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Discussion Paper 2012-23

Institut de Recherches Économiques et Sociales
de l'Université catholique de Louvain

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Efficiency gains from liberalizing labor mobility

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This paper quantifies the effect of a complete liberalization of international migration on the world GDP and its distribution across regions. We build a general equilibrium model endogenizing bilateral migration and wage disparities between and within countries. A dual strategy is developed to identify total migration costs and their legal component. Contrary to existing studies, we obtain limited efficiency gains. Accounting for incompressible moving costs strongly reduces the benefits from liberalization. When we account for endogenous productivity, congestion, heterogeneous education quality, imperfect substitution between migrants and natives, and network effects, efficiency gains reach about 4 percent of the world GDP.

This paper investigates the effect of a complete liberalization of international labor mobility on the allocation of the world labor force, world GDP/income level, and its distribution across countries and regions. This requires quantifying immigration restrictions, i.e. policy-induced costs borne by the migrant to overcome the legal hurdles set by national authorities in destination and origin countries. There is no cross-country database measuring the size of migration costs and decomposing their private and legal parts. We propose a dual approach which consists of using data on effective and desired emigration by education level to identify total migration costs and visa costs as a residual of the migration technology. On this basis, we compute efficiency gains by taking into account, for

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the first time, the existence of "incompressible" moving costs. This is a major improvement as the empirical literature on the determinants of migration has long emphasized the role of geographic and cultural distances. For example, psychic and monetary moving costs explain why within-EU migration flows have been limited despite large income differences between EU member states and free mobility agreement. They also explain why removing migration barriers in unattractive corridors (with high incompressible costs) generates small migration flows, as illustrated by the German Green-Card policy in the last decade.[1]

Quantifying the effect of liberalization also requires modeling interdependencies between migration decisions and economic performances. The macroeconomic literature of international migration is a segmented area of research; with a few exceptions, interdependencies between migration and development have received scant attention. Galor (1986) or Vidal et al. (1996) modeled migration choices and studied their welfare implications in stylized overlapping-generations models. More recently, de la Croix and Docquier (2012) endogenized high-skilled emigration decisions and poverty levels in developing countries, emphasizing the possibility of multiple equilibria. Two other papers modeled migration as the outcome of a central planning problem (de la Croix and Docquier, 2009 ; Benhabib and Jovanovic, 2012) and provided theoretical and numerical predictions. Both used a stylized representation of the world (one developing region, or a two-region framework) and a simplistic treatment of moving costs (neglected, or calibrated using US interstate transportation costs).

To the best of our knowledge, this paper is the first to provide a general equilibrium analysis of international labor mobility and income inequality across nations in a bilateral framework with (i) a large number of (origin and destination) countries, (ii) two levels of education, (iii) endogenous individual decisions to migrate, and (iv) measures of moving costs.

Existing studies of liberalization provide optimistic results. However, they use partial equilibrium or large CGE multi-sector and multi-region models which were not explicitly designed to formalize migration decisions. Clemens (2011) summarizes the main predictions of the existing literature. While removing remaining barriers to trade and capital flows would generate a small increase in world GDP (between 0.5 and 4 percent for trade and between 0.1 and 1.7 percent for capital),

[1]Germany aimed at attracting at least 20.000 specialists for its IT sector. This target was unmet, as by July 2003 less than 15.000 work permits were issued (Kolb, 2005).

eliminating all restrictions to labor mobility would induce huge efficiency gains in the range of 50 to 150 percent of world GDP. Comparing scenarios with constant physical capital and no differences in inherent productivity of people (i.e. a Mexican worker migrating to the US is as productive as a US citizen), liberalization increases world GDP by 147.3 percent in Hamilton and Whalley (1984), 122 percent in Klein and Ventura (2007), 96.5 percent in Moses and Letnes (2004). These studies assume that liberalization will lead to wage equalization across countries.[2] Hence, none of these studies accounts for "incompressible" migration costs, endogeneity of migration decisions, differences in education levels of workers, and the bilateral structure of migration costs. Iregui (2005) is the only study considering workers' educational attainment. She finds that relocating people to equalize wages would increase the world GDP by 67.0 percent. These optimistic studies suggest that migration barriers leave "trillion dollar bills on the sidewalk" (Clemens, 2011). These results are also echoed by Pritchett (2006), who argues that laws and regulations restricting migration from the South to the North carry considerable economic costs for developing countries and serve to compound existing income inequalities.[3]

Our model takes into account important missing ingredients and is parameterized using new bilateral databases on migration stocks and desires to emigrate by education level. Our philosophy is to use a simple and abstract economic model which highlights the major economic mechanisms underlying migration decisions and wage inequality, and then confront theory to data. Although the model is large (due to the number of countries included), the mechanisms are transparent. The model includes only a few equations per country and can be parametrized using econometric estimates and proper identification methods. Such a quantitative theory approach is now the dominant research paradigm used by economists incorporating rational expectations and dynamic choice into short-run macroeconomic and monetary economics models (King, 1995). However, little has been

[2]Other studies have simulated the effects of exogenous movements of workers from low-productivity to high-productivity countries enabling an increase in the world output. For example, Winters (2001) or Walmsley and Winters (2005) use a global CGE model to assess the effects of an increase in developed countries' quotas on both high-skilled and low-skilled temporary migrants equivalent to 3 percent of the labor force. The world GDP would increase by over $150 billion. Di Giovanni et al. (2012) evaluate the welfare impact of global migration using a monopolistic-competition model accounting for firm heterogeneity, endogenous number of varieties and trade. In their framework, migration improves welfare in destination countries and induces ambiguous welfare responses in origin countries: market size and number of varieties decrease, but these countries benefit from remittances.

[3]See also Dani Rodrik's weblog (http://rodrik.typepad.com/dani_rodriks_weblog/).

done so far with this methodology in long-term macroeconomics. Our research steps include the identification of consensual analytical specifications for utility and production functions, finding properly estimated elasticities in the empirical literature, identifying unobserved exogenous variables by forcing the model to match observations, and proceeding to numerical experiments to gauge the sensitivity of the model and compute the effects of liberalizing labor mobility.

Consensual microfoundations can reasonably be found in the literature of the last 15 years. Given the availability of new databases by education level, the recent empirical literature analyzes the determinants of the size and structure of international migration (Belot and Hatton, 2008; Rosenzweig, 2008; Grogger and Hanson, 2011; Beine et al., 2011a; Razin and Wahba, 2011). They all use a multinomial discrete choice model which suits the data and can be structurally estimated. Another strand of the literature has examined the impact of immigration on economic performance and welfare in destination countries (see recent works by Borjas, 2003, 2009; Card, 2009; Ottaviano and Peri, 2012). Empirical structural models are all derived from profit maximization of representative firms characterized by a nested CES production function with different stages: capital and labor, high-skilled and low-skilled labor, experience groups, migrants and natives. Other studies have investigated the effect of emigration on sending countries (Bhagwati and Hamada, 1974; Haque and Kim, 1995; Stark et al., 1997, 1998; Mountford, 1997; Beine et al., 2001, 2008). They all emphasize the role of human capital in determining workers' individual productivity and total factor productivity. It is worth noting that the same schooling externalities have been identified in rich countries (Acemoglu and Angrist 2000, Moretti 2004a, 2004b, Ciccone and Peri 2006 and Iranzo and Peri 2009). We will combine these ingredients into a large model with about 200 countries, or 40K country pairs.

Our analysis will reveal striking results. As a starting point, we use Iregui's study (Iregui, 2005) which accounts for education levels of workers. It predicts that liberalizing mobility causes a 67 percent increase in world GDP, half of Hamilton-Whalley's effect when education is disregarded. Accounting for incompressible migration costs in our basic model divides the effect by 4 (i.e. +17 percent of world GDP). In a next step, four technological refinements are introduced: endogenous total factor productivity with schooling externalities or congestion effects, downgraded education acquired in poor countries, and imperfect substitution and wage disparities between immigrants and natives. Each of these refinements reduces the efficiency response to liberalization.

Combining all of them leads to a small effect in the range of 2 percent of world GDP. Network externalities are then introduced and allow private migration costs to decrease with the size of the diaspora at destination i.e "compressing the incompressible". These externalities raise the effect by about 2 percentage points. We conclude that liberalizing labor mobility should increase world GDP by about 4 percent. This result is considered as a long-run effect and lower effects would be expected with fixed capital stock. Thus, global efficiency gains have probably been overestimated in the existing literature.

The remainder of this paper is organized as follows. In Section 1, we describe the simplest model with endogenous migration and wages. We further present our strategy of identification, the method used to disentangle migration costs, and provide a first set of results. In Section 2, we extend the model by introducing technological refinements and endogenizing private migration costs. Section 3 concludes.

I. Accounting for incompressible migration costs

In the basic specification, we endogenize migration decisions and wage disparities across countries, and disentangle the private and legal components of migration costs. The method used to disentangle migration costs is one of the main contributions of this paper. In this section, migration costs are treated as exogenous, an assumption which will be relaxed later. Following existing studies on liberalization, we consider immigrants as perfect substitutes to natives, assuming no inherent differences in productivity between workers within each educational group. Technological refinements will be introduced in the next section. Our model is static and our simulations should be considered as long-run static comparative experiments. The model does not account for capital and trade. We will justify these assumptions and discuss their implications in the beginning of Section 3.

