

Brain drain, informality and inequality: a search-and-matching model for sub-Saharan Africa*

Frédéric Docquier^{a,b,c} and Zainab Iftikhar^{a,d}

^a IRES, Université Catholique de Louvain, Belgium

^b FNRS, National Fund for Scientific Research, Belgium

^c FERDI, Fondation pour les Etudes et Recherches sur le Développement International, France

^d Department of Economics, University of Bielefeld, Germany

May 2018

Abstract

This paper revisits the effect of the brain drain on development and inequality using a two-sector model with formal and informal labor markets. Contrary to existing studies, we use a search-and-matching setting that is consistent with the income and employment patterns of poor countries. Theoretically, the brain drain induces ambiguous welfare effects for those left behind. We thus parameterize our model on 33 sub-Saharan African countries and produce comparative results for each of them. We find that skilled emigration induces heterogeneous welfare losses for the low-skilled population. The size of these losses varies between 0.2 and 8%, and is influenced by country characteristics such as the productivity gap between sectors and the education technology. The results are fairly robust to identifying assumptions, to the inclusion of technological externalities, and to the endogenization of training decisions.

Keywords: Brain Drain, Informality, Development, Inequality, Search and Matching, Sub-Saharan Africa

JEL codes: F22, J24, J46, J61, O15, O17.

1 Introduction

How does skilled emigration affect development and the welfare of those left behind? This question has been the source of repeated and controversial statements in the literature for the last fifty years or so. The reasons why skilled emigration can hurt development in poor countries are well established. Nearly one in four college-educated adults born in a low-income country now live in the developed world; this human capital flight may deprive the sending country of the necessary resources to drive economic growth, to provide key public services, and to articulate calls for greater democracy. Yet, a more recent strand of literature has identified

*The authors thank David de la Croix, Dalal Moosa, Bruno Van der Linden, Gerald Willmann and Anna Zaharieva for helpful comments. The second author acknowledges financial support from the European Commission under the auspices of the European Doctorate in Economics Erasmus Mundus framework, and to ARC 15/19-063 of the Belgian French-speaking Community. Correspondence: Frédéric Docquier: frederic.docquier@uclouvain.be; Zainab Iftikhar: zainab.kkhan@gmail.com.

positive spin-offs from skilled emigration. These include positive effects of emigration prospects on education decisions, remittances, or diaspora externalities (Docquier and Rapoport 2012). Given the lack of clear empirical relationship between human capital and development, other studies have challenged the view that human capital losses induce economic and welfare costs in the sending countries (Clemens 2015). Consequently, the economic implications of the brain drain are still uncertain. A better understanding of the relationships between brain drain, human capital and development is necessary before getting to the bottom of the dilemmas that the brain drain poses.

In this paper, we model these relationships using a two-class, two-sector model with a formal and an informal sector. The informal economy captures activities that are not taxed, monitored by any form of government, or included in official statistics, but that lead to economic transactions between agents. It represents about 40 percent of the recorded gross domestic product (GDP) in low-income countries, and attracts more than 50 percent of the labor force (Schneider 2005).¹ Informal activities are mainly characterized by low-skilled intensive technologies and provide a precious source of income to those who cannot find a job in the formal economy. By draining many low-skilled workers, informality changes the skill structure of the labor force in the formal sector, and limits the size of the labor market interactions between the highly skilled and the less educated. The informal sector also drains some high-skilled workers who cannot find regular jobs in accordance with their qualifications. Acting as a buffer, informality attenuates or neutralizes the economic effects of emigration-driven changes in human capital; this may be why returns to schooling, low-skilled wages and GDP per worker poorly respond to human capital changes in poor countries (Docquier et al. 2017). Yet, the labor market interactions between the formal and informal sectors are badly understood. Some models assume competitive labor markets and perfect mobility of workers between sectors; they fail to explain why a large income differentials exist between sectors, or why informality attracts workers from all skill groups. This paper proposes an alternative search-and-matching model *a la* Pissarides (2000), which is compatible with these facts. We use it to study how the brain drain affects the welfare of those left behind, with or without positive spin-offs from emigration. We parameterize our model on 33 sub-Saharan Africa economies. Accounting for country-specific characteristics, we produce comparative estimates of the welfare and inequality effects of the brain drain.

This paper is at the crossroad of three strands of literature. The first is the literature on *brain drain and development*. It started in the 1960s with the works of Scott and Grubel (1966) or Berry and Soligo (1969), which confront the negative and positive implications of the brain drain for the sending countries. Then, the theoretical literature of the 1970s and 1980s mainly focuses on the negative effects linked to the actual loss of human capital and to high-skilled emigration prospects. The mechanisms include labor market effects, fiscal losses, and later, the aggregate productivity responses (Bhagwati and Hamada 1974; Bhagwati and Rodriguez 1975; Rodriguez 1975; McCulloch and Yellen 1977; Miyagiwa, 1991; Haque and Kim 1995). A newer wave of studies has emerged since the mid-nineties; it discusses the ambiguous effects of the brain

¹A joint study by ILO/WTO (2009) estimates that informal employment represents 55.7% of the total employment in sub-Saharan Africa. Similarly, Verick (2008) and the UN's commission for Africa (2015) report that informality accounts for 70 percent of employment in sub-Saharan Africa. Chen (2001) estimate that 93 percent of the new jobs created in sub-Saharan Africa were created in the informal economy. African Union (2008) reports that the informal employment share exceeds the share of employment in the formal economy in Kenya and Uganda. In Ghana, almost 90 percent of the labor force is employed in informal activities.

drain on human capital accumulation (Mountford 1997; Stark et al. 1997, 1998; Beine et al. 2001, 2008) and highlights other externalities due to the presence of a diaspora abroad (Docquier and Rapoport 2012). The main contribution of the new literature is that it is evidence-based, something which was not possible until recently due to the lack of decent comparative data on international migration by educational attainment. Our approach accounts for most of the ingredients of this literature.

The second strand of literature investigates the relationship between *informality and development*. Informality can generate vicious circles through different channels. de Paula and Scheinkman (2010, 2011) emphasize the role of value-added taxes in transmitting informality through chain effects – the informality of a firm is correlated with the informality of firms from which it buys or sells. In Zenou (2008) and Leal Ordonez (2014), informality reduces the amount of fiscal revenues that the government can allocate to social protection; in turn, this affects the attractiveness of the formal economy through greater tax rates or smaller social benefits. Murphy et al. (1989) or Krugman (1991) model firms’ choice to operate formally or informally; due to fixed costs of entry, operating formally is profitable if the demand for the goods produced is large enough (i.e., when other firms industrialize and pay higher wages). In these frameworks, the predominance of informality can be seen as a result of a coordination failure. In a dynamic framework, Docquier et al. (2017) investigate the link between informality, education decisions and long-run growth. By absorbing a large share of the low-skilled labor force, the informal sector limits the skill premium in the formal sector; in addition, it facilitates child labor. Faced with lower skill premia and easier access to child labor, parents tend to choose less schooling for their children. Informality can slow down this convergence process or it can be the source of a poverty trap. The quantitative analysis reveals that the case for the poverty trap is stronger. Our model shares many ingredients with the latter study, but formalizes labor movements between the formal and informal sectors using a search-and-matching framework.

The third strand is the literature on *unemployment and underemployment in developing countries* (Ortega 2000; Yashiv 2000; Gong and van Soest 2002; Satchi and Temple 2009). Search-and-matching models à la Pissarides (2000) are widely used to study issues related to labor markets as they are considered to be based on more realistic assumptions.² The standard model assumes that the labor markets are not centralized, and that there exists no single price that is accepted by large number of buyers and sellers in labor market for trading. Instead, there are periods of involuntary unemployment and job search for workers. The wage rate is not equal to the marginal product of labor; there are profits and the marginal product of labor is shared by firms and workers. The income shares of workers and firms are decided through bargaining. Firms on the other hand have to pay cost for maintaining vacancies.

In our model, skilled emigration not only affects the marginal productivity of low-skilled and high-skilled workers in the home country. It also influences the duration and profitability of a vacancy, the process of job creation in the formal sector, and the outside options of workers. Hence, wage responses are not only due to changes in the marginal product, but also to changes in outside options. Our search-and-matching model allows endogenizing the share of highly skilled employed in the informal economy as well as the large wage gap between sectors. Although

²Recent studies focusing on the labor market impact of immigration to developed countries include Chassamboulli and Palivos (2014), Battisti et al. (2014), Moreno-Galbis and Tritah (2016).

the informal economy is recognized for being low-skilled intensive, the trend is changing and educated workers also seek for informal jobs (Verick, 2008). In Latin America, high-skilled workers accounted for about 12 percent of informal employees in 2005 (ILO/WTO, 2002), and informal wages were 44% smaller compared to those of the formal sector (ILO, 2002). To the best of our knowledge, there are no comparable figures for sub-Saharan Africa but there are some facts suggesting the presence of high skilled workers in the informal economy. In the past decades, only 37 million jobs were created between 1990 and 2010 and 28 percent of them were created in the formal sector in sub-Saharan Africa (McKinsey 2012). African economies are expected to record over 122 million entries into the labor force between 2010-2022 while only 72 million formal jobs are expected to be created. This gap between the number of formal jobs available and new entrants into labor market suggests that high-skilled workers will have to seek work in the informal economy. According to Verick (2008) many young workers with secondary or college education end up in the informal economy due to limited opportunities in the public sector and due to labor mismatches in the manufacturing and service industries. Studies by Haan (2006) and Walther (2006) also suggest the presence of high skilled workers in the informal sector of African countries.

In the first part of the study we show that under a competitive formal labor market and free mobility between sectors (as in Docquier et al. 2017), the brain drain has no impact on wage rates and inequality. The effects are totally absorbed by changes in informal employment, which acts as a perfect buffer zone at low levels of development. Nevertheless, competitive economy fails to explain the observed patterns of informality and wage differential across the two sectors. Then, in the second part of the study, we add search frictions and endogenize the wage differentials across sectors as well as involuntary informal employment using a search-and-matching model. The theoretical model yields ambiguous effects of brain drain on informality. We thus parameterize the model on 33 sub-Saharan African countries and conduct a comparative quantitative analysis. The benchmark version of the model disregards any form of technological or educational externality. In this context, high-skilled wages increase almost linearly with emigration, while the wage losses for the low skilled considerably vary across countries. In particular, they depend on the education technology and on the productivity gap between sectors. Countries with better education technology and smaller productivity gap lose more in terms of income, unemployment and inequality. The results are more pessimistic if total factor productivity increases with the average level of schooling in the home country. On the contrary, allowing productivity to increase with the diaspora abroad induces slightly smaller labor market responses. In another extension of the model, we endogenize social mobility and account for brain gain effects in line with Mountford (1997) and Beine et al. (2008). A growing empirical literature shows that incentives for human capital accumulation in developing countries are based to a significant extent on migration opportunities.³ The income loss of the brain drain is reduced by about 20% for the low-skilled when the model is calibrated to match the elasticity of training decisions to skilled migration prospects. Nevertheless, our qualitative findings remain

³Using data on 127 developing countries, Beine et al. (2008) estimate that a doubling of a country's emigration rate of highly-skilled workers is associated with a 5% increase in the stock of human capital possessed by its nationals. Studies by Chand and Clemens (2008), Gibson and McKenzie (2011), Batista et al. (2012), Shrestha (2017) or Theoharides (2017) provide micro-level evidence of a positive impact of response net effect of skilled emigration on human capital.

robust.

