, $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$

	Natives of $\mathcal{R}$		Natives of $\mathcal{P}$	
Generation	$m = m_H$	$m = m_L$	$m = m_H$	$m = m_L$
1	+0.2%	+0.3%	-0.3%	-0.4%
6	+0.7%	+0.8%	+8.8%	+13.5%
12	-1.5%	-2.0%	+4.1%	+7.0%
24	-3.2%	-3.4%	+7.7%	+12%
∞	-5.0%	-5.0%	+90%	+90%

Table 8: Welfare Gains, $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.5$

	Natives of $\mathcal{R}$		Natives of $\mathcal{P}$	
Generation	$m = m_H$	$m = m_L$	$m = m_H$	$m = m_L$
1	+0.0%	+0.1%	-0.0 %	-0.1 %
6	+0.0%	+0.1%	+0.1 %	+1.1%
12	-0.1%	-0.5%	+0.3 %	+1.2%
24	-0.5%	-1.6%	+0.8 %	+2.4%
∞	-3.2%	-4.5%	+6.3 %	+15.5%

A number of properties of the results are worth noticing. First, observe that the oldest individuals in the high TFP location gain when barriers are removed, while the opposite occurs in the low TFP location. This is straightforward: as natives of $\mathcal{R}$ hold all land in this location and the oldest individuals have mostly asset income, lifting migration barriers will lead to gains for these if the value of land increases. This is precisely what occurs as the increase in the labor input in $\mathcal{R}$ increases the marginal product of land over time, which in turn leads to a jump in the price of land at t_0.

Second, notice that welfare gains (losses) are exactly proportional for generation "∞"to changes in output per worker across steady states. This follows from the fact that across steady states rates of return do not change, so all changes in consumption correspond one-to-one to changes in wage rates, which in turn are proportional to output per worker. As the output per worker increases across steady states, so does consumption.

Third, individuals born at t_0 gain in the poor location and and lose in the rich location, and the lower the fixed moving cost, the greater the welfare gain (loss) for natives of the poor (rich) location. Notice, in particular, that individuals in $\mathcal{P}$ gain substantially on average even when only a small fraction of them eventually moves to the rich location. This is accounted for by the fact that prices change in favorable terms for newborns in $\mathcal{P}$; wage rates there increase over time because of diminishing returns to labor.

Overall, the removal of migration restrictions has non-trivial consequences on welfare, and these consequences differe substantially across locations and cohorts. At the critical date when restrictions are removed, $t = t_0$, in the rich location old and middle age individuals gain, and young individuals lose. The losses of the youngest can be sizeable: when $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$, they lose between 1.5% and 2% of consumption. The *gains*, however, of the youngest in poor location are proportionally *larger*; for the same case, they gain between 4.1% and 7.0%.

The question arises whether there exists a compensation scheme such that the removal of barriers would make everyone better off. We intend to address this question in a future version of the paper.

5 Removing Migration Barriers: The Enlargement of the European Union

We now use the model study the upcoming enlargement of the European Union. Starting in 2004, citizens from Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Slovakia and Slovenia will be allowed to work anywhere in the European Economic Area[16] This constitutes a major policy event, and naturally motivates a number of important questions that our framework is well suited to answer.

We conduct the same type of experiment than in the previous section. To this end, we need

[16] The European Economic Area consists of the European Union, Iceland, Liechtenstein and Norway. The only caveat regarding the starting date is a seven–year optional moratorium that some old member countries (e.g. Germany) will probably use.

to pin down the relative level of skills between old and new members of the Union, as well as the distribution of the population between locations. From the Penn World Tables, using labor force weights, we calculate that the ratio of output per worker pertaining the the old members of the Union relative to the new ones was 2.17 in 2000, so $y_{\mathcal{R}}/y_{\mathcal{P}} = 2.17$ is now our target in the absence of labor movements. Using the same data, we set the initial condition for the distribution of the labor force: 83.2% in old member countries, and 16.8% was in the new group of countries.