A. The basic model

Our model distinguishes two types of workers and J countries. The skill type s is equal to h for high-skilled workers (i.e. college graduates), to l for the less educated or low-skilled, and to t when low-skilled and high-skilled workers are aggregated. We identify the condition under which migration to destination country

j is profitable for a type-s individual born in a given country i. This condition will depend on migration costs and income differentials between source and destination countries. We then describe the technology and endogenize wage disparities between countries. The combination of endogenous migration decisions and equilibrium wage rates determines the market allocation of the world population and inequality.

Migration decisions. To formalize migration decisions, we follow the recent literature and use a multinomial discrete choice model without spatial correlation in the unobserved (Belot and Hatton, 2008; Rosenzweig, 2008; Grogger and Hanson, 2011; Beine et al., 2011a; Razin and Wahba, 2011). Grogger and Hanson (2011) or Rosenzweig (2008) demonstrated that the linear utility specification is superior to a log utility model in matching the patterns of positive selection and sorting in the migration data. The utility level of a type-s individual born in country i and staying in that country is given by:

$$u_{ii,s} = \alpha(w_{i,s} + z_{i,s}) + \epsilon_{ii,s}$$

where $w_{i,s}$ is the wage rate or marginal productivity of labor in country i, $z_{i,s}$ is an exogenous variable capturing non-wage income and amenities in the origin country (public goods and transfers minus taxes, non-monetary amenities), and $\varepsilon_{ii,s}$ is a iid extreme-value distributed random term ($\varepsilon_{ii,s}$ varies across individuals). Individual subscripts are omitted for clarity.

The utility obtained when the same person migrates to country j is given by:

$$u_{ij,s} = \alpha(w_{j,s} + z_{j,s} - c_{ij,s}) + \varepsilon_{ij,s}$$

where $c_{ij,s} \geq 0$ denotes average moving costs borne by the migrant such that $c_{ii,s} = 0 \; \forall i, s$. Those costs depend on factors such as physical distance, destination and origin countries' social, cultural and linguistic characteristics.

The probability that a type-s individual born in country i will move to country j is given by:

$$\frac{L_{ij,s}}{N_{i,s}} = \Pr\left[u_{ij,s} = \max_k u_{ik,s}\right] \tag{1}$$

where $N_{i,s}$ is the native or natural population of type s from country i and $L_{ij,s}$

is the number of migrants from country i to country j. $L_{ii,s}$ denotes the number of non-movers (individuals born in i and staying in i).

We use McFadden's theorem (McFadden, 1984): when the random terms $\epsilon_{ik,s}$ follow an extreme-value distribution, the probability that a type-s individual born in country i will move to country j is given by the following logit expression:

$$\Pr\left[u_{ij,s} = \max_k u_{ik,s}\right] = \frac{\exp\left[\alpha(w_{j,s} + z_{j,s} - c_{ij,s})\right]}{\sum_k \exp\left[\alpha(w_{k,s} + z_{k,s} - c_{ik,s})\right]}$$

Hence, the log-ratio of emigrants/stayers $\ln\left(L_{ij,s}/L_{ii,s}\right)$ is given by the following linear expression:

$$\ln\left[\frac{L_{ij,s}}{L_{ii,s}}\right] = \alpha\left(w_{j,s} - w_{i,s}\right) - x_{ij,s} \tag{2}$$

where $x_{ij,s} \equiv \alpha(c_{ij,s} - z_{j,s} + z_{i,s})$ measures the cost of migration, net of difference in amenities. Henceforth, we will refer to $x_{ij,s}$ as net migration costs. Obviously, we have $x_{ii,s} = 0$.

Migration costs $c_{ij,s}$ vary across country pairs and education level. Indeed, migrants face significant legal barriers, social adjustment costs, financial burdens and uncertainties while they try to reach and settle in their destination. We distinguish legal or visa costs, and private or assimilation costs. Private costs cover a wide range of hurdles faced by the migrants in finding employment, housing, covering transportation costs, living far from one's community, deciphering foreign cultural norms, adjusting to a new linguistic and economic environment, etc. We denote private costs by $\underline{c}_{ij,s}$. Legal or visa costs represent policy-induced costs borne by the migrant to overcome the legal hurdles set by national authorities at destination and origin. We denote them by $b_{ij,s}$, implying $c_{ij,s} = \underline{c}_{ij,s} + b_{ij,s}$. We define private or incompressible net migration costs as:

$$\underline{x}_{ij,s} \equiv \alpha(\underline{c}_{ij,s} - z_{j,s} + z_{i,s})$$

Liberalizing labor mobility therefore means removing all legal migration costs and simulating the equilibrium allocation of labor when $x_{ij,s}$ falls to $\underline{x}_{ij,s}$.

Production function. Each country has a large number of homogeneous firms characterized by the same production function. Output in country i (Y_i) is produced using labor in efficiency units (Q_i):

(3) $$Y_i = A_i Q_i$$

where A_i reflects the level of the total factor productivity (henceforth referred to as TFP) in country i. The world GDP or income level writes as $Y_W \equiv \sum_i Y_i$.

Following the labor market and growth literatures[4], we assume that labor in efficiency units (Q_i) is a nested CES function of highly educated workers ($Q_{i,h}$), and less educated workers ($Q_{i,s}$):

(4) $$Q_i = \left[\theta_h Q_{i,h}^{\frac{\sigma-1}{\sigma}} + \theta_l Q_{i,l}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

where (θ_h, θ_l) are the value share parameters of highly educated and less educated workers (such that $\theta_h + \theta_l = 1$), and σ is the elasticity of substitution between the two groups of workers.

Denoting the total labor force by $Q_{i,t} \equiv Q_{i,h} + Q_{i,l}$, average income per worker ($y_i^w = Y_i/Q_{i,t}$) can be expressed as:

(5) $$y_i^w = A_i \left[\theta_h h_i^{\frac{\sigma-1}{\sigma}} + \theta_l (1-h_i)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

where $h_i = Q_{i,h}/Q_{i,t}$ measures the proportion of college graduates in the labor force.

Given their identical production function (3), each firm in country i takes A_i as given and maximizes its profits. The equilibrium wage rate for type-s workers in country i is equal to the marginal productivity of labor:

(6) $$w_{i,s} = A_i \frac{\partial Q_i}{\partial Q_{i,s}} = \theta_s A_i \left(\frac{Q_i}{Q_{i,s}}\right)^{1/\sigma}$$

From these profit maximization conditions, it is straightforward to show that total output equals total income: $Y_i = w_{i,h} Q_{i,h} + w_{i,l} Q_{i,l}$. The college graduates

[4]See Katz and Murphy (1992), Card and Lemieux (2001) or Caselli and Coleman (2006) among others.

to less educated wage ratio is given by:

$$\frac{w_{i,h}}{w_{i,l}} = \frac{\theta_h}{\theta_l}\left(\frac{Q_{i,l}}{Q_{i,h}}\right)^{1/\sigma} \tag{7}$$

It follows:

LEMMA 1: *Income per worker is increasing in the proportion of college graduates* ($\frac{\partial y_i^w}{\partial h_i}$) *in country* i *if and only if the wage ratio* $\frac{w_{i,h}}{w_{i,l}}$ *exceeds one.*

This condition is reasonably satisfied in all the countries. The country-specific effect of liberalizing labor mobility on income per worker will be positive (resp. negative) if the change in the proportion of college graduates is positive (resp. negative).

Equilibrium allocation. In each country, the type-s resident labor force ($Q_{i,s}$) is the sum of national stayers and immigrants, whereas the native or natural labor force ($N_{i,s}$) is the sum of national stayers and emigrants. In the basic specification, we assume that native and foreign workers are perfect substitutes within each education group. Given the notations above, we have:

$$Q_{i,s} \equiv \sum_{k\in J} L_{ki,s} \tag{8}$$

$$N_{i,s} \equiv \sum_{k\in J} L_{ik,s} \tag{9}$$

Hence, the world equilibrium allocation of labor can be defined as follows:

DEFINITION 1: *For a given distribution of the native population* $\{N_{i,s}\}_{\forall i,s}$, *of TFP values* $\{A_i\}_{\forall i}$, *and bilateral structure of net migration costs* $\{x_{ij,s}\}_{\forall ij,s}$, *an equilibrium allocation of labor is a set* $\{L_{ij,s}\}_{\forall i,j,s}$ *satisfying (i) aggregate constraints (8) and (9), (ii) utility maximization conditions (2) and (iii) profit maximization conditions (6) for all* i, j *and* s.

An equilibrium allocation of labor is characterized by a system of $2\times J\times(J+1)$, i.e. $2\times J\times(J-1)$ bilateral log-ratio of migrants to stayers, $2\times J$ wage rates, and $2\times J$ aggregation constraints. In the next section, we use data for 195 countries (developed and developing independent territories) and explain how we parametrize our system of 76,440 simultaneous equations. Once properly calibrated, this model can be used to conduct a large variety of numerical experiments.