The remainder of the paper is organized as follows. Section 2 presents the model with exogenous total factor productivity levels and education decisions, discusses its parameterization, and quantifies the cost of the brain drain. Section 3 discusses extensions with endogenous total factor productivity levels and human capital accumulation. Finally, Section 4 concludes.

2 Benchmark model

We consider a developing economy with two types of infinitely-lived individuals (the highly skilled and the low-skilled, denoted by $S = (H, L)$) and with two production sectors (the formal and the informal, denoted by F and I). For simplicity, we assume that firms in the two sectors produce the same final good. Our model disregards fiscal aspects and sees informality as a subsistence sector, a relevant assumption for low-income countries. Individuals are mobile across sectors and heterogeneously mobile across countries; low-skilled workers cannot emigrate while an exogenous fraction p of the high-skilled population emigrate at each moment in time. We first describe the population dynamics and the benchmark technological assumptions in Section 2.1. Then, we investigate the welfare implications of skilled emigration under the competitive labor market in Section 2.2. We then revisit the brain drain effects using a search-and-matching model in Section 2.3. In the latter setting, we focus on the steady state of the economy.

2.1 Population and technology

We consider an exponential population growth framework in which each group S of individual exhibits an instantaneous natural growth rate equal to g_S (reflecting exogenous fertility decisions and mortality rates). In addition, at each moment in time, an exogenous fraction ρ of the low-skilled population becomes high-skilled, while an exogenous fraction p of high-skilled individuals emigrates to a rich country (as in Mountford 1997; Stark et al. 1997, 1998; Beine et al. 2001, 2008). An extension of the model with endogenous social mobility will be considered in Section 3. The dynamics of population is governed by:

$$\begin{aligned}\dot{L} &= L(g_L - \rho), \\ \dot{H} &= H(g_H - p) + L\rho, \\ \dot{M} &= Hp.\end{aligned}$$

where $\dot{X} = dX/dt$, L and H stands for the low-skilled and high-skilled populations, and M represents the stock of emigrants.

A balanced growth path for the population is reached when the size of the three groups of individual grows at the same rate g :

$$g \equiv \frac{\dot{L}}{L} = \frac{\dot{H}}{H} = \frac{\dot{M}}{M}.$$

Denoting the economy-wide skill ratio by $Z \equiv H/L$, and the proportion of high-skilled

expatriates by $P \equiv M/H$, the balanced growth path condition can be rewritten as:

$$g \equiv g_L - \rho = g_H - p + \frac{\rho}{Z} = \frac{p}{P}.$$

In the benchmark version of the model, we assume that g_L , g_H , p and ρ are exogenous, and we write $g_H = ng_L$ (where $n < 1$ captures the population growth differential between high-skilled and low-skilled individuals). Hence, the long-run rate of the population growth, $g = g_L - \rho$, is exogenous. On the balanced growth path, Z and P are constant. Their steady state levels are given by:

$$Z = \frac{\rho}{g_L(1-n) - \rho + p}, \quad (1)$$

$$P = \frac{p}{g}. \quad (2)$$

The economy-wide skill ratio increases with ρ and n , and decreases with g and p . In particular, the no-migration (i.e., $p = 0$) level of the skill ratio can be defined as $Z_0 = (g_L(1-n) - \rho)^{-1} \rho$. The proportion of high-skilled expatriates increases with p and decreases with g . We impose $p < g$. If g is small, a small instantaneous rate of emigration p can give rise to a large proportion of expatriates in the long-run. In the no-migration economy, P_0 is nil.

Non-migrant workers can be employed in two sectors, the formal economy and the informal economy, where a homogenous final good is produced. The market for the final good is perfectly competitive and the price of the final good is used as the *numéraire*. The share of type- S workers employed in the informal economy is denoted by i_S . These shares are endogenous, as explained in the next sections. Hence, the (endogenous) skill ratios in the informal and formal economies are given by:

$$\begin{aligned} Z_I &= \frac{i_H}{i_L} Z \\ Z_F &= \frac{1 - i_H}{1 - i_L} Z \end{aligned} \quad (3)$$

We now characterize the technological environment. In line with Murphy et al. (1989, 1991), Brezis et al. (1993), Mookherjee and Ray (2010) or Docquier et al. (2017), we model the informal economy as a traditional or subsistence sector characterized by constant returns. Alternative technological assumptions will be used in the robustness analysis (Appendix C). In the benchmark model, the quantity of final good Y_I is produced using a linear technology:

$$Y_I = A_I(L_I + H_I), \quad (4)$$

where A_I measures the level of total factor productivity (TFP), $L_I = i_L L$ is the number of low-skilled employees, and $H_I = i_H H$ is the number of high-skilled employees. Labor productivity in the informal sector is independent of education. The marginal productivity of each worker is equal to A_I . The labor market in the informal economy is competitive.

The formal economy corresponds to the modern sector that fully exploits the complementarities between workers. Following Acemoglu (2001), we assume that the final good Y_F is produced

using a CES combination of intermediate inputs, Y_L and Y_H , which are produced by low-skilled and high-skilled workers, respectively:

$$Y_F = A_F \left[\alpha Y_L^{\frac{\sigma-1}{\sigma}} + (1-\alpha) Y_H^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where A_F is the TFP level in sector F , α is a parameter governing the preference for the two inputs and their income shares, σ is the elasticity of substitution between the two intermediate goods. Given the assumption of perfect competition on the market for final goods, the price of each intermediate good is equal to its marginal product, $y_S \equiv \partial Y_F / \partial Y_S$. Inputs are produced using a linear technology and equal the number of workers employed in the sector, $Y_L = (1-i_L)L$ and $Y_H = (1-i_H)H$. Hence, the marginal products of each input can be written as:

$$y_L = A_F \alpha \left[\alpha + (1-\alpha) Z_F^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}}, \quad (5)$$

$$y_H = A_F (1-\alpha) Z_F^{\frac{-1}{\sigma}} \left[\alpha + (1-\alpha) Z_F^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}}. \quad (6)$$

Without loss of generality, we define the relative TFP in informality as $\psi \equiv A_I / A_F$. Such a model without physical capital features a globalized economy with a common international interest rate. This hypothesis is in line with Kennan (2013) or Klein and Ventura (2009) who assume that capital "chases" labor.

2.2 Competitive labor market: informality as a buffer zone

We first derive the optimal allocation of the labor force and the welfare implications of emigration under a competitive labor market in the formal sector. Perfect competition implies that the wage rates are equal to the marginal products in all sectors and for all categories of workers: $\omega_S = y_S$ in the formal sector, and $\omega_I = \psi A_F$ in informality. We first characterize the condition under which the informal sector exists and describe the optimal allocation of the workforce. Then, we study the macroeconomic and welfare implications of skilled emigration under the informality regime.

The model with competitive labor market generates two possible regimes. The first one, the *informality regime*, is obtained when output and employment are positive in the informal economy; the second one, the *formal regime*, is obtained when all workers are employed by formal firms. The condition under which the informality regime emerges requires full employment in the formal economy to be suboptimal for at least one category of worker. In particular, given (4) and (5), full employment in formality is suboptimal for low-skilled workers if the economy-wide skill ratio, Z , is smaller than a critical level:

$$\begin{aligned} A_F \alpha \left[\alpha + (1-\alpha) Z^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} &< \psi A_F \\ \iff Z &< (1-\alpha)^{\frac{-\sigma}{\sigma-1}} \left[\left(\frac{\psi}{\alpha} \right)^{\sigma-1} - \alpha \right]^{\frac{\sigma}{\sigma-1}} \equiv \bar{Z}_F(\psi, \alpha), \end{aligned} \quad (7)$$

where the critical level of the skill ratio, $\bar{Z}_F(\psi, \alpha)$, is an increasing function of ψ . For example,

if $\sigma = 2$, $\bar{Z}_F \equiv \left(\frac{\psi - \alpha^2}{\alpha(1-\alpha)} \right)^2$, which is positive if $\psi > \alpha^2$. A change in ψ induces convex effects on $\bar{Z}_F$.

When condition (7) holds, a fraction of the low-skilled labor force finds it optimal to work in the informal sector. If $\psi = 0$, this condition never holds as $\bar{Z}_F(0, \alpha)$ is negative. However, when ψ is large enough, low levels of human capital translate into positive informality employment. The movement stops when wages are equalized across sectors, i.e. when $Z_F = \bar{Z}_F(\psi, \alpha)$. At this level of the skill ratio, the wage rate of the highly skilled exceeds the low-skilled wage if

$$\bar{Z}_F(\psi, \alpha) < \left(\frac{1 - \alpha}{\alpha} \right)^\sigma. \quad (8)$$

If condition (8) holds, high-skilled workers are better paid in the formal economy. They receive a salary $\omega_H = \Theta \omega_I$ with $\Theta = \frac{1-\alpha}{\alpha} \bar{Z}_F^{-\frac{1}{\sigma}} > 1$. This implies $i_H = 0$. As for the low-skilled, the equilibrium share of informal employment is such that $Z_F = \bar{Z}_F$: using (3), this implies $i_L = \frac{\bar{Z}_F - Z}{\bar{Z}_F} > 0$, which decreases with Z (i.e., increases with p given Eq. (1)). Let us denote the average instantaneous income of type-S workers as:

$$\bar{w}_S \equiv (1 - i_S) \omega_S + i_S \omega_I, \quad (9)$$

while $\bar{w}$ (without skill subscript) represent the average income of non-migrants (a weighted sum of $\bar{w}_L$ and $\bar{w}_H$).