We pin down the ratio $h_{\mathcal{R}}/h_{\mathcal{P}}$ using measured differences in educational attainment across the two groups of countries. From Barro and Lee (2001), the population–weighted average years of education (among those in the population 15 years or older), is quite similar between the two groups: 9.5 for new members and and about 8.7 old members. We view this as evidence that there are not significant differences in labor quality between natives of "old" and "new" Europe. That is, we take a conservative approach and set $h_{\mathcal{R}}/h_{\mathcal{P}} = 1.0$. Therefore, this parameterization attributes *all* initial differences in output per worker to differences in TFP.

We consider three levels of the moving cost: m_1, m_2 and m_3. We set m_1 and m_2 to 0.5 and 1 times annual GDP per worker in the poor location. We set m_3 to a much larger value: 2 times annual GDP per worker in the poor location.[17]

Results are presented in Tables 9, 10 and 11 and in Figure 2. Key findings are the following. In the long run, output in Europe (old + new) will rise by about 8 percent as a consequence of the removal of the restrictions. This figure is robust to a wide range of values for the fixed moving cost, in line with our previous findings when all initial differences are due to TFP.

[17] In 1995 US dollars, these values correspond to \$42,964, \$21,482 and \$10,741 for m_3, m_2 and m_1 respectively.

Figure 2: Enlargement of the European Union

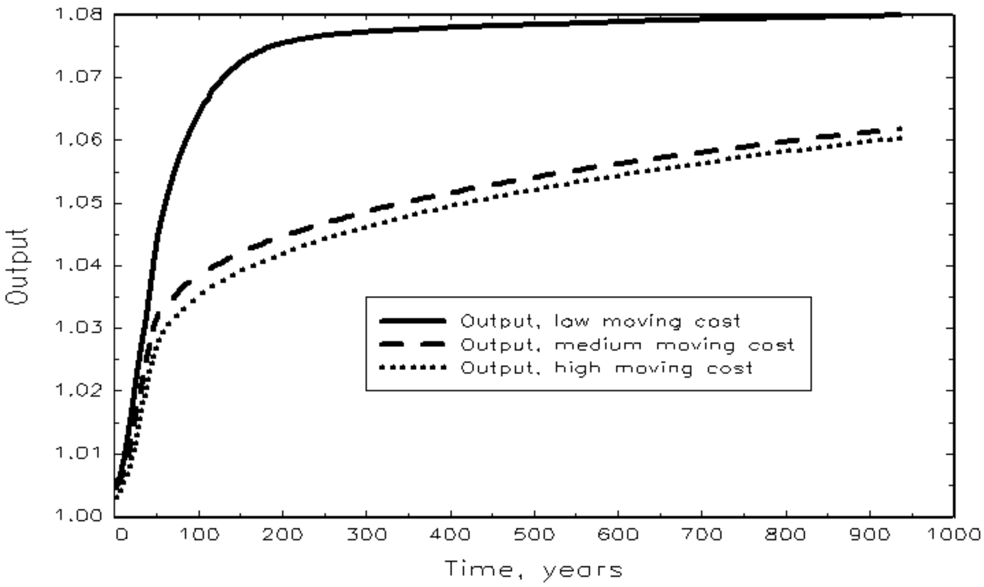

Table 9: % Change of Key Variables across Steady States

Economy	European Capital	European Output	Pop. ($\mathcal{R}$)	Output per worker ($\mathcal{R}$)	Output per worker ($\mathcal{P}$)
$m = m_1$	+8%	+8%	+20 %	-1%	+73%
$m = m_2$	+8%	+8%	+20%	-1%	+73%
$m = m_3$	+8%	+8%	+20%	-1%	+73%

Second, the transition between steady states is again long, so output gains take a long time to materialize. This is true even for the lowest moving cost. In this case, after ten years european output goes up by only 1% approximately, and by about 4% after 10 years.

Finally, *if* TFP differences remain in Europe, the new member countries will eventually be depopulated almost entirely. But in the short run, population movements are much less dramatic. Even with the lowest value for the moving cost, about half of the population of "New" Europe is still there in 50 years. After 10 years, the model predicts a population increase of "Old" Europe as a result of immigration from "Old" Europe of only 3-4 percent; that is, migration rates at the annual level not exceeding 0.4%. This is tiny compared even to current immigration rates into Western Europe.