Static comparative analysis. The first concern of our analysis is efficiency and therefore the main variable of interest is the world (denoted W) income per worker, y_W^w. However, redistributive effects across regions must also be considered. Finally, we are also interested in alternative income measures in order to evaluate the effects of liberalization on the different types of agents (i.e. migrants and stayers). Besides income per worker y_i^w (average income of workers employed in a given country), we will analyze the effect of liberalization on income per natural y_i^n (average income of national workers born in a given country), and income per remaining stayer y_i^r (average income of natives staying in their country of birth). The latter variable includes remittances sent by expatriates, which are assumed to be proportional to expatriates' income. Income variables of interest are defined as:

$$(10a) \qquad Y_i^w = \sum_{\substack{j\in W \\ s=l,h}} L_{ji,s} w_{i,s}; \qquad y_i^w = \frac{Y_i^w}{Q_{i,t}}$$

$$(10b) \qquad Y_i^n = \sum_{\substack{j\in W \\ s=l,h}} L_{ij,s} w_{j,s}; \qquad y_i^n = \frac{Y_i^n}{\sum\limits_{s=l,h} N_{i,s}}$$

$$(10c) \qquad Y_i^r = \sum_{s=l,h} L_{ii,s} w_{i,s} + \tau_i \sum_{\substack{j\neq i \\ s=l,h}} L_{ij,s} w_{j,s}; \qquad y_i^r = \frac{Y_i^r}{\sum\limits_{s=l,h} L_{ii,s}}$$

where τ_i is the exogenous propensity to remit income to country i.

At the margin, the effect of a change in the allocation of labor (i.e. a set of $dQ_{i,s} \forall i, s$ such that $\sum\limits_{i\in W} dQ_{i,s} = 0 \; \forall s$) on the average income per worker at world level (dy_W^w) is given by:

$$(11) \qquad dy_W^w = \sum_{\substack{i\in W \\ s=l,h}} \left(y_i^w + Q_{i,t} \frac{dy_i^w}{dh_i} \frac{dh_i}{dQ_{i,s}} \right) \frac{dQ_{i,s}}{Q_{W,t}}$$

Equation (11) highlights the two mechanisms at play when labor mobility is liberalized. The first term between brackets reflects the gain in income induced by the relocation of workers from low-wage to high-wage countries. The second term captures the general equilibrium effect on stayers' income, i.e. workers remaining in the home countries and citizens of immigration countries. Given Lemma 1, the effect on stayers' income depends on the change in the distribution of human capital across the world ($dh_i \; \forall i$).

The regional income per worker takes into account redistribution effects which are not reflected by changes in the world production frontier. Denoting regional aggregate variables by subscript R, the change in regional income per worker writes:

$$dy_R^w = \sum_{\substack{i \in R \\ s=l,h}} \left(y_i^w - y_R^w + Q_{i,t} \frac{dy_i^w}{dh_i} \frac{dh_i}{dQ_{i,s}} \right) \frac{dQ_{i,s}}{Q_{R,t}} \tag{12}$$

The term in brackets represents the change in regional income. Two effects are again simultaneously at play: a relocation of workers from low-wage to high-wage countries and an impact on the stayer's wage rates, weighted by the workforce size of each country. It must be stressed that regional averages hide different realities, given the aggregation of regional population and production. Therefore, average income per worker at the regional level can increase even if the proportion of high-skilled workers decreases. To illustrate this, suppose that a part of the regional population moves from a low-income country to a higher-income country located in the same region. Regional population remains constant while total production increases. Even if some high educated workers leave the region, average income can increase if a sufficiently large number of workers reallocate (or arrive) in the more productive countries.

The effect on regional average income per natural is written:

$$dy_R^n = \sum_{\substack{i \in R \\ j \in W \\ s=l,h}} w_{j,s} \frac{dL_{ij,s}}{N_R} + \sum_{\substack{i' \in W \\ j' \in W \\ s'=l,h}} \left(\sum_{\substack{i \in R \\ j \in W \\ s=l,h}} \frac{dw_{j,s}}{dL_{i'j',s'}} L_{ij,s} \right) \frac{dL_{i'j',s'}}{N_R} \tag{13}$$

with $\sum_{j' \in W} dL_{i'j',s} = 0 \; \forall i', s'$. Only the distributional effect on native wages is taken into account given that the number of natives from a certain region is constant. The first term accounts for the reallocation of workers born in region R. For $j \in R$, the reallocation takes place inside the region (e.g. a Korean worker moving to Japan) while for $j \notin R$ the worker leaves the region (e.g. a

Korean worker migrating to the US). The second term incorporates the general equilibrium effects induced by labor mobility on the wages across the world e.g. a Korean worker living in the US can experience a change in income due to the arrival of additional Indian and Brazilian migrants to the US.

Denoting stayers in region R by $S_{R,t} = \sum_{\substack{i\in R\\ s=l,h}} L_{ii,s}$ we can write the effect on income per stayer as:

(14)

$$dy_R^r = \sum_{\substack{i\in R\\ s=l,h}} w_{i,s}\frac{dL_{ii,s}}{S_R} + \sum_{\substack{i'\in W,\ j'\in W\\ s'=l,h}} \left[\left(\sum_{\substack{i\in R\\ s=l,h}} \frac{dw_{i,s}}{dL_{i'j',s}} L_{ii,s}\right)\frac{dL_{i'j',s}}{S_R} - y_R^r \frac{dS_R}{S_R}\right]$$
$$+ \sum_{\substack{i'\in W,\ j'\in W\\ s'=l,h}} \left[\sum_{\substack{i\in R,\ j\neq i\\ s=l,h}} \tau_i \left(\frac{dL_{ij,s}}{dL_{i'j',s'}} w_{j,s} + L_{ij,s}\frac{dw_{j,s}}{dL_{i'j',s}}\right)\right]\frac{dL_{i'j',s}}{S_R}$$

The average income per stayer depends on the changes in the number of non-movers in region R. Furthermore, labor mobility can impact on the wage rates (both inside and outside region R) and thereby also on the amount of money remitted by emigrants to stayers in the source country (general equilibrium effects).

B. *Parametrization*

Given the availability of migration data, we calibrate our model on the year 2000 and distinguish 195 countries. The goal of this section is to calibrate the common, country-specific and bilateral parameters of our model. This section further describes our data sources and identification strategy. Table 1 provides summary statistics by region.

[INSERT TABLE 1]

Calibration of the production technology. We proceed in three steps. First, several data sources can be used to assess the size and skill structure of the labor force of each country ($Q_{i,s}\ \forall i,s$). The size of the working-age labor force (i.e. population aged 25 and over) is provided by the United Nations. Labor force data is then split across skill groups using international indicators of education attainment. Here, we follow Docquier, Lowell and Marfouk (2009) and combine different data sets documenting the proportion of college graduates in the population aged 25 and over. They use De la Fuente and Domenech (2006) for OECD countries and Barro and Lee (2001) for non-OECD countries. For countries where Barro and Lee's measures are missing, they use rescaled proportions from Cohen and Soto (2007). In the remaining countries where both Barro-Lee and Cohen-Soto data are missing (about 70 countries in 2000), they apply the proportion of college graduates of the neighboring country having the closest enrollment rate in secondary/tertiary education, or the closest GDP per worker. Columns 2 and 3 in Table 1 give the regional distribution of the total labor force and number of college educated workers.

Second, to compute the quantity of labor in efficiency units ($\widehat{Q}_i\ \forall i$), we need to specify the value of σ, the elasticity of substitution between high-skilled and low-skilled workers. There is a large group of influential papers which proposes specific estimated values. Johnson (1970) and Murphy et al (1998) estimate values for σ around 1.30 (respectively 1.34 and 1.36); Ciccone and Peri (2005) and Krusell et al. (2000) estimate values around 1.50 (respectively 1.50 and 1.66) and Ottaviano and Peri (2012) estimate a value close to 2. Angrist (1995) recommends a value above 2 to explain the trends in the college premium on the Palestinian labor market. Parameters σ and θ_h are common to all countries and can be calibrated as follows. First, the college premium and the share of college graduates in the US are close to 50 percent. From Eq. 7, matching these facts implies that θ_h must be equal to 0.6. We then calibrate σ to obtain realistic skill premia in developing countries, i.e. an average skill premium of 11 percent per year of schooling (see Cohen and Soto, 2007; Rosenzweig, 2008, Epifani and Gancia, 2008). This implies σ=3.0.

Finally, combining GDP data in US$ from the World Development Indicators provided by the World Bank ($Y_i\ \forall i$) and labor data ($\widehat{Q}_i\ \forall i$), it is straightforward to identify the TFP level, $\widehat{A}_i$, for each country i as a residual of (3): $\widehat{A}_i = Y_i/\widehat{Q}_i$. The regional distribution of income is given in the first column of Table 1. In addition, the wage rate for type-s workers in country i ($\widehat{w}_{i,s}\ \forall i, s$) can be easily computed using (6).

Migration technology. The marginal utility of income, α, is estimated by Grogger and Hanson (2011). They obtain, for the sorting equations, the values of $\alpha = 0.026$ and $\alpha = 0.06$ when using pre-tax wage data from the World Development Indicators and the Luxembourg Income Study respectively. Both estimations will be used in our simulations and will yield similar results.

Migration data are taken from Docquier et al. (2011) who produce 195x195 comprehensive matrices of bilateral migration stocks. Those matrices are computed for the two skill groups (college graduates and less educated individuals), and for two years (1990 and 2000). Here we only use the 2000 matrices. Migration is defined on the basis of country of birth. The methodology used in Docquier et al. (2010) consists of three steps. The starting point is the database described in Docquier, Lowell and Marfouk (2009) documenting bilateral migration stock to OECD host countries. It is based on a collection of census and register immigration data by country of birth and educational level in the 30 OECD countries. The second step consists of a collection of similar immigration data from 46 non-OECD destinations. Finally, data collected in steps 1 and 2 are used to predict the size and structure of migration to the remaining 119 non-OECD host countries in 2000. Gravity regression models were estimated for the size of bilateral migration ($L_{ij,s}$) from country i to country j in the education group s. Columns 4 and 5 in Table 1 provide regional numbers of immigrants and emigrants (without distinction of education levels).