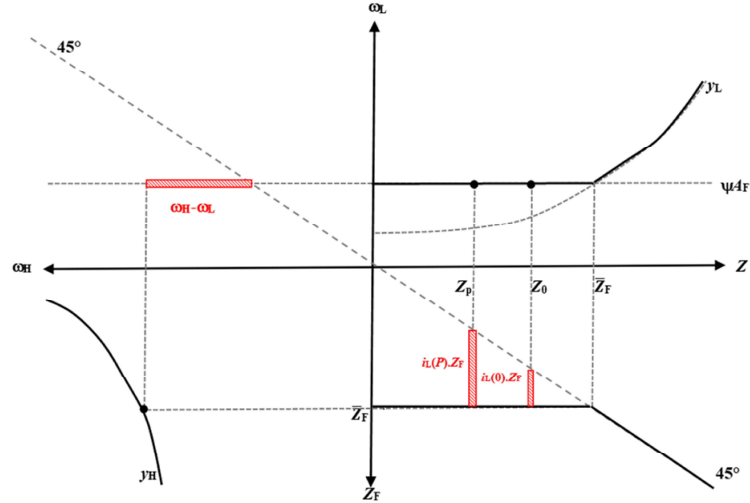
We thus obtain the following result:

Proposition 1. *Under a competitive labor market and under the conditions $Z < Z_0 < \bar{Z}_F(\psi, \alpha) < \left(\frac{1-\alpha}{\alpha} \right)^\sigma$, the informality regime arises for any level of p . The skill ratio in the formal economy is constant. The skill-specific wage rates and the average instantaneous income levels are independent of changes in the emigration rates ($\frac{\partial \bar{w}_S}{\partial p} = \frac{\partial \omega_S}{\partial p} = 0$). The brain drain has no effect on inequality between skill groups. It increases the informal employment share of the low-skilled ($\frac{\partial i_L}{\partial p} > 0$), but induces no income loss.*

The condition $Z_0 < \bar{Z}_F(\psi, \alpha)$ means that a complete repatriation of high-skilled emigrants does not induce a regime switch from informality to formality; given (1), this is the case if ρ is sufficiently small. Figure 1 illustrates the mechanics of the model with a competitive labor market in the formal sector. The top-right panel shows compares the marginal productivity of low-skilled workers in both sectors. At the critical level $\bar{Z}_F$, the wage rates are equal. If $Z_0 < \bar{Z}_F$, the wage rate of low-skilled workers equals ψA_F and the informality regime arises. The bottom-right panel shows the equilibrium level of human capital in the formal economy, Z_F . If $Z_0 < \bar{Z}_F$, we have $Z_F < \bar{Z}_F$ and the informal employment rate is proportional to the difference $\bar{Z}_F - Z_0$ (the red area). By reducing human capital from Z_0 to Z_p , the brain drain increases the size of the informal economy but has no effect on the low-skilled wage rate. The bottom-left panel gives the marginal product of the highly skilled as a decreasing function of Z_F . Under the informality regime, the wage rate of the highly skilled is constant. Finally, the top-left panel represents the wage gap between high-skilled workers and the less educated.

Proposition 1 does not imply that the brain drain has no impact on macroeconomic performance. Let us define the average informality rate (share of informal employment in total

Figure 1: Welfare effect of the brain drain (competitive labor market)



employment) by i , the recorded (formal) level of income per capita by Y^r , the national (informal + formal) level of income per capita by Y^n , and the average income per worker in the formal economy by Y^w .

The steady state levels of these variables are given by:

$$\begin{aligned} i &\equiv \frac{i_L L + i_H H}{L + H} = \frac{\bar{Z}_F - Z}{(1 + Z)\bar{Z}_F}, \\ Y^r &\equiv \frac{(1 - i_L)L\omega_L + (1 - i_H)H\omega_L}{L + H} = \frac{Z}{1 + Z} \left(\Theta + \frac{1}{\bar{Z}_F} \right) A_I, \\ Y^n &\equiv \frac{(1 - i_L)L\omega_L + i_L L\omega_I + (1 - i_H)H\omega_L}{L + H} = \frac{1 + \Theta Z}{1 + Z} A_I, \\ Y^w &\equiv \frac{(1 - i_L)L\omega_L + (1 - i_H)H\omega_L}{(1 - i_L)L + (1 - i_H)H} = \frac{1 + \Theta \bar{Z}_F}{1 + \bar{Z}_F} A_I. \end{aligned}$$

By reducing Z , the brain drain increases the average share of informal employment $\left(\frac{di}{dp} > 0\right)$, decreases recorded and national income per capita $\left(\frac{dY^r}{dp}, \frac{dY^n}{dp} < 0\right)$, but has no effect on the level of income per worker in the formal economy, on skill-specific wages and on income inequality $\left(\frac{dY^w}{dp}, \frac{d\omega_S}{dp}, \frac{d\Theta}{dp} = 0\right)$. This is because the migration-induced changes in the economy-wide skill ratio have no effect on $\bar{Z}_F$, the skill ratio of the formal sector. Similar predictions are obtained if emigration prospects induce limited changes in human capital, or if the brain drain gives rise to technological externalities that jointly affect the two productive sectors (leaving ψ unchanged).

Such a competitive economy is incompatible with some observed patterns of informality. First, it implies that low-skilled workers receive identical earnings in both sectors; the empirical literature has shown that significant wage disparities exist between the two sectors and for workers with similar skills (ILO 2002). Second, it implies that informal firms only employ low-skilled workers; although the average skill level is smaller in the informal sector, the empirical

literature evidences the presence of high-skilled workers and entrepreneurs (Haan 2006; Walther 2006; Verick 2008). Third, the model predicts that a rising productivity gap between the two sectors (i.e., fall in ψ) induces large movements of workers between sectors; the empirical literature has shown that convergence in manufacturing productivity did not translate into large labor movements and convergence in recorded income per capita (e.g., Rodrik 2013). For these reasons, the next section revisits the welfare implications of the brain drain in a model with labor market frictions.

2.3 Labor market with search and matching

We now consider an alternative search-and-matching model that is compatible with (and endogenizes) income disparities between sectors for each skill group. All workers have the option to search for a better-paid job in the formal sector. If the individual does not get a job in the formal sector, she works in informality. Hence, the informal economy consists of a subsistence sector that overcomes the lack of a sound, public unemployment insurance scheme. As shown in Gerxhani (2004) and World Bank (2014, p.23), one third of developing economies do not have any social protection policy or strategy, and the number of such countries has increased very recently (Haan 2006; Walther 2006; McKinsey 2012). In the absence of social protection, informality is widely tolerated by the government because it provides people with an alternative way to live (see Vodopivec 2013; Robalino and Weber 2013; Margolis et al. 2012; Charlot et al. 2014, among others) and/or a minimum wage (see Basu, Chau and Kanbur 2015; Basu, Chau and Siddique 2012, among others). In our search-and-matching model, workers who cannot be employed by formal firms are absorbed by the informal sector. Informally employed workers are treated as equivalent to unemployed workers with unemployment benefit equal to wage ω_I . In equilibrium, we always have workers searching for jobs in formal sector, wages are greater in formality, and each informal employee has an incentive to move from informality to the formal economy.

We assume all informal employees search for a formal job and are matched with vacancies through a matching function $F(I_S, V_S)$ at each moment in time. The matching function exhibits constant returns to scale; I_s is the total number of type- S employees in the informal sector (i.e. $I_L = i_L L$, and $I_H = i_H H$), and V_S is the total number of vacancies available for type- S workers. Practically, we consider a standard Cobb-Douglas function with identical elasticities (both are equal to 0.5, in line with the existing literature):

$$F(I_S, V_S) = \mu_S \sqrt{I_S V_S} \quad (10)$$

where μ_S is a scale factor.

The job finding rate for workers in each period is given by

$$\lambda(\theta_S) = \frac{F(I_S, V_S)}{I_S} = \mu_S \sqrt{\theta_S},$$

where θ_S is the market tightness and is equal to $\frac{V_S}{I_S}$. The vacancy filling rate $q(\theta_S)$ is given by:

$$q(\theta_S) \equiv \frac{F(I_S, V_S)}{V_S} = \mu_S \sqrt{\frac{1}{\theta_S}} = \frac{\lambda(\theta_S)}{\theta_S},$$

such that $\frac{\partial q(\theta_S)}{\partial \theta_S} < 0$ and $\frac{\partial \lambda(\theta_S)}{\partial \theta_S} > 0$. Firms pay a cost k_S for hiring a type- S worker. The cost is skill specific and includes among others, advertising costs, interview arrangements, initial training, time and resources invested by the firms to find a worker as well as the forgone output while maintaining the vacancy. For simplicity, we assume job search cost for workers and costs for creating a vacancy to be nil. We also disregard tax rates or severance payments both for simplicity and because of the lack of data.

Search-and-matching equilibrium for low-skilled workers. – Let $\Omega_{F,S}$ and $\Omega_{I,S}$ represent the lifetime value of formal employment and informal employment for type- S individuals, respectively. For low-skilled workers, these values are defined as:

$$\begin{aligned} r\Omega_{F,L} &= \omega_L - \delta_L(\Omega_{F,L} - \Omega_{I,L}) + \rho(\Omega_{I,H} - \Omega_{F,L}), \\ r\Omega_{I,L} &= \omega_I + \lambda(\theta_L)(\Omega_{F,L} - \Omega_{I,L}) + \rho(\Omega_{I,H} - \Omega_{I,L}), \end{aligned}$$

where δ_L is the exogenous job destruction rate for low-skilled workers (at this rate the employed low skilled workers lose their jobs and go back into the pool of informal employees); r is the discount rate; ω_L is the wage rate paid by formal firms, and ω_I is the outside option in informality; at the rate ρ , the low-skilled become highly skilled, lose the low skilled job and enter into the pool of highly skilled informally employed workers (implying a loss of $\Omega_{F,L}$, and a gain of $\Omega_{I,H}$). Similarly, an informal employee may also become high skilled with an exogenous probability ρ . In the latter case, the agent loses $\Omega_{I,L}$ and gains $\Omega_{I,H}$.

It follows that:

$$\Omega_{F,L} - \Omega_{I,L} = \frac{\omega_L - \omega_I}{r + \delta + \lambda(\theta_L) + \rho}.$$

In equilibrium $\Omega_{F,L} > \Omega_{I,L}$. Hence, workers in informal sector always find it advantageous to search for a formal job and to accept a job offer from a formal firm.