Table 10: European Output

(Percentage increase with respect to the initial steady state)

Economy	10 years	25 years	50 years	∞
$m = m_1$	+1%	+2%	+4%	+8%
$m = m_2$	+1%	+1%	+3%	+8%
$m = m_3$	+0%	+1%	+3%	+8%

Table 11: Old Europe Population

(Percentage increase with respect to the initial steady state)

Economy	10 years	25 years	50 years	∞
$m = m_1$	+4%	+8%	+11%	+20%
$m = m_2$	+3%	+6%	+7%	+20%
$m = m_3$	+3%	+5%	+7%	+20%

6 Removing Migration Barriers: Opening up the OECD

We now use the model study the hypothetical full removal of migration restrictions between rich and poor countries. To this end, we divide up the world economy in two: a rich location that we identify with a composite of OECD countries, and a poor location, which corresponds to countries outside this club. We choose to consider this case because of the very large disparities in output per worker between these two groups of countries, the severe barriers to labor movements and the fact that most of the world's labor force is concentrated outside our group of rich countries.[18]

Once again we need to pin down the relative level of skills between locations, the respective sizes of the labor force and the relative levels of TFP. From the Penn World Tables, using labor force

[18] The countries included in the OECD group are Australia, Austria, Belgium, Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

weights, we find that the ratio of output per worker between OECD and non–OECD countries was 5.66 in 2000, so $y_{\mathcal{R}}/y_{\mathcal{P}} = 5.66$ is now our target in the absence of labor mobility.[19] Using the same data, we set the initial condition for the distribution of the labor force: 82.2% in non-OECD economies, and 17.8% in the OECD group.

¿From Barro and Lee (2001), the population–weighted average years of education (among those in the population 15 years or older), is about 5.81 in non-OECD countries and about 9.76 in OECD countries. Using a rate of return to years of education of 10%, we get of about $h_{\mathcal{O}}/h_{\mathcal{N}} = 1.48$. We note that this estimate is in close conformity with the results provided by other authors. For example, Hendricks (2002), using data on immigrant earnings, reports results that imply a ratio of 1.41 for low income countries. Altogether, the parameter choices imply a contribution of TFP to relative output per worker differences of a factor of about 3.7.[20]

We consider three levels of the moving cost: m_1, m_2 and m_3. For comparison purposes, we keep choose m_1 and m_2 to be the same in absolute terms as in our analysis of the enlargement of the European Union. This implies that the fixed cost amounts to 1.23 and 2.46 times output per worker of the non-OECD group in the initial situation. For illustration purposes, the high cost, m_3, is set so as to keep 60 percent of the world's popoulation outside the OECD in the long run. Given the substantial incentives to move to the rich location, this number is rather large: it corresponds to about 10.3 times output per worker outside the OECD.

Results are presented in Tables 12, 13 and 14 and in Figure 3. Across steady states, the removal of barriers lead to quite substantial changes in output, capital and the location of the labor force. Unless the fixed moving cost is very high, output and capital increase in the long run by about 172%, and nearly the entire world's population is located in the OECD in the long run. The reasoning presented in previous sections accounts for these findings. Specifically, large differences in TFP across locations lead to large movements of people and these, in

[19] We note that using simple averages, the ratio of output per worker between the two groups is much lower, about 3.96. This is esentially due to the fact that in the non–OECD group, larger countries (e.g. China and India) tend to be poorer than average.

[20] The implied importance of TFP differences is in line with results provided by other authors. Gourinchas and Jeanne (2003), Table 10, conclude that TFP accounts for a factor of about 3.3 for the output per worker differences between this group and the US. Hendricks (2002) obtains a factor of 3 for a comparison of his set of low income countries and the US.

turn, generate capital accumulation and the reallocation of capital across locations. Notice in particular the extent to which the large differences in TFP interact with the initial distribution of the labor force. Unlike the case of the enlargement of the European Union, now not only TFP differences are much larger, but the bulk of the world's labor is originally situated in the poor location. Thus, in light of our previous discussions, the magnitude of steady state changes should not be surprising.