Combining bilateral migration stocks and labor force data gives estimates for the log-ratio of migrants to stayers, $\ln \left(L_{ij,s}/L_{ii,s} \right)$, for all country pairs. We have no data on migration costs but propose to identify them using a dual approach. Using migration data and the wage rate proxies described above, we compute $\widehat{x}_{ij,s}$ as a residual of (2):

$$\widehat{x}_{ij,s} = \alpha \left(\widehat{w}_{j,s} - \widehat{w}_{i,s} \right) - \ln \left[\frac{L_{ij,s}}{L_{ii,s}} \right]$$

We have $\widehat{x}_{ii,s} = 0 \; \forall i, s$, and for pairs of countries with zero immigrants ($L_{ij,s} = 0$), we set $\widehat{x}_{ij,s}$ to an arbitrarily large value. Using this dual approach, our net migration costs are perfectly compatible with bilateral migration and income data observed in 2000.

Disentangling migration costs. To our knowledge, no data quantifying visa costs and policy restrictions are available so far. Again, we use a dual approach and identify legal costs as residual of the migration equation (2) in which effective migration stocks are replaced by desired migration stocks. In order to estimate the desired migration stocks, we rely on the Gallup World Survey. This survey was organized between 2007 and 2009. It is based on phone and face-to-face interviews with 260.000 adults (1.000-3.000 per country), aged 15+, in a total of 135 countries (representing about 93% of the world's adult population). Two questions are of interest for our discussion:

- Q1 - Ideally, if you had the opportunity, would you like to move permanently to another country, or would you prefer to continue living in this country?
- Q2 - To which country would you like to move?

Question Q1 is of primary importance. We consider that "having the opportunity" is interpreted by the respondents as the complete absence of policy restrictions to movement. Our interpretation is likely to overestimate the importance of legal costs and thereby the effect of liberalization. Indeed, for some people, it is likely that "having the opportunity" means obtaining a visa and being able to pay private migration costs. Furthermore, some people mentioning a desire to leave might end up emigrating, even in the absence of changes in mobility restrictions. However, potential overestimation is not a big issue given that our objective is to demonstrate that efficiency gains have been overestimated in the existing literature.

For each country, we collect data on the proportion of stayers who want to emigrate, d_i (see Table 1). By definition, these proportions aggregate desires to leave of college graduates and less educated stayers, weighted by country-specific proportions of college graduates and less educated stayers. Gallup also disentangles the desire to leave by education level but data are only available by region; we denote by $d_{R,s}$ the proportion of would-be migrants of skill s in region R. Assuming $d_{R,s}$ is homogeneous within each region, the desire to leave for each educational group ($\widehat{d}_{i,s}$) can be estimated:

$$
\begin{aligned}
d_i \quad &= \quad \frac{L_{ii,h}}{L_{ii,l}+L_{ii,h}}\widehat{d}_{i,h} + \frac{L_{ii,l}}{L_{ii,l}+L_{ii,h}}\widehat{d}_{i,l} \\
&\Longrightarrow \quad \widehat{d}_{i,l} = d_i\left[1+\frac{L_{ii,h}}{L_{ii,l}+L_{ii,h}}\left(\frac{d_{R,h}}{d_{R,l}}-1\right)\right]^{-1} \\
&\Longrightarrow \quad \widehat{d}_{i,h} = \widehat{d}_{i,l}\left(\frac{d_{R,h}}{d_{R,l}}\right)
\end{aligned}
$$

The number of additional migrants after liberalization are then given by $\widehat{d}_{i,s}L_{ii,s}$. The last two columns in Table 1 present desires to emigrate by region and by education level as provided by Gallup. A particularly high fraction of skilled workers wants to emigrate from Sub-Saharan Africa (36%), Latin America and the Caribbean (26%), the European Union (24%) and Middle-East/North Africa (24%). The respective leading regions for the low-skilled are Sub-Saharan Africa (26%), Latin America and the Caribbean (17%) and Middle-East/North Africa (17%). Positive selection among migrants can be highlighted by dividing the proportion of college graduates among new migrants by the same proportion among pre-liberalization stayers. The ratio is large in Europe, Russia, Africa and Latin America.

Then, we assume that the destination shares of these migrants are identical to the shares observed in effective emigration, excluding country pairs with free mobility agreements. This assumption is in line with immigration predictions from Gallup's Q2 (Gallup immigration predictions are publicly available by region only). Denoting these destination shares by $\rho_{ij,s}$, we can compute the "unconstrained" allocation of labor which would be observed in the absence of migration barriers:

$$L^u_{ij,s} = L_{ij,s} + \widehat{d}_{i,s} L_{ii,s} \rho_{ij,s} \quad \forall ij, s$$

Assuming that respondents do not internalize general equilibrium effects generated by the migration of other stayers in the world (i.e. wages are fixed to their baseline values), we can identify incompressible migration costs ($\underline{x}_{ij,s}$) as:

$$\widehat{\underline{x}}_{ij,s} = \alpha \left(\widehat{w}_{j,s} - \widehat{w}_{i,s} \right) - \ln \left[\frac{L^u_{ij,s}}{L^u_{ii,s}} \right]$$

Migration barriers can then be quantified either by nominal value in \$ ($\widehat{b}_{ij,s} \equiv \widehat{x}_{ij,s} - \widehat{\underline{x}}_{ij,s}$) or as a proportion of net migration costs ($\beta_{ij,s} \equiv \widehat{b}_{ij,s} / \widehat{x}_{ij,s}$). On average, these barriers represent 21% of net migration costs for both, the high-skilled and low-skilled workers. The quartiles are respectively [0.12-0.27] for the low-skilled and [0.10-0.25] for the high-skilled. Thus, incompressible migration costs still represent an important part of total migration costs and should not be ignored when addressing the consequences of reducing restrictions to mobility.

Remittances. The exogenous propensity to remit, τ_i (remittances divided by emigrants' aggregate income), is calibrated so as to match the amount of remittances observed in the 2000 equilibrium. Remittance data are taken from the World Development Indicators.

Simulation algorithm. The calibrated model can now be used to simulate a liberalization of labor mobility. Each experiment requires simulating a system of 76,440 simultaneous equations. We use a Gauss-Seidel "shooting" algorithm. Each iteration I starts with a set of 2×38,025 guesses for $\widehat{\ell}^{I}_{ij,s}(\equiv L_{ij,s}/L_{ii,s})$ for $s = h, l$. For each set of guesses, we compute the size and structure of the labor force and wage rates in each country. We then use the utility-maximization condition to compute the solution for $\overline{\ell}^{I}_{ij,s}$. The next iteration then starts with a new set of guesses, $\widetilde{\ell}^{I+1}_{ij,s} = \eta\widetilde{\ell}^{I}_{ij,s} + (1-\eta)\overline{\ell}^{I}_{ij,s}$, where $1-\eta$ is the correction factor. We use $\eta = 0.95$, a slow convergence process toward the new equilibrium. The importance of this convergence parameter will be stressed in Section 3.1. The algorithm stops when the sum of errors (in absolute value) falls below a convergence threshold: $\sum_{i,j,s}\left|\widetilde{\ell}^{I}_{ij,s} - \overline{\ell}^{I}_{ij,s}\right| < \varepsilon$.

C. *Results*

In order to present the results, we group countries in ten different regions and use the respective abbreviations throughout the rest of the paper. The ten regions are: USA = United States, EU27 = 27 members of European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries.

We simulate a complete liberalization of labor mobility ($x_{ij,s} \to \underline{x}_{ij,s} \quad \forall ij, s$). Focusing on the partial equilibrium effects with exogenous wages, we reproduce Gallup movement predictions. Columns 2 to 4 in Table 2 summarize the change in the world and regional stocks of migrants and the proportion of high-skilled in the labor force. Liberalizing labor mobility restrictions increases the world stock of migrants by 523.7 percent (from 100.5 to 627.0 million). The fraction of workers living outside their country of birth increases from 3% to 19%. The increase is stronger for the low-skilled (+627.9%) than for the high-skilled (+227.8%). Typical migration destinations (such as US, EU27, CANZ and GCC) experience a larger rise in immigration than in emigration, reinforcing their position as migration magnets. Asian countries face a dramatic increase in labor movements which have to be considered in the light of the rather low levels of immigration and emigration at the initial equilibrium. Finally, typical emigration regions such as North- and Sub Saharan Africa or Latin America see their population decrease further.

As shown in section 2.1, the composition of the moving workers, in terms of education, is crucial for the effects on the average income. In the partial equilibrium framework, we disregard changes in wage rates and highlight the benefits from relocating workers, the first component of Eq. (11). However, the average worker's education level varies if the proportion of educated workers among the arriving immigrants differs from that of the residing population. Table 2 shows that there is in fact positive selection in the sending regions and negative selection in the receiving regions. In other words, college educated workers emigrate proportionally more from the sending countries while the fraction of college graduates among the immigrants is below the pre-liberalization level observed in the receiving countries. All regions, except for MENA, end up with a lower fraction of skilled workers among their workforce. In the latter case, the region loses proportionally more low- than high-skilled workers.