As far as firms are concerned, let $\Phi_{V,L}$ denote the present value of a vacancy, and $\Phi_{F,L}$ be the present value of filled job for a low-skilled workers. These values are given by:

$$\begin{aligned} r\Phi_{F,L} &= y_L - \omega_L - (\delta_L + \rho)(\Phi_{F,L} - \Phi_{V,L}), \\ r\Phi_{V,L} &= -k_L + q(\theta_L)(\Phi_{F,L} - \Phi_{V,L}). \end{aligned}$$

where y_L is the marginal product of low-skilled workers, δ is the job destruction rate, and ρ is the rate at which the low-skilled become highly skilled and find a job in the high-skilled sector (consequently, jobs in the low-skilled sector become vacant at the rate $\delta + \rho$).

On the balanced growth path, free entry implies that $\Phi_{V,L} = 0$ or, equivalently:

$$\begin{aligned} \Phi_{F,L} &= \frac{y_L - \omega_L}{r + \delta_L + \rho}, \\ \Phi_{F,L} &= \frac{k_L}{q(\theta_L)}. \end{aligned}$$

Hence, the job creation condition can be written as:

$$\frac{y_L - \omega_L}{r + \delta_L + \rho} = \frac{k_L}{q(\theta_L)}, \quad (11)$$

which determines the equilibrium level of market tightness (θ_L). This condition states that in equilibrium, the marginal benefit from a filled vacancy is equal to the marginal cost of opening a vacancy.

The wage rate is determined through Nash bargaining:

$$(1 - \beta_L)(\Omega_{F,L} - \Omega_{I,L}) = \beta_L(\Phi_{F,L} - \Phi_{V,L}),$$

where β_L is the bargaining power of low-skilled workers. Solving for the low-skilled wage gives:

$$\omega_L = \frac{\omega_I(1 - \beta_L)(r + \delta_L + \rho) + \beta_L(\delta_L + r + \lambda(\theta_L) + \rho)y_L}{r + \delta_L + \beta_L\lambda(\theta_L) + \rho}. \quad (12)$$

It is simply a weighted average of the wage of the informal sector and the marginal product in the formal sector.

As for the share of informal employment, its dynamics is governed by

$$\begin{aligned} \dot{I}_L &= (L - I_L)\delta_L - \lambda(\theta_L)I_L + g_L L - \rho I_L \\ \Leftrightarrow \frac{\dot{I}_L}{I_L} &= \left(\frac{L}{I_L} - 1\right)\delta_L - \lambda(\theta_L) + (g + \rho)\frac{L}{I_L} - \rho. \end{aligned}$$

On the balanced growth path, $\frac{\dot{I}_L}{I_L} = \frac{\dot{L}}{L} = g$. As $i_L \equiv \frac{I_L}{L}$, the steady state condition implies that:

$$i_L = \frac{\delta_L + g + \rho}{\delta_L + g + \lambda(\theta_L) + \rho}. \quad (13)$$

Search-and-matching equilibrium for high-skilled workers. – We proceed the same way for high-skilled workers, accounting for the fact that they emigrate abroad with a probability p . Let $\Omega_{F,H}$, $\Omega_{I,H}$ and Ω^* represent the lifetime value of formal employment, informal employment, and employment abroad, respectively. We have:

$$\begin{aligned} r\Omega_{F,H} &= \omega_H - \delta_H(\Omega_{F,H} - \Omega_{I,H}) + p(\Omega^* - \Omega_{F,H}), \\ r\Omega_{I,H} &= \omega_I + \lambda(\theta_H)(\Omega_{F,H} - \Omega_{I,H}) + p(\Omega^* - \Omega_{I,H}). \end{aligned}$$

At the rate p , high-skilled workers leave their jobs from any of the two sectors and go abroad to work. We assume the home country to be small; hence, Ω^* is unaffected by the labor market conditions in the home country. The wage of high skilled workers is denoted by ω_H . Since a worker can find a job abroad during employment in the informal sector or during her job in the formal sector with the same probability, p appears both in her employment and informal employment asset value functions.

As far as firms are concerned, the present values of a vacancy ($\Phi_{V,H}$) and of a filled job

$(\Phi_{F,H})$ are given by:

$$\begin{aligned} r\Phi_{F,H} &= y_H - \omega_H - (\delta_H + p)(\Phi_{F,H} - \Phi_{V,H}) \\ r\Phi_{V,H} &= -k_H + q(\theta_H)(\Phi_{F,H} - \Phi_{V,H}) \end{aligned}$$

where y_H is the marginal product of the skill-intensive intermediate input. The vacancy is filled at a rate $q(\theta_H)$.

On the balanced growth path, the free entry condition implies that $\Phi_{V,H} = 0$, or equivalently:

$$\begin{aligned} \Phi_{F,H} &= \frac{y_H - \omega_H}{r + p + \delta_H}, \\ \Phi_{F,H} &= \frac{k_H}{q(\theta_H)}, \end{aligned}$$

so that the job creation condition writes as:

$$\frac{y_H - \omega_H}{r + p + \delta_H} = \frac{k_H}{q(\theta_H)}. \quad (14)$$

The wage rate is determined through Nash bargaining:

$$(1 - \beta_H)(\Omega_{F,H} - \Omega_{I,H}) = \beta_H(\Phi_{F,H} - \Phi_{V,H}),$$

where β_H is the bargaining power of high-skilled workers.

Solving for the high-skilled wage gives:

$$\omega_H = \frac{\omega_I(1 - \beta_H)[r + p + \delta_H] + \beta_H[\delta_H + r + p + \lambda(\theta_H)]y_H}{r + \delta_H + p + \beta_H\lambda(\theta_H)}, \quad (15)$$

while the equilibrium share of informal employment requires $\frac{\dot{I}_H}{I_H} = \frac{\dot{H}}{H} = g$. This implies:

$$i_H = \frac{\delta_H + g + p}{\delta_H + g + \lambda(\theta_H) + p}. \quad (16)$$

Definition of the general equilibrium. – We can define the steady state, general equilibrium of our search-and-matching model by combining the technological characteristics of the economy, the conditions governing population dynamics, and the labor market equilibrium conditions for both types of workers. This gives:

Definition 1. For a set of country-specific parameters $\{g, n, \rho, p, \sigma, \alpha, r, \beta, A_F, A_I\}$ and a set of skill-specific parameters $\{\delta_S, k_S, \mu_S\}_{S=(H,L)}$, the steady state equilibrium of the search-and-matching model is a set $\{Z, Z_F, y_L, y_H, \theta_L, \theta_H, i_L, i_H, \omega_L, \omega_H\}$ of ten endogenous variables satisfying the following ten conditions: (i) the optimal composition and allocation of the workforce is given by (1) and (3), (ii) the profit-maximizing levels of marginal productivity are given by (5) and (6), (iii) and the search-and-matching equilibrium conditions are (11), (12), (13), (14), (15) and (16).

The other variables of the model can either be computed as a transformation of the parame-

ters (e.g., $\omega_I = A_I$, $\psi = A_I/A_F$, $P = p/g$) or can be computed as by-products of the endogenous variables (e.g., $\bar{w}_S$ combines ω_S and i_S using Eq. (9)).

Effect of the brain drain. – How does the brain drain affect the steady state of the economy and the welfare of non-migrants? First, in Eq. (1), skilled emigration changes the composition of the labor force. For given informality rates, this induces first-order effects on the composition of the labor force in the formal economy (see Eq. (3)), and subsequent changes in the marginal products of intermediate goods, governed by Eqs. (5)-(6). The size of these first-order effects on the marginal products depends on the elasticity of substitution between intermediate goods: changes in y_S are small if σ is large, and conversely. Second, changes in the marginal products translate into changes in market tightness and wage rates; these changes are obtained by solving Eqs. (11)-(12) for the low-skilled, and by solving Eqs. (14)-(15) for the highly skilled. Third, emigration has a direct negative effect on the expected values of a filled vacancy and of accepting a formal job which affects market tightness and wage. Finally, changes in market tightness affects informality rates, as shown in Eqs. (13) and (16), with second-order effects on Z_F and on the marginal products of intermediate goods.

The model is strongly non linear and a closed-form solution cannot be identified. However, to shed light on the mechanics of the model, let us dissect the labor market responses. For the low-skilled population, the equilibrium value of $y_L - w_L$ can be derived from (12) and from (11); equalizing them gives:⁴

$$\frac{(1 - \beta_L)(y_L - \omega_L)}{(r + \delta_L + \rho) + \beta_L \lambda_L(\theta_L)} = \frac{k_L \lambda_L(\theta_L)}{\mu_L^2}.$$

For the highly skilled, the equilibrium value of $y_H - w_H$ can be derived from (15) and from (14); equalizing them gives:

$$\frac{(1 - \beta_H)(y_H - \omega_I)}{(r + \delta_H + p) + \beta_H \lambda_H(\theta_H)} = \frac{k_H \lambda_H(\theta_H)}{\mu_H^2}.$$

where λ_H is at the equilibrium level of θ_H .

We have:

Proposition 2. *Under a search-and-matching labor market, the informality regime arises for any level of p . The effect of the brain drain on inequality between skill groups depends on the substitutability between high-skilled and low-skilled intermediate goods in the formal economy. If the elasticity of substitution is large, it decreases inequality (making high-skilled, non-migrants worse off). If the elasticity of substitution is small, the brain drain most likely increases inequality between skill groups (making low-skilled workers worse off, and high-skilled, non-migrants better off).*

We now demonstrate this result. The wage of the high skilled can also be expressed as follows

$$\omega_H = \omega_I + (y_H - \omega_I) \beta_H \left[1 + \frac{(1 - \beta_H) \lambda_H(\theta_H)}{r + \delta_H + p + \beta_H \lambda_H(\theta_H)} \right] \quad (17)$$

ω_H is strictly decreasing in p but increasing in θ_H . The informality of high skilled can be expressed as follows

⁴We use $\lambda_S(\theta_s) = \mu_S \sqrt{\theta_s}$ and $\lambda_S(\theta_s) q_S(\theta_s) = \mu_S^2$ from (10).

$$i_H = \frac{1}{1 + \frac{\lambda_H(\theta_H)}{\delta_H + g + p}} \quad (18)$$

Here informality of high skilled is strictly increasing in p while decreasing in θ_H .