The transitions to new steady states are depicted in Figure 3 and illustrated in Table 13. Notice that again there is a slow convergence to the steady state, and that this speed depends crucially on the fixed moving cost. In all cases, the half–life for world output exceeds 50 years. While world output increases across steady states by about 172% for the lowest moving cost (about 1.23 times initial output per worker of the poor location), this variable goes up by only 81% after 50 years.

Table 12: % Change of Key Variables across Steady States

Economy	World Capital	World Output	Pop. ($\mathcal{R}$)	Output per worker ($\mathcal{R}$)	Output per worker ($\mathcal{P}$)
$m = m_1$	+172%	+172%	+461%	-12.1%	np
$m = m_2$	+172%	+172%	+461%	-12.1%	np
$m = m_3$	+50%	+50%	+125%	-5.9%	+2.4

np = not precise

Table 13: World Output

(Percentage increase with respect to the initial steady state)

Economy	10 years	25 years	50 years	∞
$m = m_1$	+7.4%	+25.6%	+81.4%	+172%
$m = m_2$	+5.9%	+20.1%	+73.3%	+172%
$m = m_3$	-0.0%	+0.1%	+1.6%	+50%

Figure 3: Opening up the OECD

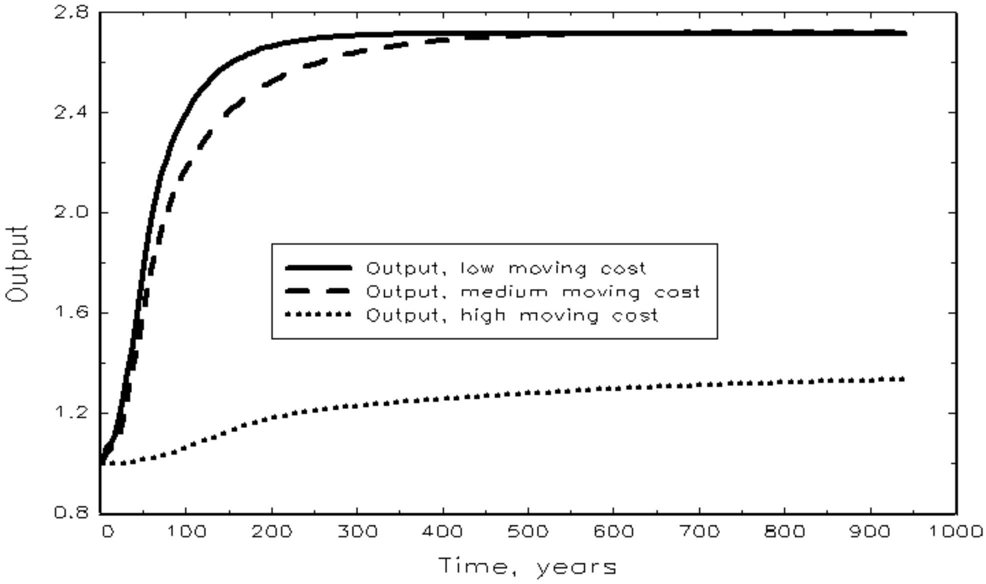

Table 14: OECD Population

(Percentage increase with respect to the initial steady state)

Economy	10 years	25 years	50 years	∞
$m = m_1$	+100%	+222%	+315%	+461%
$m = m_2$	+75%	+165%	+257%	+461%
$m = m_3$	+0.2%	+0.8%	+7.8%	+125%

7 Concluding remarks

[TO BE WRITTEN]

Appendix I: Equilibrium Definition

Equilibrium An equilibrium consists of a sequence of value functions $v_t(z)$, optimal decision rules $a_t'(z)$, $c_t(z)$ and $\varphi_t(z)$, aggregate variables $K_x(t)$ and $L_x(t)$ for $x = \{\mathcal{R}, \mathcal{P}\}$, a measure ψ_t and prices $r_x^k(t)$, $w_x(t)$, $r_x^f(t)$ and $p_x(t)$ for $x = \{\mathcal{R}, \mathcal{P}\}$ such that

1. The optimal decision rules $a_t'(z)$, $c_t(z)$ and $\varphi_t(z)$ solve the individuals' dynamic problem and $v_t(z)$ are the resulting value functions.