[INSERT TABLE 2]

Table 3 shows the percentage deviation of GDP per worker at the regional level ($d \ln y_i^w$). The reallocation of workers to more productive regions leads to a production increase of 17.7% at world level.[5] In the US and EU27, GDP per worker decreases by 3.3% and 0.6% respectively while it is reduced by 8.3% in GCC. The regions benefiting from a higher income per worker are MENA (+14.9%), ASIA (+15.7%) and LAC (+18.3%). Even though there is positive selection among their emigrants, average income per worker increases in ASIA and LAC. In ASIA, where total population increases only marginally, this positive effect is primarily due to a reallocation at the intra-regional level. Many workers move to countries paying higher wages but located in the same region (e.g. 3 million additional workers move from Korea to Japan). In LAC, total population strongly decreases. However, the intra-regional distribution is strongly affected by the movements. While the ten richest countries lose 2.7 million low-educated workers, 12.9 million low-educated workers leave the ten poorest LAC.

Taking into account general equilibrium effects by endogenizing the wage formation changes the results slightly. At world level, migration stocks increase somewhat less (514.3% for $\alpha = 0.026$ and 505.2% for $\alpha = 0.060$) than in the

[5]Given the constant population at world level, the increase in GDP per worker and production are equivalent.

partial equilibrium scenario (523.7%).

In our perfectly competitive labor markets framework, emigrants have a positive effect on the stayers' income belonging to the same skill group. The other workers are nevertheless negatively affected. On the other hand, substitutable workers in the receiving countries face additional competition on the labor market which reduces their wages.[6] Table 3 shows a 16.7% rise in GDP per worker at world level with $\alpha = 0.026$, one percentage point below the partial equilibrium case. The respective figure with $\alpha = 0.06$ is 16.3%. At the regional level, the typical immigration receiving countries experience a marginally stronger decrease in GDP per worker while emigration regions benefit somewhat less. Our results are quite robust to the choice of α. We therefore focus our analysis on $\alpha = 0.026$ while presenting the corresponding results for $\alpha = 0.06$ in each table.

The evolution of the three different income variables presented in Eq. (10) is provided in Table 3. These three income measures capture heterogeneous realities thereby highlighting the consequences of liberalization for different groups of workers.

The only natives who experience a lower income per natural are those from GCC (-0.7%). As shown in Table 2, this region experiences a tremendous increase in immigration while at the same time suffering the highest decrease in its proportion of skilled workers (-36.4%). This points to a particularly low-skilled immigration. The remaining natives from immigration destinations benefit on average from a slight improvement in their income (USA +0.3% and EU 27 +2.1%). On the other hand, the impact is much stronger for natives from sending countries as they are by definition the ones who move to countries paying higher wages. Naturals from ASIA benefit on average from a 79.3% rise in their income while naturals from CHIND and MENA earn close to 37% more. Natives from SSA still experience a rise of 26% on average.

Focusing on the income per stayer, a first notable change is the slightly negative evolution of EU27 stayers' income. This is caused by the emigration of high-skilled workers and simultaneous immigration of low-skilled workers. The source regions continue to benefit from improved revenues particularly due to the remittances sent back by the diasporas established abroad. The main beneficiaries are stayers

[6]Using the framework of di Giovanni et al. (2012), host countries would experience welfare gains because migration increases market size and number of varieties at destination. Their model neglects the migration impact on labor productivity.

in ASIA (+41.4%), MENA (+14.5%) and CHIND (+12.8%).

Combining the three different income measures it can be concluded that the main beneficiaries are the emigrants themselves. The remittances sent to the stayers more than cover their revenue loss caused by the positive selection of emigrants. Finally, the income measures focusing on the people (income per natural and per stayer) contrast sharply with the results focusing on the geographical dimension (GDP per worker), which has led authors such as Pritchett (2006) to advocate a preference for the former. However, in order to remain coherent with the existing literature, we focus primarily on GDP per worker.

[INSERT TABLE 3]

II. Extensions

Accounting for incompressible private migration costs reduces the efficiency gains from liberalizing labor mobility. Compared to Iregui's study (the most pessimistic in the existing literature), the effect is divided by four and we obtain an increase in world GDP of 17 percent. Should this result be considered as too pessimistic? The basic model assumes an upper-bound value for σ (the elasticity of substitution between high-skilled and low-skilled workers), disregards trade and capital, relies on a simplistic treatment of labor interactions between immigrants and natives, and considers private migration costs as exogenous.

First, choosing a lower elasticity of substitution, e.g. $\sigma = 1.3$ as suggested by Borjas (2003), reduces the efficiency gains at the world level to 12.5%. Second, we believe that introducing capital and trade in the model would generate even more pessimistic results. By assuming that output is proportional to labor in efficiency units in (3), we have in mind a model without slowly accumulating factors. It may represent a globalized economy in which capital follows people[7] or a long-run version of a model with capital accumulation. Under constant physical stock in each country, increased migration would reduce income per worker in the richest immigration countries and lower efficiency gains from liberalization, as

[7] Indeed, assuming that (i) output is produced using physical capital and labor in efficiency units, (ii) production is represented by a CRS Cobb-Douglas function, (iii) physical capital is mobile across firms and nations, (iv) each single firm and each single country are too small to affect the international interest rate, would lead to the same linear specification. Indeed, the returns to physical capital would be equalized across firms and countries, thereby implicitly defining the equilibrium capital-to-labor ratio in the economy. Plugging this arbitrage condition into the production function, a firm's output becomes a linear function of labor in efficiency units.

demonstrated in the existing literature. Defenders of trade could also object that trade and migration are closely related. In the Heckscher-Ohlin's tradition, trade and migration are perfect substitutes: increasing migration flows would have no effect on wages. More realistically, trade and migration are likely to be imperfect substitutes because countries produce differentiated goods or migration induces trade-creation effects (e.g., Gould, 1994, Head and Ries, 1998; Rauch and Trindade, 2002, Rauch and Casella, 2003, Combes, Lafourcade and Mayer, 2005). By excluding trade responses, we ignore uncertain effects related to the substitution or complementarity between trade and migration. If substitution forces dominate, they should decrease the efficiency gains of liberalization.

Refining technological interactions between natives and immigrants would generate more uncertain effects. Efficiency gains from increasing labor mobility are likely to be affected if TFP is endogenized, if skills accumulated in poor and rich countries are neither equivalent nor perfectly transferable, or if adjusted skills of immigrants and natives are not perfect substitutes on the labor market. The effect will depend on the relative impact on productivity in origin and destination countries. In this section, we account for these different technological interactions and examine how they affect our predictions. For each extension, we modify the model as described in the next sub-sections, revise the identification of unobserved exogenous variables and simulate the effect of a complete liberalization of labor mobility ($x_{ij,s} \rightarrow \underline{x}_{ij,s} \;\; \forall ij, s$). Table 4 presents the results for each variant simulated separately. Table 5 combines all the technological variants.

[INSERT TABLE 4]

The assumption of exogenous "incompressible" migration costs is also questionable. Section 3.5 accounts for network externalities and allows private migration costs to be compressed when the size of the bilateral diaspora increases. Network externalities have been disregarded in the existing literature on liberalization and we expect them to reinforce the gains.

A. Endogenous TFP

The first adjustment to the model considers the possibility of a positive externality from highly educated workers, in the spirit of the recent literature (Acemoglu and Angrist 2000, Ciccone and Peri 2006, Moretti 2004a, 2004b and Iranzo and Peri 2009). There is a large body of growth literature (beginning with Lucas 1988, and extending to Azariadis and Drazen 1990, Benhabib and Spiegel 2005, Cohen and Soto 2007, Vandenbussche et al 2009) that emphasizes the role of human capital (schooling) on technological progress, innovation and growth of GDP per worker. This includes empirical papers showing that human capital contributes to the level of income per person beyond its private returns. In the spirit of Lucas (1988), we now assume that TFP is an increasing function of the schooling intensity in the domestic labor force:

$$A_i = a_i F\left(\frac{Q_{i,h}}{Q_{i,t}}\right) \tag{15}$$

where a_i captures the part of TFP independent of the human capital externality, and $Q_{i,h}/Q_{i,t}$ is the proportion of college graduates in the domestic labor force. $F(\cdot)$ depicts the functional form for the technological externality which needs to be identified and calibrated.

Modeling migration decisions and endogenous TFP can modify the dynamic properties of the model. In particular, it can amplify the general equilibrium effects (dh) emphasized in equation (11). It is abundantly documented that high-skilled workers are relatively more migratory than the less educated (see Docquier et al., 2009). If TFP is exogenous as in Section 2, emigration of college graduates increases high-skill wages at origin, damping down incentives to leave for other educated workers. If TFP is endogenous, brain drain reduces TFP and may reduce high-skill wages at origin, inducing strategic complementarities in emigration decisions. De la Croix and Docquier (2012) derived the conditions under which interactions between migration and income give rise to multiple equilibria. Their numerical experiments reveal that coordination failures are only observed in small developing countries (less than 4 million inhabitants), where the elasticity of the brain drain to poverty is larger. Hence, our model with endogenous TFP could exhibit multiplicity. However, our iterative algorithm, which converges slowly to the new equilibrium (given the choice of η=0.95), is likely to capture the local effect of the shock. It thereby prevents the possibility of switches to other equilibria.[8] Furthermore, multiplicity is not considered to be a serious problem here given that it only concerns small states which represent less than one percent of the world GDP.