If σ is large, there is no effect of p on y_H . But an increase in p means high skill workers quit more frequently, so the present value of profits for firms is falling. Firms push a part of these losses towards workers via bargaining, so ω_H is falling. This is the direct effect. In addition, because of lower profits firms open less vacancies, so the market tightness θ_H is falling. This is the indirect effect, which leads to worse outside opportunities of workers and reduces wages of high skill workers even further. As for informality of high skilled, it can be noticed from 18 that a rise in p has a direct negative effect on i_H while an indirect negative effect through falling θ_H . Both effects increase i_H . On the other hand y_L does not vary and the brain drain has no effect on the labor market outcomes of low-skilled workers. So, with infinite elasticity of substitution between high-skilled and low-skilled workers increased brain drain reduces inequality by making high skilled workers worse-off.

If σ is small, brain drain increases y_H . An increase in the marginal product of the skill-intensive input increases profits from high skilled vacancy and θ_H increases. At the same time a rise in p has a direct negative effect on the value of filled high skilled job. The profits from high-skilled jobs decrease and θ_H may decrease as well. Hence, ω_H may increase with p due to rise in y_H and improved outside options but if the negative effect of p on θ_H dominates its positive effect on θ_H then ω_H may fall. Since the high skilled workers are scarce in these countries we expect the rise in θ_H due to a higher y_H effect to dominate and lead to a higher wage and lower informality of high-skilled workers. We now turn our attention to the low skilled. When p increases, the first-order effect is channelled by the marginal product of low-skilled workers. Due to a decline in the number of high-skilled workers, y_L decreases. A fall in y_L reduces the profits from low-skilled jobs and the level of θ_L declines. Hence, the value of outside option decreases as well, all of this deteriorates ω_L and i_L rise as well. For a finite sigma as explained above that y_H rises after brain drain but variation in θ_H is uncertain. In case of a higher θ_H inequality increases between the two groups making non-migrant high-skilled workers better-off while low-skilled workers worse-off.

We see from the discussion above that once labor market frictions are included into the model, the inequality response to the brain drain becomes somewhat ambiguous. Numerical simulations can thus be used to identify which of these two outcomes is the most plausible.

2.4 Quantitative analysis

Our benchmark model is parameterized to match the economic and socio-demographic characteristics of 33 sub-Saharan African economies in the year 2010, which is meant to represent the steady state. The choice of 33 countries is guided by data availability; more precisely, we select sub-Saharan African countries for which estimates of the informality shares in employment and value added are available. We parameterize the model to match the population structure of each country, its recorded level of income per capita, as well as its shares of informality in employment and in the value added. Once the model is calibrated, we quantify the effect of the

brain drain by simulating a counterfactual search-and-matching equilibrium with $p = 0$. In this section, we describe the parameterization strategy and discuss the simulation results. We check the robustness of our results to a number of identifying assumptions and to the technological environment in Appendix C.

Paramaterization. – Table 1 summarizes the calibration outcomes (see Table A1 in the Appendix for more details). The model includes six parameters that we consider identical across countries. Using data from Kremer and Chen (1999), we compute the differential fertility in 1985-89 for 26 developing countries. The correlation between country-specific fertility differentials and the human capital of women is low (0.14). We thus consider the fertility differential as independent of the level of development. The average fertility differential g_H/g_L between high-skilled (i.e., college graduates) and low-skilled workers (i.e., the less educated) equals 0.605; it shows little variations across countries. We use the value $n = 0.605$ in all countries. As far as the elasticity of substitution between intermediate goods is concerned, we use the elasticity of substitution between high-skilled and low-skilled workers estimated by Ottaviano and Peri (2012) for a one-sector model; this gives $\sigma = 2$. For the interest rate, we use the average t-bill rate for developed countries (4% per year) and compute the monthly rate; this gives $r = 0.0033$. In line with Gong and Soest (2002) and Satchi and Temple (2009) on Mexico, the job destruction rates are set to $\delta = 0.06$ for both skill groups. The vacancy cost is assumed to be equal to 40% of the wage rate; we use $k_S = 0.4\omega_S$ in the pre-shock economy and for both skill groups; however, when brain drain shocks are simulated, we keep the absolute level of k_S (in USD) constant. As for the bargaining power of workers, the literature on developed countries uses a value around 0.5. However, Satchi and Temple (2009) recommends a value of 0.7 when informal sector represents more than 30% of workforce; we use $\beta = 0.7$ in all countries. Alternative parameters values are considered in the robustness analysis.

Tab. 1. Common and country-specific parameters

	Description	Mean	St. dev.	Source/Moment matched
Parameters without country variation				
n	Pop. growth differential	0.605	-	Kremer and Chen (1999)
σ	Elast. subst. btw inputs	2.000	-	Ottaviano and Peri (2012)
r	Monthly interest rate	0.003	-	Satchi/Temple (2009), Iftikhar /Zaharieva (2016)
δ_S	Monthly job destruction	0.060	-	Gong/Soest (2002), Satchi/Temple (2009)
k_S/ω_S	Vacancy cost/Wage	0.400	-	Satchi and Temple (2009)
β	Bargaining power	0.700	-	Satchi and Temple (2009)
Parameters varying across countries				
A_F	TFP in the formal sector	2055.0	2600.0	Matches official GDP per capita
α	Firm preference for input	0.506	0.104	Matches observed wage ratio
A_I	TFP in the informal sector	139.3	195.6	Matches informal inc. per worker
p	Monthly emigration rate	7.9E-04	7.4E-04	Matches prop. of HS emigrants
ρ	Social mobility rate	4.8E-05	3.17E-05	Matches observed skill ratio
g	Monthly pop. growth rate	4.3E-04	9.4E-05	Matches pop. growth rate
μ_L	Matching scale factor, LS	0.103	0.048	Matches share of formal empl.
μ_H	Matching scale factor, HS	0.214	0.068	Matches share of formal empl.

The model also includes eight parameters that vary across countries to match some moments for the year 2010. We collect data on official GDP and on the working-age population size and growth rates (g) from the World Development Indicators (World Bank, 2016), and data on the proportion of college graduates in the labor force from Artuç et al. (2015). We combine them with data on informal employment as percentage of the labor force, and informal activities as percentage of official income from Schneider (2012). The latter database does not distinguish informal workers by education level; in the benchmark simulations, we assume that the informal employment rate of college graduates is half the informal employment rate of the less educated (i.e., $i_H = 0.5i_L$).⁵ This allows us to proxy the size and the skill structure of the labor force in each sector, as well as the average levels of income per worker. The TFP levels in the formal and informal sectors, A_F and A_I , match these average income levels, while α is calibrated to match the wage ratio between college graduates and less educated workers, as estimated in Hendriks (2004). The monthly emigration rates of college graduates, p , is calibrated to match the proportion of high-skilled expatriates reported in Artuç et al. (2015). The social mobility rate, ρ , matches the observed skill ratio. Finally, the scale factors of the matching function, μ_L and μ_H , are calibrated to match the formal and informal shares in employment.

Welfare effect of the brain drain.— We use the parameterized model to quantify the welfare and inequality effects of skilled emigration. To do so, we simulate the hypothetical search-and-matching equilibrium assuming a zero emigration rate for the highly skilled. On Figure 2, we plot the effect of the brain drain (measured as the relative difference between the observed equilibrium value and the no-migration counterfactual equilibrium value) on the vertical axis, and the observed proportion of high-skilled expatriates (P) on the horizontal axis. A positive variation on the vertical axis means that the brain drain increases the level of the variable of interest. Note that all results in Figure 2 are also reported in Table A2 in the Appendix.

Figure 2.a reports the results for the average monthly income of all non-migrants (i.e. $\bar{w}$ measured by Eq. (9)). The effect of the brain drain is negative in all countries and the loss increases with the intensity of migration. However, the coefficient of correlation between $\Delta\bar{w}/\bar{w}$ and P only amounts to 0.5; this suggests that the average welfare effect of the brain drain is not only determined by P , but also depends on other country characteristics. For example, the greatest income loss amounts to 12.1% in the Democratic Republic of Congo, which only has 15% of its college-educated natives abroad; by comparison, the average income loss equals 4.2% in Gambia, where P amounts to 68%. Figure 2.b represents the inequality response to the brain drain; inequality is proxied by the ratio of average income between high-skilled non-migrants and the low-skilled ($\bar{w}_H/\bar{w}_L$). The inequality effect of the brain drain increases linearly with P , and the correlation with P is close to unity. The largest effect is obtained in the Gambia (+69.7%), while Burkina Faso exhibits the smallest response (+3.2%).

Figures 2.c and 2.d depict the effect on the average income of low-skilled and high-skilled workers (i.e., $\bar{w}_L$ and $\bar{w}_H$, respectively). As far as high-skilled workers are concerned, the effect is always positive and proportional to the size of the brain drain (correlation of 0.99 with P). The income response is large, reaching 67% in the Gambia. This is due to the fact that the proportion of high-skilled is small in sub-Saharan African countries (between 2 and 5%). Hence, these countries produce a low quantity of skill intensive, intermediate goods, and the marginal

⁵Alternative identifying assumptions are used in the robustness checks in Appendix.

productivity of these goods is large. In other words, a small decrease in the number of highly educated workers induces large aggregate productivity changes in the formal sector. The semi-elasticity of the average income of the high-skilled to P is close to unity. On the contrary, the welfare response for the low-skilled is strongly heterogeneous across countries, and less correlated with P (correlation equal to -0.58). This is clearly in line with Figure 2.a. As stated above, the low-skilled population represents between 95 and 98% of the labor force in developing countries; income responses for the low-skilled are almost equal to the average income response of the whole population. This suggests that the parameters governing the search-and-matching equilibrium matter for the low-skilled.

Figures 2.e and 2.f disentangle the income responses of the low-skilled, distinguishing between the informal employment effect (on i_L) and the wage effect (on ω_L). In all cases, the brain drain increases the share of informality and reduces the wage rate. The correlation between the wage and employment responses equals 0.95. Hence, there are countries where the labor market outcomes of the low-skilled are highly responsive to the brain drain (e.g., the Democratic Republic of Congo, Liberia, Nigeria, Tunisia or Zimbabwe), and others where they are much less responsive (e.g., Rwanda, Uganda, the Gambia). Finally, Figures 2.g and 2.h disentangle the income responses of the high-skilled. The brain drain decreases the share of informality and increases the wage rate; the effects are virtually linear in P .