2. Markets are competitive:

$$r_x^k(t) = G_1(K_x(t), L_x(t), F_x; A_x) - \delta,$$

$$w_x(t) = G_2(K_x(t), L_x(t), F_x; A_x),$$

and

$$R_x^f(t) = G_3(K_x(t), L_x(t), F_x; A_x)$$

for all $x = \{\mathcal{R}, \mathcal{P}\}$.

3. There are no arbitrage opportunities. This implies that all assets earn a common rate of return $r(t)$; specifically,

$$r(t) = r_x^k(t)$$

and

$$1 + r(t) = \frac{p_x(t) + R_x^f(t)}{p_x(t-1)}$$

for all $x \in \{\mathcal{R}, \mathcal{P}\}$

4. Markets clear so that

$$L_x(t) = \sum_{j=1}^{J} \psi_t(\mathbb{R}, \mathcal{I}; j, x, x) \cdot e(j, x) + \sum_{j=1}^{J} \int_{\mathbb{R}\times\mathcal{I}} (1 - \theta(i)) \cdot e(j, -x) d\psi_t(a, i; j, x, -x)$$

for all $x = \{\mathcal{R}, \mathcal{P}\}$ and

$$\sum_{x\in\{\mathcal{R},\mathcal{P}\}} \sum_{j=1}^{J} [\int_{\mathbb{R}\times\mathcal{I}} a\, d\psi_t(a; i, j, x, x) + \int_{\mathbb{R}\times\mathcal{I}} a\, d\psi_t(a; i, j, x, -x)] = K(t+1) + p_{\mathcal{R}}(t)F_{\mathcal{R}} + p_{\mathcal{P}}(t)F_{\mathcal{P}}$$

$$K(t) = K_{\mathcal{R}}(t) + K_{\mathcal{P}}(t)$$

5. The world resource constraint is satisfied:

$$G(K_{\mathcal{R}}(t), L_{\mathcal{R}}(t), F_{\mathcal{R}}; A_{\mathcal{R}}) + G(K_{\mathcal{P}}(t), L_{\mathcal{P}}(t), F_{\mathcal{P}}; A_{\mathcal{P}}) + (1-\delta)K(t) -$$
$$\sum_{j=1}^{J} \sum_{x\in\{\mathcal{R},\mathcal{P}\}} \int_{\mathbb{R}\times\mathcal{I}} \theta(i)\, e(j, -x) G_2(K_x(t), L_x(t), F_x)\, d\psi_t(a; i, j, x, -x) =$$
$$\sum_{j=1}^{J} \sum_{x\in\{\mathcal{R},\mathcal{P}\}} [\int_{\mathbb{R}\times\mathcal{I}} c(a; i, j, x, x)\, d\psi_t(a; i, j, x, x) + \int_{\mathbb{R}\times\mathcal{I}} c(a; i, j, x, -x)\, d\psi_t(a; i, j, x, -x)] +$$
$$K(t+1) + \sum_{j=1}^{J} \sum_{x\in\{\mathcal{R},\mathcal{P}\}} \int_{\mathbb{R}\times\mathcal{I}} \varphi_t(a; i, j, x, x)\ m\, d\psi_t(a; i, j, x, x)$$

6. Measure of agents over types ψ_t is generated as in the text.

Appendix II: Computation

Below we describe how to compute equilibria in the model economy we study. We divide our discussion in two parts: (i) computation of steady states; (ii) computation of transitions between steady states.

II.1 Steady States

There are two cases we need to consider. The first one pertains to the case in which no labor mobility is allowed (or equivalently, mobility costs are arbitrarly high). Hence, given $N_{\mathcal{R}}$ people in location $\mathcal{R}$ and $N - N_{\mathcal{R}}$ people in location $\mathcal{P}$, we need to calculate the steady state for the 'world' economy with perfect (costless) mobility of capital.