[8]We find no sign of jumps toward other trajectories in our numerical experiments.

In Lucas (1988), TFP is a concave function of the economy-wide average level of human capital. De la Croix and Docquier (2012) estimate the elasticity of TFP to the proportion of college graduates by using simple cross-country OLS-FE regression. Using a sample of developing countries (142 observations), they obtain an elasticity of 0.277; using a larger sample of 195 developing and developed countries, they obtain an elasticity of 0.447. In the empirical literature on wage determination in US cities, states or metropolitan areas, the log of local wage is regressed on the average proportion of college graduates which suggests an exponential effect of human capital on TFP. There is still a certain level of disagreement between those who find substantial schooling externalities and those who do not find significant externalities. Acemoglu and Angrist (2000) find a value close to 0.00; Iranzo and Peri (2009) suggest using 0.44 while Moretti (2004a, 2004b) finds values between 0.75 and 1.00.

We want the schooling externality to be compatible with the TFP data identified in Section 2. We identify the TFP levels of our 195 countries between 1980 and 2005 (one observation every 5 years), collect human capital data on the same period (Defoort, 2008), and use dynamic regressions. TFP growth is regressed on its lagged value and a transformation $F(\cdot)$ of the proportion of college graduates in the labor force. We compared different functional forms for the function $F(\cdot)$ in (15). The logarithmic transformation gives the best fit and reveals a concave effect of human capital on the TFP level. Furthermore, a minimal threshold of human capital below which there is no externality is allowed for.

We find that human capital has no significant impact on TFP when the share of college graduates is lower than 1.5 percent. For higher levels of human capital, the elasticity of TFP to human capital is equal to 0.17 in the short-run and to 0.32 in the long-run. The log-log specification is slightly superior to the log-linear model estimated on US states and cities. Finally, we need to calibrate the country fixed effect a_i as a residual of Eq. (15).[9]

The 2nd and 6th columns of Table 4 present the outcome on GDP per worker in the presence of endogenous technology. At the world level, the rise in GDP per worker is reduced by half, from +17.7% to +8.9%. The negative impact in all the regions points once again to the positive selection of emigrants in the sending countries and the negative selection of immigrants in the receiving countries (see

[9] Further details on the estimation procedure are provided in Appendix A.

Table 2). Given Eq. (11), we expect larger crowding out effect on non-migrants' income levels. The US, CANZ and EU27 suffer from a reduction in income per worker between -7 and -9 percent, compared to -0.8 to -4 percent previously. Income growth is further strongly reduced in some countries (like LAC, ASIA or MENA) while positive selection leads to stronger income per worker reductions in regions such as SSA and CIS.

B. Congestion

An additional aggregate effect of immigration may stem from its impact on the aggregate scale of production. On the one hand, the existence of a fixed factor in production (such as land) would cause aggregate decreasing returns. On the other hand, the efficiency of production may be increased by a rise in employment density due to "agglomeration externalities" as in Ciccone and Hall (1996). In general congestion effects can be modeled by assuming that the TFP is also a function of the aggregate scale of production (Q_t). An extension of expression (15) above can be stated as follows:

$$A'_t = a'_i (Q_{i,t})^{-\phi}$$

In this expression, the crowding effect of the labor force size on land, assuming a share of land in production of 0.03 in rich countries (see Ciccone and Hall 1986) would imply $\phi = 0.03$. Again, a'_i is calibrated as a residual of the TFP equation.

Results with congestion, assuming that TFP does not vary with the schooling intensity of the workforce, are presented in Columns 3 and 7 of Table 4. At the world level the impact of congestion is quite low as GDP per worker still increases by 15.4% (respectively 14.7% for $\alpha = 0.06$). This effect reinforces negative tendencies in receiving countries while it slightly counterbalances the income losses in sending countries. A particularly notable effect is seen for the GCC where the strong increase in net immigration combined with the congestion effect leads to a decrease of 10.5 percent in GDP per worker (compared to -6.7 percent in the benchmark).

C. Quality of education

Our basic specification assumes equivalence between national and foreign degrees in terms of quality. It is widely documented that many immigrants with higher education tend to find jobs in occupations typically staffed by less educated natives (see Mattoo et al, 2008). In particular, highly educated immigrants trained in developing countries could be less productive in high-skill jobs than natives with similar educational degrees.

Evidence of such heterogeneity in the quality of education is provided by Coulombe and Tremblay (2009), who compare the skill intensity and schooling levels of Canadian immigrants and natives who were both submitted to standardized tests in literacy, math, and problem-solving. These tests provide measures of proficiency that are comparable across countries and over time. On this basis, Coulombe and Tremblay estimate a 'skill-schooling gap' expressed in years of schooling. A skill-schooling gap of n years for a given country means that Canadian nationals with y years of schooling are as productive as immigrants with $y + n$ years of schooling. The larger the skill-schooling gap, the lower the quality of education in the country of origin. Simple bivariate OLS regressions show that the skill-schooling gap is a decreasing function of per worker income of the origin country. Their -0.10 point estimate of the slope coefficient indicates that the skill-schooling gap is one year smaller when per worker income increases by US$10 000 in the origin country. Using this estimate and cross-country data on per worker income, we construct an indicator of skill-schooling gap for each origin country. Then, assuming that one year of schooling generates a productivity gain of 8 percent, we estimate the relative productivity of educated immigrants and natives in each country, with a benchmark value of one for workers trained in Canada (as well as workers trained in richer origin countries, i.e. the upper bound of this index is one). For example, college graduate immigrants from Angola and Portugal have productivity levels equal to 0.73 and 0.85 percent of Canadian college graduates, respectively.

In order to keep the world labor force constant across simulations, our adjustment consists in multiplying the number of college graduates originating from a given country by the relative productivity index computed for that country, and considering the remaining fraction as less educated workers. In the previous example, a college graduate from Angola is considered as a combination of 0.73 college graduates and 0.27 non-college graduates. This method has two main limitations. First, as our adjustment factor is based on Canadian data, it suffers from a selection bias. Indeed, Moroccan migrants to Canada are more than likely to have higher skills than Moroccan migrants to France. Second, while our benchmark non-adjusted measure implies that immigrants' human capital is equivalent to that of natives (as if all migrants were trained in the host country), our adjusted measure implies that all immigrants were trained in their birth country. Reality is obviously somewhere in between. However our only objective here is to explore whether a correction for education quality can modify our predictions. Hence, an extremely negative assumption simply implies that our estimate is a lower bound of the wage effect.

In columns (4) and (8) of Table 4, we provide the results obtained after adjusting for quality of education. First, it must be noted that this transformation changes the population structure and thereby the levels of the different variables at the reference equilibrium. In particular, the number of educated workers decreases in developing countries. At the world level, the effect on income per worker is barely unchanged, the increase in GDP per worker being 0.4 percentage points below the figure observed in the benchmark case of Table 3. The decrease in income per worker is amplified by 0.4 to 0.9 percentage points in the typical immigration regions (US, EU27 and CANZ) while it is marginally reduced in sending regions (like SSA, CIS or CHIND).[10]

D. Labor interactions between natives and immigrants

Simulations presented in Section 2 assume that natives and immigrants with identical levels of education are perfect substitutes in the production function, i.e. $Q_{i,s}$ is simply equal to the sum of natives' and immigrants' labor supplies. Recent literature has shown that there might be some complementarity between natives and foreign workers (Card, 2009; Ottaviano and Peri, 2012; Manacorda et al., 2012). There are various reasons to believe that native and immigrant workers may differ in several aspects which are relevant to the labor market. First, immigrants have skills, motivations and tastes that may set them apart from natives. Second, in manual and intellectual work, they may have culture-specific skills and limitations (e.g., limited knowledge of the language or culture of the host country), which create comparative advantages in some tasks and disadvantages in others. Third, even in the absence of comparative advantage, immigrants tend

[10]To address the first limitation of our method, we have conducted simulations with a correction based on the square of the Canadian index. Under the squared correction, one college graduate immigrant from Angola or Portugal accounts for 0.51 or 0.72 units of highly skilled workers, respectively. Taking the squared correction has little impact on the effects. World GDP per worker increases by 16.1% (respectively 15.6% for $\alpha = 0.06$) compared to 16.3% (15.9%) in the simple correction case. Regional outcomes also remain identical.

to concentrate in different occupations than natives due to migration networks or historical accidents. In particular, new immigrants tend to cluster disproportionately in those sectors or occupations where previous migrant cohorts are already over-represented.

In this section, immigrants and natives within the same skill/education category are allowed to be imperfect substitutes within a CES structure. We use the following specification:

$$Q_{i,s} = \left[\theta_n L_{ii,s}^{\frac{\delta-1}{\delta}} + \theta_m \left(\sum_j L_{ji,s}\right)^{\frac{\delta-1}{\delta}}\right]^{\frac{\delta}{\delta-1}}$$

where $L_{ii,s}$ is the number of type-s native workers and $\Sigma L_{ji,s}$ is the number of type-s immigrant workers who are present in the country; δ is the elasticity of substitution between natives and immigrants in group s; parameters (θ_n, θ_m) capture the value share parameters of natives and immigrants (such that $\theta_n + \theta_m = 1$).