Dissecting cross-country disparities. – We now focus on the average monthly income of the low-skilled, and investigate the source of cross-country disparities in the response to the brain drain (as shown on Figure 2). Our model includes eight country-specific parameters that influence these responses. These parameters can be grouped into three subsets: $X^Z = \{\rho, g\}$ are parameters governing human capital accumulation, $X^M = \{\mu_L, \mu_H\}$ are parameters governing the effectiveness of the matching process, $X^T = \{A_F, \alpha, \psi\}$ are parameters reflecting technological differences across countries. The generic function governing the income response to the brain drain for the low-skilled can be expressed as:

$$\frac{\Delta \bar{w}_L}{\bar{w}_L} = R(X^Z, X^M, X^T; p)$$

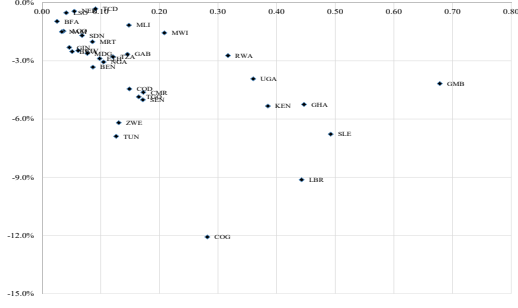
To identify the role of each set of country characteristics, we simulate the country specific changes in the average monthly income of the low-skilled for all parameters' subsets X jointly set at the median (X_{med}), and for each subset of parameter set at its median value one at a time. We obtain four counterfactual vectors of variations in expected income (each vector includes 33 country-specific simulation results), denoted by $R^A = R(X_{med}^Z, X_{med}^M, X_{med}^T; p)$, $R^Z = R(X_{med}^Z, X^M, X^T; p)$, $R^M = R(X^Z, X_{med}^M, X^T; p)$ and $R^T = R(X^Z, X^M, X_{med}^T; p)$. Figure 3 shows the results of these counterfactual experiments, which can be easily compared to the baseline results in Figure 2.c.

Figure 3.a shows that R^A is a smooth convex function of P : if all countries shared the same characteristics, the average income loss for the low skilled could be almost perfectly predicted using a quadratic function of P . The R-squared of this P -trend, quadratic regression on 33 observations equals 0.965.⁶ To identify the role of country characteristics, similar regressions

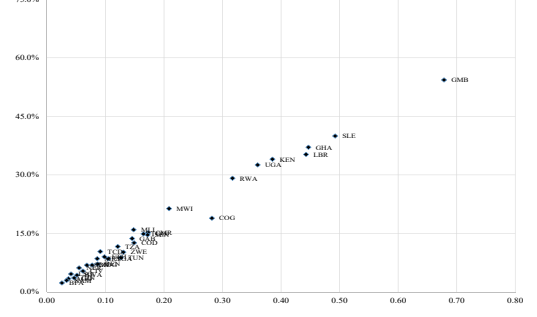
⁶Note that the R-squared reaches 0.998 when assuming that vacancy costs remains proportional to the wage rate of the formal economy in the no-migration equilibrium. In the baseline model with country-specific characteristics (see Figure 2.c), conducting a similar quadratic regression generates a R-squared of 0.457 only (i.e., the quadratic

Figure 2: Welfare effect of the brain drain with search and matching; (Horizontal axis: baseline; Vertical axis: Alternative identifying assumptions)

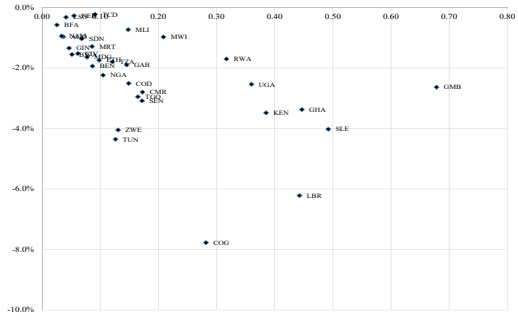
2.a. Average income effect ($\frac{\Delta \bar{w}}{\bar{w}}$)



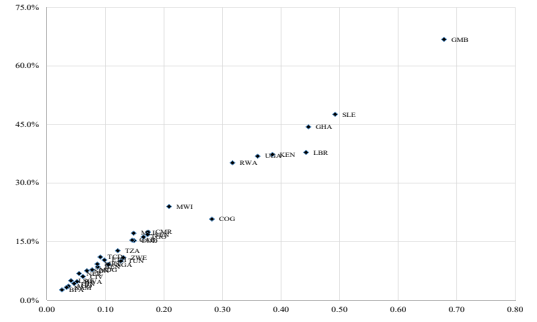
2.b. Inequality effect ($\frac{\Delta \bar{w}_H}{\bar{w}_H} - \frac{\Delta \bar{w}_L}{\bar{w}_L}$)



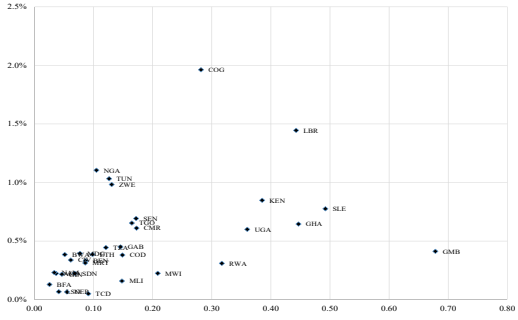
2.c. Income effect for low skilled ($\frac{\Delta \bar{w}_L}{\bar{w}_L}$)



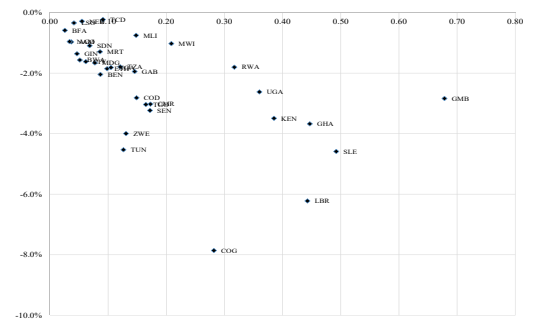
2.d. Effect for high skilled ($\frac{\Delta \bar{w}_H}{\bar{w}_H}$)



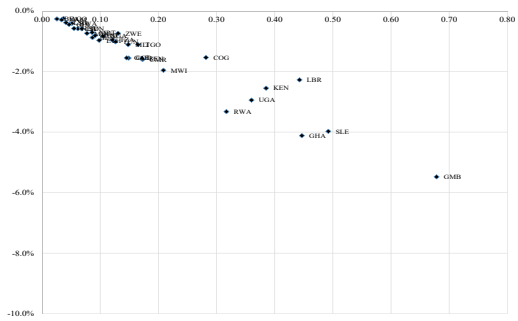
2.e. Effect on informality for low skilled (Δi_L)



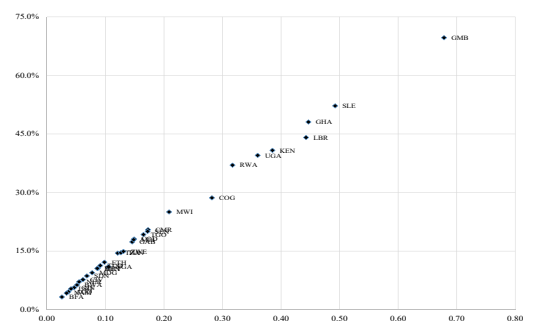
2.f. Wage effect for low skilled ($\frac{\Delta \omega_L}{\omega_L}$)



2.g. Effect on informality for high skilled (Δi_H)



2.h. Wage effect for high skilled ($\frac{\Delta \omega_H}{\omega_H}$)



small. On the contrary, the contributions of educational and technological parameters mostly govern the cost of the brain drain for the low-skilled. Countries exhibiting brain drain costs above the quadratic P -trend have a better educational technology (i.e., ρ is large or g is small), and a large productivity gap between sectors (i.e., A_F is large or ψ is small). In these countries, the informal sector is less productive and emigration-driven shocks on human capital are mostly absorbed by the formal economy (as it would be the case in a one-sector model). This group of countries includes Botswana, the Republic of Congo, Cote d'Ivoire, Guinea, Namibia, Tunisia and Zimbabwe. Countries exhibiting brain drain costs below normal exhibit poor education systems (i.e., ρ is small), and a small productivity gap between sectors (i.e., A_F is small or ψ is large). This group includes Chad, the Gambia, Lesotho, Malawi, Mali, Niger, Rwanda and Uganda). In these countries, the informal economy acts as a buffer zone, which attenuates the effect of the brain drain. The role of the productivity gap is intuitive. In countries where the productivity gap between the two sectors is small, it is less costly for low-skilled workers to leave the formal sector. Similarly, in countries with better education technology the low skilled have a higher marginal product in the formal sector and hence higher wage than in the countries with the worse education technology. So, the brain drain driven decline in θ_L in all countries leads to a bigger wage loss to low-skilled in countries with better education technologies.

Tab. 2. Brain drain effect above vs. below the P-trend

	X^Z			X^M	X^T		
$ R \gg R^A $ Income loss above trend	Botswana Rep. Congo Tunisia Zimbabwe			Zimbabwe	Botswana Guinea Rep. Congo Namibia Cote d'Ivoire Tunisia Zimbabwe		
$ R \ll R^A $ Income loss below trend	Gambia	Malawi	Mali		Tchad	Lesotho	Malawi
	Niger	Rwanda	Uganda		Mali	Rwanda	Uganda

3 Additional mechanisms

We now investigate whether the income responses to skilled emigration are affected by technological externalities (i.e., by TFP responses to emigration) and endogenous training decisions. The size of technological externalities and of the emigration-driven incentives to educate has generated a certain level of debate in the literature. We use here simple specifications for the externalities and optimistic elasticity levels that can be found in the literature. We then check whether such spillover effects influence the size of the welfare responses to skilled emigration.

Extension with endogenous productivity. – We consider two types of externalities and two scenarios regarding their sector-biased structure. We first consider a standard schooling externality, assuming that TFP increases with the skill ratio in the whole economy. In the first variant, we assume that this externality is sector-biased and only affects the formal economy. We have:

$$A_F = \bar{A}_F Z^\epsilon,$$

where $\bar{A}_F$ is a scale factor parameterized to match the observed TFP level. Following de la Croix and Docquier (2012) and Aubry et al. (2016), we consider a concave function with an elasticity ϵ equal to 0.3. This implies that A_F increases by a factor of $(Z_0/Z)^{0.3}$ in the counterfactual with $p = 0$. In the second variant, we assume that the same schooling externality operates in the informal sector as well and with the same intensity (i.e., $A_I = \bar{A}_I Z^\epsilon$), due to intersectoral spillover effects.