The algorithm is as follows:

1. Guess steady state world capital, K^*.
2. Obtain aggregate labor input in both locations (this can be done since we know that newborns are in proportion to total population and that type does not change as people age).
3. Obtain capital in both locations by solving

$$G_1(K^* - K^*_{\mathcal{R}}, L^*_{\mathcal{P}}, F_{\mathcal{P}}; A_{\mathcal{P}}) = G_1(K^*_{\mathcal{R}}, L^*_{\mathcal{R}}, F_{\mathcal{R}}; A_{\mathcal{R}})$$

4. Calculate wage rates in both locations and the rate of return on assets $(w^*_{\mathcal{R}}, w^*_{\mathcal{P}}, r^*)$. Calculate the steady state price of land in both locations.
5. Solve for individual decisions.
6. Obtain the implied steady state measure ψ^*. Do this simply by following a single generation through life.
7. From ψ, find the value of implied world assets A. Also, find the value of world assets by adding world capital to the value of land.

8. If the values above are consistent with one another and with the inital guess of world capital, STOP. Otherwise, update.

The second case to consider pertains to the situation in which people could have moved across locations in the past. Given the presence of the moving cost, there can be a continuum of distributions of people across locations (e.g. $N_{\mathcal{P}}$, $N - N_{\mathcal{P}}$) that are consistent with a steady state. Formally, in terms of people residing in the poor location, let the interval $D = [N^-_{\mathcal{P}}, N^+_{\mathcal{P}}]$ be the interval that contains the distributions of population consistent with a steady state.

We will search for the upper bound of D, the population level $N^+_{\mathcal{P}}$. This is the population level of the poor location that is part of a steady state and generates the highest wage gap in favor of the rich location. Notice that the population level of the poor location that generates equal wages in both locations, $\tilde{N}_{\mathcal{P}}$, is necessarily a member of D. That is, $\tilde{N}_{\mathcal{P}} \in D$. The algorithm described below bisects the interval $[\tilde{N}_{\mathcal{P}}, N]$ in order to find $N^+_{\mathcal{P}}$

We proceed as follows:

1. Find $\tilde{N}_{\mathcal{P}}$. Do this by searching across steady states without migration for the steady state with $w_{\mathcal{R}} = w_{\mathcal{P}}$. Notice that nobody will attempt to migrate in this situation!

2. Let $N^L_{\mathcal{P}} = \tilde{N}_{\mathcal{P}}$ (lower bound of bisection interval). Let $N^H_{\mathcal{P}} = N$ (upper bound of bisection interval).

3. Guess $N^0_{\mathcal{P}} \in [N^L_{\mathcal{P}}, N^H_{\mathcal{P}}]$. Solve for an open economy steady state under the assumption that nobody moves (moving costs are prohibitively expensive).

4. Check whether or not individuals would move, given $m < +\infty$. If somebody moves, then $N^H_{\mathcal{P}} = N^0_{\mathcal{P}}$ and go back to step 3. Else, if nobody wants to move, then $N^L_{\mathcal{P}} = N^0_{\mathcal{P}}$ and go back to step 3.

5. Iterate until convergence.

II.2 Transitions Between Steady States

Consider a transition induced by the unexpected removal of migration barriers. We calculate the steady states associated with for given initial conditions in terms of the distribution of population, and when people have migrated in the past. Then, we obtain values of world capital and in each location, labor in both locations as well as rental and land prices.[21] We specify terminal time T, so that the economy hits the new steady state after T periods. More precisely, at time $t = T$ the relevant statistics of the economy are those pertaining to the new steady state.

We follow the following steps.