There is debate in the literature on the estimates of the elasticity of substitution between natives and immigrants. Borjas et al (2008) put it essentially at infinity (as in our basic specification), Ottaviano and Peri (2012) and Card (2009) around 20 while Manacorda et al. (2012) estimate it around 5. We use 20 in Table 4. Moreover, the relative productivity of natives is set to $\theta_n = 0.6$ in order to account for wage differentials between natives and immigrants.

Results with imperfect substitution between natives and immigrants are presented in Column (5) and (9) of Table 4. Compared to the benchmark case, the increase in GDP per worker is cut by half when labor interactions are considered with $\delta = 20$ (+8.6% compared to +16.7%). Income per worker decreases in particular in immigration receiving countries, given that immigrants now receive lower wages than in the benchmark case (which is due to their lower relative productivity). GDP per worker shrinks in the US (-11.2%), EU27 (-6.8%), CANZ (-15.9%) and GCC (-21.8%). Similarly, emigration countries such as CIS (-5.2%) and SSA (-3.2%) face a stronger decrease in income per worker due to the loss of relatively more productive natives.[11]

[11] It is worth noting that changing the elasticity of substitution to $\delta = 5$ as in Manacorda et al. (2012) slightly mitigates the outcomes compared to the scenario with $\delta = 20$. World GDP per worker increase by 10.2% while the regional results remain qualitatively similar. The lower relative productivity

E. Network externalities

The critical role of diasporas on migration patterns has been clearly recognized in the sociology, demography and economics literatures and extensively analyzed over the last twenty years (such as Boyd, 1989). Many authors have shown that established migrants' networks play an important role on the migration decisions of current would-be migrants. Relying on network information, newcomers can reach relatively better and safer decisions in the case of uncertainty and imperfect information. They might also more easily decipher foreign cultural norms, adjust to the new linguistic and cultural environment or overcome legal entry barriers through sponsorship by immediate family members and other relatives (Massey et al., 1993; Carrington et al., 1996; Pedersen et al., 2008; Beine et al., 2011a). In this section, our goal is to study the extent to which network externalities might expand the effects of liberalizing labor mobility.

The size of global network externalities is estimated in Beine et al. (2011a). They use a bilateral data set on international migration by educational attainment from 195 countries to 30 OECD countries and assess how diasporas affect the size and human capital structure of migration flows. They find that the diasporas are by far the most important determinant, explaining over 70 percent of the observed variability of the flow size. They obtain semi-elasticities of bilateral migration cost to the size of the total diaspora at destination, $\partial c_{ij,s}/\partial \ln(1 + L_{ij,T})$, of 0.625 for college graduate migrants and 0.778 for the less educated. These elasticities sum up effects on legal and private migration costs.

In a subsequent paper, Beine et al. (2011b) disentangle the relative importance of the two channels using US immigration data by metropolitan areas and country of origin. Assuming that both effects are governed by the same log-linear functional forms, they obtain semi-elasticities of visa cost to network size, $\partial b_{ij,s}/\partial \ln(1 + L_{ij,T})$, of 0.229 for college graduates and 0.383 for the less educated. When the functional homogeneity assumption is relaxed, the semi-elasticity reaches an average of 0.577 (they do not provide estimates by education level). Although this value only characterizes the immigration policy of the US, we will use it for all countries. We subtract the visa effect from the total semi-

of immigrant workers influences the results more strongly than the choice of the elasticity of substitution value.

elasticites and endogenize incompressible migration costs ($\underline{x}_{ij,s}$) as follows:

$$\underline{x}_{ij,l}^{new} = \underline{x}_{ij,h}^{base} - 0.20 \cdot \ln\left(\frac{1+L_{ij,T}^{new}}{1+L_{ij,T}^{base}}\right)$$
$$\underline{x}_{ij,h}^{new} = \underline{x}_{ij,l}^{base} - 0.05 \cdot \ln\left(\frac{1+L_{ij,T}^{new}}{1+L_{ij,T}^{base}}\right)$$

Starting from the benchmark simulation of Section 2, results with network externalities are presented in the first two columns of Table 5. Taking into account the effect of diasporas on incompressible migration costs increases GDP per worker compared to the benchmark (+24.5% and +23.8% for the different values of α) as more workers are reallocated to higher productivity regions. Immigration destinations experience higher immigration inflows and suffer from a slightly stronger decrease in GDP per worker. On the other hand, sending countries experience an evolution in income per worker which is more favorable than in the benchmark case. Compared to the latter, more workers leave countries located in regions such as MENA, LAC or ASIA, benefiting from the existing diasporas in high income countries.

F. Combining extensions

In this last subsection, all the extensions sketched previously are combined in the last four columns of Table 5. Results are first provided without network externalities for both values of α. Thereafter, network effects are introduced in the last two columns. As stated previously, endogenous TFP and labor interactions each reduce the effect of liberalizing mobility by half while the effects of the other technological extensions remain rather marginal. However, combining these extensions leads to rather marked changes, as shown in Table 5. GDP per worker increases by merely 2 percent for $\alpha = 0.026$ (+1.7% for $\alpha = 0.06$) at world level. Average GDP per worker decreases in immigration receiving countries with income losses of 16.2 percent (14.7 percent) in the US, 12.6 percent (11.7 percent) in the EU27 and 23.9 percent (22.5 percent) in GCC. However, sending regions are also largely worse off in this scenario with average income in LAC changing from +16.6 percent in the benchmark to -4.3 percent (-3.6 percent) and in ASIA from +14.8 percent to -2.4 percent (-2.8 percent). The marked differences in outcomes are explained by the negative effects that the extensions exert on immigration sending countries. More productive natives leave the country thereby reducing the average income in sending countries while TFP decreases in all the regions due to the positive selection of emigrants and negative selection of immigrants.

[INSERT TABLE 5]

III. Conclusion

In this paper, we endogenize bilateral migration and income inequality across countries in a general equilibrium model of the world economy with skill heterogeneity, private migration costs and immigration restrictions. The model is calibrated using a unique database on labor force characteristics, bilateral migration stocks by education level, and economic variables. Further, we estimate and decompose migration costs using a dual approach. The model is then used to simulate a complete liberalization of labor mobility. Taking into account incompressible migration costs reduces the efficiency gains resulting from our simulation to 17 percent of world GDP which is much lower than those reported in the literature. Additional technological extensions, such as endogenous total factor productivity and more realistic labor interactions between natives and immigrants amplifying general equilibrium effects, further reduce the gains. In particular, positive selection of emigrants and negative selection of immigrants reinforces the negative impact for both, sending and receiving regions. Considering network effects induced by existing diasporas on incompressible migration costs accelerates the distribution of workers among higher productivity countries. Finally, combining all the possible mechanisms, our model predicts efficiency gains between 2 and 4 percent of the world GDP, which contrasts with the extremely optimistic results that can be found in the existing literature. Obviously, political economy issues arise as liberalization induces income losses for stayers in high-income immigration receiving countries. Addressing them is beyond the scope of this paper.[12]

An interesting extension to the model could be the addition of endogenous trade and foreign direct investments in order to study the nexuses between the three main dimensions of globalization. The model could also be extended with endogenous education and population size. Furthermore, it could be used to simulate TFP and preference shocks or to predict trends in migration when applied with long term population projections. These extensions are left for future research.

[12] A politically sustainable mechanism, stimulating rich countries to host more immigrants is discussed in de la Croix and Docquier (2009).

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Table 1—: Data on income, labor force, migration stocks and desire to leave by region

	Income data[a]	Labor force data[b]		Total migration[b]		Desire to leave[e]	
Regions	Total income[c]	Total[c]	College graduates[d]	Immigration	Emigration	College graduates	Less educated
World	45,195.7 (100.0)	3,180.0 (100.0)	356.4 (11.2)	100.5	100.5	-	-
USA	9,579.3 (21.2)	183.8 (5.8)	94.3 (51.3)	24.3	0.9	9	13
EU27	9,757.7 (21.6)	337.1 (10.6)	65.2 (19.3)	22.3	20.2	24	13
CANZ	1,381.2 (3.1)	35.5 (1.1)	15.5 (43.6)	8.6	1.5	8	11
GCC	544.3 (1.2)	14.1 (0.4)	1.8 (12.8)	5.7	0.4	24	17
MENA	1,442.8 (3.2)	132.2 (4.2)	10.3 (7.8)	4.3	8.5	24	17
SSA	689.6 (1.5)	203.6 (6.4)	4.8 (2.4)	12.7	14.1	36	26
CIS	2,053.6 (4.5)	172.8 (5.4)	30.5 (17.7)	7.9	10.6	19	11
CHIND	7,712.2 (17.1)	1,240.9 (39.0)	42.7 (3.4)	1.7	9.0	18	14
ASIA	7.577.4 (16.8)	561.2 (17.7)	57.1 (10.2)	8.2	16.2	18	14
LAC	3,615.7 (8.0)	250.8 (7.9)	28.5 (11.4)	2.4	15.6	26	17

Note: [a] Total income in billions of USD (Source: World Development Indicators); [b] Millions of people aged 25+(Source: Docquier, Lowell and Marfouk, 2009); [c] Proportion of the world total between parentheses; [d] Proportion of the regional population between parentheses; [e] Proportion of stayers would who want to leave (Source: Gallup World Poll). Regions: USA = United States, EU27 = 27 members of European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries.