The second externality is a diaspora externality. It captures the effect of emigration on trade and FDI, and the resulting effect of trade and FDI on TFP. A first strand of literature has identified a causal impact of migration on trade and FDI, with respective elasticities of 0.1 and 0.2 (e.g. Iranzo and Peri 2009; Felbermayr et al. 2010; Parsons and Vezina 2017; Kugler and Rapoport 2007; Javorcik et al. 2011). Another strand has identified a causal effect of trade and FDI on TFP, with respective elasticities of 0.3 and 0.01 (see Anderson et al. 2017; Feyrer 2009). Combining these findings gives an elasticity of TFP to migration around 0.05. We assume that this externality is expressed as

$$A_F = \bar{A}_F(1 + \kappa m),$$

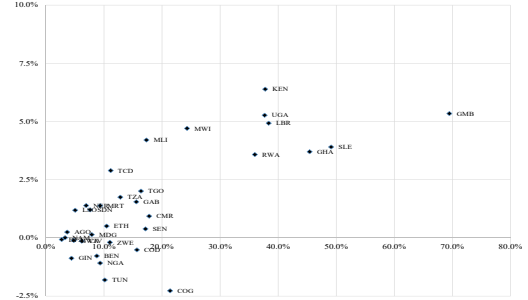
where m denotes the proportion of migrants abroad (in our model, m is the product of the proportion of high-skilled by the proportion of emigrant, $m = \frac{zP}{1+z}$), κ is the incidence parameter. The choice of this analytical form ensures that the TFP level remains positive when $m = 0$. The elasticity of TFP to the proportion of emigrants is thus given by $\frac{\kappa m}{1+\kappa m}$. We calibrate κ in such a way that this elasticity is equal to 0.05 when the proportion of migrants abroad equals 1.5% (the average level observed in low-income countries); this gives $\kappa = 3.5$. This implies that A_F decreases by 3.5% in the counterfactual with $p = 0$. In the second variant, we assume that the same diaspora externality operates in the informal sector with the same intensity (i.e., $A_I = \bar{A}_I(1 + \kappa m)$).

Fig. 4 compares the effect of the brain drain on the average monthly income of the low-skilled (left panel) and of the high-skilled (right panel) with or without technological externalities.

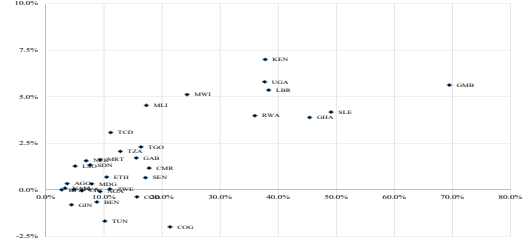
As far as the low-skilled are concerned, the schooling externality plays a key role. On average, the loss of income increases by a factor of 4.4 when the externality operates in the formal sector only (Figure 4.a), and by a factor of 5.0 when it affects both sectors of the economy (Figure 4.c). In countries with low human capital levels, the effect is multiplied by 10 to 15. These include the Gambia, Uganda, Sierra Leone, Ghana, Kenya, and to a lesser extent, Malawi and Mali. The diaspora externality has smaller albeit non-negligible effects; it divides the income loss by 2 when the externality operates in both sectors (Figure 4.e).

As for the high-skilled, the income gain is divided by ten when schooling externalities are accounted for (Figures 4.b and 4.c). High-skilled workers experience average income losses in Benin, Botswana, the Republic of Congo, Guinea, Nigeria, Tunisia and Zimbabwe. On the contrary, the diaspora externality has much smaller effects (Figures 4.f).

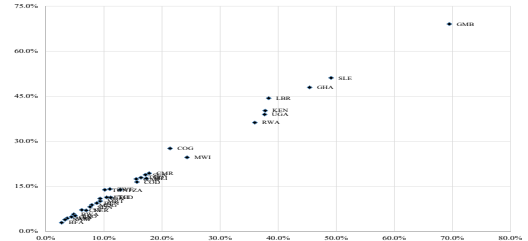
Extension with endogenous social mobility. – Finally, in line with the recent *brain gain* literature (Mountford 1997; Stark et al. 1997, 1998; Beine et al 2001, 2008), emigration prospects can stimulate the expected return to education, and increase the fraction of young adults acquiring education. In our benchmark model, the acquisition of human capital is reflected by the exogenous variable ρ , which measures the fraction of the low-skilled population becoming

4.b. Schooling ext. on A_F only ($\frac{\Delta \overline{w_H}}{\overline{w_H}}$)

4.d. Schooling ext. on A_F and $A_I(\frac{\Delta \overline{w_H}}{\overline{w_H}})$



4.f. Diaspora ext. on A_F and $A_I(\frac{\Delta \overline{w_H}}{\overline{w_H}})$


$$\rho = \left(\frac{1}{a}E\right)^{1/\gamma},$$

To simplify the analysis, we disregard differences between formal and informal employees and assume that low-skilled workers choose ρ (or equivalently, E) so as to maximize the mean

present value of income (net of training costs) in a coordinated way:

$$\begin{aligned} & \text{Max}_{\rho} (1 - i_L)r\Omega_{F,L} + i_Lr\Omega_{I,L} - E(\rho) \\ \text{where } & \begin{cases} r\Omega_{F,L} = \omega_L - \delta_L(\Omega_{F,L} - \Omega_{I,L}) + \rho(\Omega_{I,H} - \Omega_{F,L}) \\ r\Omega_{I,L} = \omega_I + \lambda(\theta_L)(\Omega_{F,L} - \Omega_{I,L}) + \rho(\Omega_{I,H} - \Omega_{I,L}) \end{cases} \end{aligned}$$

The first order condition for this maximization problem writes as

$$\rho = \left[\frac{(1 - i_L)(\Omega_{I,H} - \Omega_{F,L}) + i_L(\Omega_{I,H} - \Omega_{I,L})}{a\gamma} \right]^{\frac{1}{\gamma-1}}, \quad (19)$$

where the parameter γ governs the sensitivity of training decisions to income shocks.

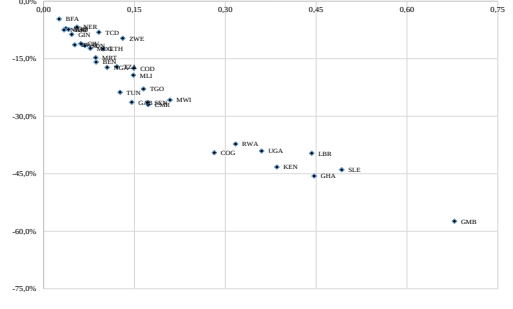
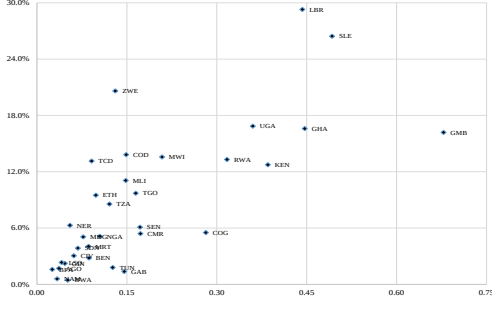
We calibrate γ to be in line with the empirical literature on emigration and human capital formation. In line with Beine et al. (2008), we simulate the same shock on p (dividing p by 2) in all countries and compute the elasticity of ρ (our proxy for pre-migration human capital investment) to p as $\frac{\Delta \ln \rho}{\Delta \ln p} = -2\Delta \ln \rho$. The empirical paper of Beine et al. (2008) provides an estimate of 0.05 for this elasticity. We thus choose γ in such a way that the mean elasticity $-2\Delta \ln \rho$ in our sample equals -0.05. This gives $\gamma = 9$. Once γ is fixed, we calibrate the country-specific level of the scale parameter a to match the benchmark level of ρ . We then add Eq. (19) into the model. Without shock, the pre-shock equilibrium is identical to that of the model with exogenous social mobility. In the counterfactual with $p = 0$, the extended model accounts for the change in training decisions. The first direct effect of setting $p = 0$ is that the asset value of (in)formal employment decreases. Then, general equilibrium effects operate through (in)formal employment and wages levels.

The results with endogenous social mobility are illustrated on Figure 5. Figure 5.a describes the relative changes in ρ , defined as percentage deviations from the no-migration counterfactuals, as a function of the baseline proportion of emigrants (P). On average, ρ increases by 2% in countries exhibiting emigration rate around 10%. The effect varies across countries: ρ increases by 25% in Liberia and Sierra Leon where emigration rates are around 50%. Figure 5.b compares the effect of high-skilled migration on the skill ratio with exogenous (X-axis) or endogenous (Y-axis) social mobility. The effect of the brain drain is obviously smaller in the model with endogenous social mobility, although we do not identify any case of net brain gain. The incentive effect is too small to reverse the human capital flight. On average, the human capital loss caused by the brain drain is 18% smaller in the context with endogenous ρ . Finally, Figures 5.c and 5.d compare the low-skilled informality and wage responses to the brain drain with exogenous (X-axis) or endogenous (Y-axis) social mobility. These labor market responses are slightly smaller when social mobility is endogenized but are qualitatively similar to our benchmark results. Our conclusions are thus robust to the brain gain mechanism.

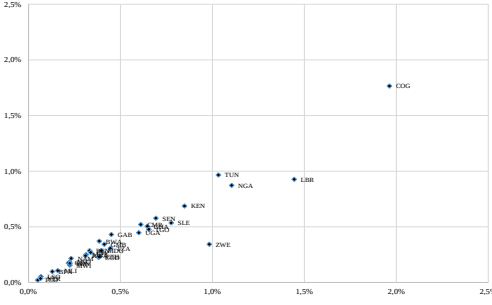
4 Concluding remarks

This paper investigates the implications of skilled emigration for a subset of sub-Saharan African countries. We develop a model with two classes of workers and two-sectors (formal and informal) producing a homogenous final good. In a competitive framework with perfect mobility across

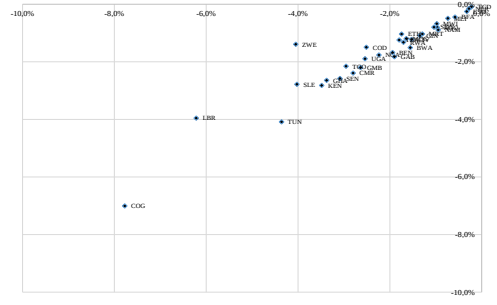
Figure 5: Results with endogenous social mobility
5.a. Training response and P 5.b. Effect on skill ratio



5.c. Effect on informality for low-skilled



5.d. Wage effect for low-skilled



sectors, we show that the informal economy acts as a buffer zone that perfectly neutralizes human capital and emigration shocks. Skilled emigration increases the size of the informal sector but has no effect on income levels and inequality. Nevertheless, such a competitive model fails to explain the existence of persistent wage differentials between sectors as well as the presence of high-skilled workers in informality.