1. Guess sequences $\{K(t)\}_{t=1}^{T}$ and $\{L_x(t)\}_{t=1}^{T}$, $x \in \{\mathcal{R}, \mathcal{P}\}$.
2. Obtain capital in each location by equating marginal products of capital. Find $\{R_x(t)\}_{t=1}^{T}$, $\{w_x(t)\}_{t=1}^{T}$ and $\{r(t)\}_{t=1}^{T}$ by calculating marginal products. Hence calculate land prices

$$\begin{cases} p_x(T) &= p_x^* \\ p_x(t-1) &= \dfrac{p_x(t) + R_x(t)}{1 + r(t)} \end{cases}$$

   for $t = T-1, T-2, ...1$.
3. Solve for individual decisions.
4. Aggregate individual decisions and obtain implied sequences $\{K'(t)\}_{t=1}^{T}$ and $\{L'_x(t)\}_{t=1}^{T}$. If these sequences are sufficiently close to those guessed, STOP. If not, update and return to step 2.

[21] Notice that land prices in a steady state are given simply by $p_x^* = \frac{R_x^*}{r^*}$

References

Auerbach, A. J., & Kotlikoff, L. J. (1987). *Dynamic Fiscal Policy.* Cambridge University Press, New York.

Baker, M., & Benjamin, D. (1994). The Performance of Immigrants in the Canadian Labor Market. *Journal of Labor Economics*, *12*(July), 369–405.

Barro, R., & Sala–i–Martin, X. (1999). *Economic Growth.* Cambridge, Massachusetts and London, England: MIT Press.

Barro, R. J., & Lee, J. W. (2001). Schooling Quality in a Cross-Section of Countries. *Economica*, *68*, 465–488.

Ben-Gad, M. (2003). The Economic Effects of Immigration: a Dynamic Analysis. Manuscript, University of Haifa.

Borjas, G. J. (1994). The Economics of Immigration. *Journal of Economic Literature*, *32*(4), 1667–1717.

Borjas, G. J. (1995). The Economics Benefits from Immigration. *Journal of Economic Perspectives*, *9*(2), 3–22.

Caselli, F., & Coleman, J. (2001). The U.S. Structural Transformation: A Reinterpretation. *Journal of Political Economy*, *109*(3), 584–616.

Castro, R. (2003). Economic Development and Growth in the World Economy. Manuscript, Université de Montréal.

Cooley, T. F., & Prescott, E. C. (1995). Economic Growth and Business Cycles. In Cooley, T. F. (Ed.), *Frontiers of Business Cycle Research*, chap. 1. Princeton University Press, Princeton.

Gollin, D. (2002). Getting Income Shares Right. *Journal of Political Economy*, *110*(2), 458–474.

Gourinchas, P.-O., & Jeanne, O. (2003). The Elusive Gains from International Financial Integration. Manuscript, Princeton University.

Hall, R., & Jones, C. (1999). Why Do Some Countries Produce So Much More Output per Worker than Others? *Quarterly Journal of Economics*, *114*(1), 83–116.

Hamilton, B., & Whalley, J. (1984). Efficiency and Distributional Implications of Global Restrictions on Labour Mobility: Calculations and Policy Implications. *Journal of Development Economics*, *14*(1-2), 61–75.

Hatton, T., & Williamson, J. (1998). *The Age of Mass Migration: An Economic Analysis.* New York: Oxford University Press.

Hendricks, L. (2002). How Important is Human Capital for Development? Evidence from Immigrant Earnings. *American Economic Review*, *92*(1), 198–219.

Jones, C. I. (2002). *Introduction to Economic Growth*. New York: W. W. Norton & Company.

Mundlak, Y. (2001). Production and Supply. In Gardner, B., & Rausser, G. (Eds.), *Handbook of Agricultural Economics*, chap. 1. Elsevier Science B.V.

O'Rourke, K., & Williamson, J. (1999). *Globalization and History: The Evolution of the Nineteenth–Century Atlantic Economy*. Cambridge, Massachusetts: MIT Press.

Prescott, E. (1998). Needed: A Theory of TFP. *International Economic Review*, *39*(3), 525–551.

Rao, D. S. P. (1993). *Intercountry comparisons of agricultural output and productivity*. Rome: Food and Agricultural Organization of the United Nations.

Storesletten, K. (2000). Sustaining Fiscal Policy Through Immigration. *Journal of Political Economy*, *108*(2), 300–323.

Urrutia, C. (1998). On the Self–Selection of Immigrants. Manuscript, Universidad Carlos III de Madrid.