Table 2—: Effect of a complete liberalization on total migration stocks and proportion of college graduates in the labor force (perc. dev. from the baseline)

	Partial equilibrium			General Eq. with $\alpha = 0.026$			General Eq. with $\alpha = 0.060$		
Regions	Tot. immig	Tot emig	Prop college	Tot. immig	Tot emig	Prop college	Tot. immig	Tot emig	Prop college
World	523.7	523.7	0.0	514.3	514.3	0.0	505.2	505.2	0.0
USA	385.0	177.1	-16.7	369.9	185.1	-15.4	353.0	195.0	-14.0
EU27	384.2	251.4	-16.6	381.2	248.2	-16.1	377.8	244.7	-15.5
CANZ	370.6	228.4	-18.8	359.2	233.7	-18.0	346.6	239.9	-17.0
GCC	656.5	20.5	-47.9	649.0	19.4	-36.4	643.3	19.0	-28.6
MENA	511.7	408.9	3.8	510.7	404.4	1.7	509.9	399.5	0.4
SSA	504.6	639.6	-24.7	505.8	636.0	-25.0	507.3	632.2	-25.0
CIS	285.8	295.9	-8.5	285.4	296.5	-9.2	284.9	297.2	-10.0
CHIND	1,136.4	1,658.4	-3.1	1,139.6	1,595.9	-7.3	1,143.1	1,540.5	-10.6
ASIA	1,481.9	609.2	-15.6	1,433.6	601.9	-13.6	1,394.7	594.6	-12.2
LAC	773.5	394.5	-14.7	777.3	386.2	-16.0	782.0	376.8	-17.0

Note: Regions: USA = United States, EU27 = 27 members of European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries.

Table 3—: Effect of a complete liberalization on income

	Observations	Partial Eq.	Gen Eq. with α=0.026			Gen Eq. with α=0.060		
Regions	y^w in USD	$\Delta \ln y^w$	$\Delta \ln y^w$	$\Delta \ln y^n$	$\Delta \ln y^s$	$\Delta \ln y^w$	$\Delta \ln y^n$	$\Delta \ln y^s$
World	14,212.7	17.7	16.7	16.7	9.2	16.3	16.3	8.8
USA	52,133.3	-3.3	-3.4	0.3	0.6	-3.1	0.2	0.5
EU27	28,943.4	-0.6	-0.8	2.1	-0.8	-0.7	2.0	-0.8
CANZ	38,857.6	-3.6	-4.0	0.8	1.0	-3.7	0.8	0.9
GCC	38,520.0	-8.3	-6.7	-0.7	-0.4	-4.9	-0.7	-0.3
MENA	10,914.3	14.9	14.2	36.6	14.5	14.0	36.5	14.1
SSA	14,415.3	-0.9	-1.3	26.0	7.4	-1.6	25.1	7.0
CIS	11,882.3	-1.7	-1.9	9.9	2.6	-2.1	10.2	2.6
CHIND	6,214.9	-0.9	-1.4	36.5	12.8	-1.8	35.9	12.2
ASIA	4,612.1	15.7	14.8	79.3	41.4	14.7	77.8	40.8
LAC	13,502.3	18.3	16.6	18.8	9.8	17.0	18.6	9.5

Note: $\Delta \ln y^w$ = perc. dev. in income per worker from baseline. Regions: USA = United States, EU27 = 27 members of European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries.

Table 4—: Effect of a complete liberalization on GDP per worker under technological variants (perc. dev. from baseline)

	Gen Eq. with α=0.026				Gen Eq. with α=0.060			
Regions	Endog TFP	Congestion	Downgrading	Labor inter	Endog TFP	Congestion	Downgrading	Labor inter
World	8.9	15.4	16.3	8.6	8.2	14.7	15.9	8.2
USA	-8.2	-4.4	-4.1	-11.2	-7.2	-4.0	-3.7	-10.4
EU27	-7.1	-1.1	-1.2	-6.8	-7.0	-1.0	-1.1	-6.3
CANZ	-9.1	-5.5	-4.7	-15.9	-8.2	-5.1	-4.4	-15.1
GCC	-6.5	-10.5	-5.9	-21.8	-4.5	-9.0	-4.2	-20.4
MENA	7.9	12.9	14.4	6.1	6.9	12.0	14.2	5.9
SSA	-6.5	-0.7	-1.0	-3.2	-7.0	-0.9	-1.2	-3.1
CIS	-4.4	-1.7	-1.8	-5.2	-4.4	-1.7	-2.0	-5.1
CHIND	-2.9	-1.0	-1.3	-1.4	-3.4	-1.2	-1.6	-1.6
ASIA	3.0	14.3	15.7	4.8	2.3	14.1	15.6	4.7
LAC	0.5	14.3	16.6	7.7	0.1	13.9	17.0	7.8

Note: Regions: USA = United States, EU27 = 27 members of European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries.

Table 5—: Effect of a complete liberalization on GDP per worker with network externalities and the combination of all technological variants (perc. dev. from baseline)

	Network externalities		Combination of all technological variants			
			Without network externalities		With network externalities	
Regions	α=0.026	α=0.060	α=0.026	α=0.060	α=0.026	α=0.060
World	24.5	23.8	2.0	1.7	3.3	2.7
USA	-5.0	-4.4	-16.2	-14.7	-20.8	-18.5
EU27	-1.2	-1.0	-12.6	-11.7	-15.9	-14.7
CANZ	-6.4	-5.8	-21.7	-20.3	-28.3	-26.2
GCC	-9.0	-6.7	-23.9	-22.5	-27.9	-26.2
MENA	19.6	19.2	0.8	0.1	1.4	0.0
SSA	-0.8	-1.3	-6.7	-6.4	-6.0	-6.1
CIS	-2.4	-2.7	-7.3	-6.9	-8.2	-7.8
CHIND	-1.5	-2.2	-2.2	-2.2	-0.2	-0.8
ASIA	21.7	21.4	-2.4	-2.8	-2.0	-2.8
LAC	26.7	27.2	-4.3	-3.6	-7.9	-6.2

Note: Regions: USA = United States, EU27 = 27 members of European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries.

Appendix A: Endogenizing total factor productivity (- To be published online)

In order to calibrate the TFP externality, we use panel data on TFP and the proportion of college graduates covering 195 countries and 5 periods of 5 years (from 1985 to 2005). TFP data is computed as in Section 2.2 and panel data on human capital is taken from Defoort (2008). As sluggishness is likely to characterize productivity adjustments, we adapt (15) and use a dynamic model and regress productivity growth on its lagged value and a transformation $F(\cdot)$ of the proportion of college graduates. We have compared different functional forms for the function $F(\cdot)$ in (15). The logarithmic transformation gives the best fit (concave effect of human capital on the TFP level). We have also allowed for a threshold h_0 below which there is no externality. To examine such possibility, we allow the effect of human capital to differ across countries depending on whether $h < h_0$ or $h_0 \geq h_0$. In practice we estimated the following dynamic version of (15) using OLS-FE:

$$\text{(A1)} \qquad \ln\left(\frac{A_{i,t+1}}{A_{i,t}}\right) = \alpha_i + \alpha_t - \beta\ln(A_{i,t}) + \rho\ln(h^-_{i,t}) + \lambda\ln(h^+_{i,t}) + \varepsilon_{i,t}$$

where $h^-_{i,t} = h_{i,t}$ if $h_{i,t} < h_0$ and $h^-_{i,t} = h_0$ otherwise, $h^+_{i,t} = h_{i,t}$ if $h_{i,t} \geq h_0$ and $h^+_{i,t} = h_0$ otherwise; α_i and α_t are country and time fixed effects; β is the speed of convergence toward the steady state, ρ and λ are the short-run elasticities of TFP to human capital for countries with $h_{i,t} < h_0$ and $h_{i,t} \geq h_0$, respectively.

The estimation was run for different values of h_0 and confirms, that the elasticity changes with the level of human capital. The choice of the threshold h_0 was based on the adjusted R^2 which appears to be the highest for $h_0 = 0.015$. Given this threshold, the mean estimate (and t-stat between parentheses) of the coefficients are 0.53 (5.23) for β, 0.07 (1.53) for ρ, and 0.17 (3.04) for λ. Hence ρ is non significant while λ and β are significant at 1 percent. The overall quality of fit is good; we have 780 observations, the adjusted R^2 equals 0.30, the inclusion of country's fixed effects is supported by the F-test ($F(194, 582) = 2.45$). Note that the log-log specification in (A1) is slightly superior to the log-linear model estimated on US states and cities (see Moretti 2004a, 2004b). Replacing $\ln(h_{i,t})$ by $h_{i,t}$ in (A1) gives similar qualitative predictions but a slightly lower adjusted R^2. Note that results are better when GCC countries are excluded from the sample. We found no evidence of human capital externalities in these countries where wealth comes from the exploitation of natural resources. Hence, we assume that the level of TFP is exogenous in the GCC countries.

Finally, we need to calibrate the country fixed effect a_i in (15). Human capital has no significant impact on TFP when the share of college graduates is lower than 1.5 percent. For higher levels of human capital, the elasticity of TFP to human capital is equal to 0.17 in the short-run (λ), and to 0.32 in the long-run (λ/β). We will use this long-run elasticity in our simulations. In the long-run,

(15) rewrites as

$$A_i = a_i \left[Max \left(0.015; \frac{Q_{i,h}}{Q_{i,h} + Q_{i,l}} \right) \right]^{0.32} \tag{A2}$$

We calibrate the fixed effect in the TFP (a_i $\forall i$) as a residual of this equation.

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ISSN 1379-244X D/2012/3082/023