We thus develop an alternative search-and-matching model that is compatible with these facts, and we use it to revisit the welfare and inequality implications of the brain drain. Our quantitative analysis suggests that skilled emigration increases the income and formal employment levels of the highly skilled. On the contrary, it decreases the welfare of the low-skilled. These welfare losses are highly heterogeneous across countries. This heterogeneity is mostly governed by cross-country differences in the training technology and in the relative productivity of the informal sector. Countries with low productivity differentials and good training technologies suffer more from the brain drain. In the other countries, emigration shocks are better absorbed by the informal sector. Our results are robust to identifying assumptions, to the inclusion of technological externalities, or to the endogenization of training decisions.

References

- [1] Acemoglu, D. (2001). Good Jobs versus Bad Jobs. *Journal of Labor Economics* 19(1): 1 21.
- [2] African Union (2008). Study on the Informal Sector in Africa. Sixth Ordinary Session of the Labor and Social Affairs Commission of the African Union, Addis Ababa.

- [3] Anderson, J. E. & M. Larch & Y.V. Yotov (2017). Trade liberalization, growth, and FDI: A structural estimation framework. Conference paper: ZBW – Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationzentrum Wirtschaft.
- [4] Artuc, E. & F. Docquier & C. Ozden & Ch. Parsons (2015). A global assessment of human capital mobility: the role of non-OECD destinations. *World Development* 65, 6–26.
- [5] Aubry, A. & M. Burzynski & F. Docquier (2016). The welfare impact of global migration in the OECD countries. *Journal of International Economics* 101, 1–21.
- [6] Basu, A.K. & N.H. Chau & R. Kanbur (2015). Contractual Dualism, Market Power and Informality. *Economic Journal* 125, 1534–1573.
- [7] Basu, A.K. & N.H. Chau & Z. Siddique (2012). Tax evasion, minimum wage noncompliance, and informality. *Research in Labor Economics* 34, 1–53.
- [8] Batista, C. & A. Lacuesta & P.C. Vicente (2012). Testing the brain gain hypothesis: Micro evidence from Cape Verde. *Journal of Development Economics* 97(1), 32–45.
- [9] Battisti M. & G. Felbermayr & G. Peri & P. Poutvaara (2014). Immigration, Search and Redistribution: A Quantitative Assessment of Native Welfare, NBER working paper 20131.
- [10] Beine, M. & F. Docquier & H. Rapoport (2001). Brain Drain and Economic Growth: Theory and Evidence. *Journal of Development Economics* 64(1), 275–89.
- [11] Beine, M. & F. Docquier & H. Rapoport (2008). Brain Drain and Human Capital Formation in Developing Countries: Winners and Losers. *Economic Journal* 118(528), 631–52.
- [12] Bhagwati, J. & K. Hamada (1974). The Brain Drain, International Integration of Markets for Professionals and Unemployment: A Theoretical Analysis. *Journal of Development Economics* 1(1), 19–42.
- [13] Bhagwati, J. & C. Rodriguez (1975). Welfare-Theoretical Analysis of the Brain Drain. Working papers from Massachusetts Institute of Technology (MIT), Department of Economics, No 158.
- [14] Berry, R.A. & R. Soligo (1969). Some Welfare Aspects of International Migration. *Journal of Political Economy* 77(5), 778–94.
- [15] Brezis, E.S. & P.R. Krugman & D. Tsiddon (1993). Leapfrogging in International Competition: A Theory of Cycles in National Technological Leadership. *American Economic Review* 83(5), 1211–1219.
- [16] Chand, S. & M.A. Clemens (2008). Skilled Emigration and Skill Creation: A Quasi-experiment. Center for Global Development Working Paper 152.
- [17] Charlot, O. & F. Malherbet & M. Ulus (2014). Unemployment Compensation and the Allocation of Labor in Developing Countries. *Journal of Public Economic Theory*. forthcoming.
- [18] Chassamboulli, A. & T. Palivos (2014). A Search-Equilibrium Approach To The Effects Of Immigration On Labor Market Outcomes. *International Economic Review* 55, 111–129.

- [19] Chen, M.A. (2001). Women in the Informal Sector: a Global Picture, the Global Movement. SAIS Review, Winter-Spring 2001.
- [20] Clemens, M. (2015). Losing Our Minds? New Research Directions on Skilled Migration and Development. CGD Working Paper 415, September 2015.
- [21] de la Croix, D. & F. Docquier (2012). Do brain drain and poverty result from coordination failures? *Journal of Economic Growth* 17 (1), 1–26.
- [22] de Paula, A. & J.A. Scheinkman (2010). Value-Added Taxes, Chain Effects, and Informality. *American Economic Journal: Macroeconomics* 2 (4), 195–221.
- [23] de Paula, A. & J.A. Scheinkman (2011). The Informal Sector: An Equilibrium Model and Some Empirical Evidence from Brazil. *Review of Income and Wealth* 57, S8–S26.
- [24] Docquier, F. & T. Müller & J. Naval (2017). Informality and Long-Run Growth. *Scandinavian Journal of Economics*, forthcoming.
- [25] Docquier, F. & H. Rapoport (2012). Globalization, brain drain and development. *Journal of Economic Literature* 50 (3), 681–730.
- [26] Felbermayr, G. J. & B. Jung & F. Toubal (2010). Ethnic networks, information, and international trade: Revisiting the evidence. *Annals of Economics and Statistics* 41–70.
- [27] Feyrer, J. (2009). Trade and income exploiting time series in geography. NBER Working Paper No. 14910.
- [28] Gërxxhani, K. (2004). The Informal Sector in Developed and Less Developed Countries: A Literature Survey. *Public Choice* 120, 267–300.
- [29] Gibson, J. & D. McKenzie (2011). The Microeconomic Determinants of Emigration and Return Migration of the Best and Brightest: Evidence from the Pacific. *Journal of Development Economics* 95(1), 18–29.
- [30] Gong, X. & A. van Soest (2002). Wage differentials and mobility in the urban labour market: a panel data analysis for Mexico. *Labour Economics* 9(4), 513–529.
- [31] Grubel, H. & A. Scott. (1966). The International Flow of Human Capital, *American Economic Review* 56(1/2), 268–274.
- [32] Günther, I. & A. Launov (2012). Informal Employment in Developing Countries. Opportunity or Last Resort? *Journal of Development Economics* 97, 88–98.
- [33] Haan, H.C. (2006). Training for Work in the Informal Micro-Enterprise Sector: Fresh Evidence from Sub-Sahara Africa. Unesco-Unevoc, Springer, The Netherlands
- [34] Haque, N.U. & S.-J. Kim (1995). Human Capital Flight’: Impact of Migration on Income and Growth. *International Monetary Fund Staff Papers* 42(3), 577–607.
- [35] Hendricks, Lutz, (2004). A database of Mincerian earnings regressions. <http://www.lhendricks.org/Mincer.htm>.

- [36] Iftikhar, Z. and Zaharieva A. (2016). General Equilibrium Effects of Immigration in Germany: Search and Matching Approach, No 2017008, Discussion Papers (IRES - Institut de Recherches Economiques et Sociales)
- [37] International Labour Office (2002). Decent Work and the Informal Economy. Report of the Director-General, International Labour Conference, 90th Session, Report VI, ILO, Geneva.
- [38] ILO/WTO (2009). Globalization and Informal Jobs in Developing Countries.
- [39] Iranzo, S. & G. Peri (2009). Migration and trade: Theory with an application to the Eastern-Western European integration. *Journal of International Economics* 79(1), 1–19.
- [40] Javorcik, B.S. & C. Ozden & M. Spatareanu & C. Neagu (2011). Migrant networks and foreign direct investment. *Journal of Development Economics* 94(2), 231–241.
- [41] Kennan, J. (2013). Open borders. *Review of Economic Dynamics* 16(2), 1-13.
- [42] Klein, P. & Ventura, G. (2009). Productivity differences and the dynamic effects of labor movements. *Journal of Monetary Economics* 56(8), 1059-1073.
- [43] Kremer, M. & D. Chen (1999). Income-distribution dynamics with endogenous fertility. *American Economic Review* 89(2), 155–160.
- [44] Kugler, M. & H. Rapoport (2007). International labor and capital flows: Complements or substitutes? *Economics Letters* 94(2), 155–162.
- [45] Krugman, P. (1991). History versus Expectations. *Quarterly Journal of Economics* 106, 651–67.
- [46] Leal Ordonez, J.C. (2014). Tax Collection, the Informal Sector, and Productivity. *Review of Economic Dynamics* 17, 262–286.
- [47] Maloney, W.F. (2004). Informality Revisited. *World Development* 32, 1159–1178.
- [48] Margolis, D.N. & L. Navarro & D. Robalino (2012). Unemployment Insurance, Job Search and Informal Employment. IZA Discussion Paper 6660.
- [49] McCulloch, R. & J.L. Yellen (1977). Factor Mobility, Regional Development, and the Distribution of Income. *Journal of Political Economy* 85(1), 79–96.
- [50] McKinsey (Global Institute) (2012). Africa at Work: Job Creation and Inclusive Growth.
- [51] Miyagiwa, K. (1991). Scale Economies in Education and the Brain Drain Problem. *International Economic Review* 32(3), 743–59.
- [52] Mookherjee, D. & D. Ray (2003). Persistent inequality. *Review of Economic Studies* 70, 369-393.
- [53] Moreno-Galbis, E. & A. Tritah (2016). The effects of immigration in frictional labor markets: Theory and empirical evidence from EU countries. *European Economic Review* 84(C), 76-98.

- [54] Mountford, A. (1997). Can a Brain Drain Be Good for Growth in the Source Economy? *Journal of Development Economics* 53(2), 287–303.
- [55] Murphy, K.M. & A. Shleifer & R.W. Vishny (1989). Industrialization and the Big Push. *Journal of Political Economy* 97, 1003–1026.
- [56] Murphy, K.M. & A. Shleifer & R.W. Vishny (1991). The Allocation of Talent: Implications for Growth. *Quarterly Journal of Economics* 106(2), 503–530
- [57] Ortega J., (2000). Pareto-Improving Immigration in an Economy with Equilibrium Unemployment. *The Economic Journal*, 110, 92–112.
- [58] Ottaviano, G.I. & G. Peri (2012). Rethinking the effect of immigration on wages. *Journal of the European Economic Association* 10(1), 152–197.
- [59] Parsons, C. R. & P.L. Vezina (2017). Migrant networks and trade: The Vietnamese boat people as a natural experiment. *The Economic Journal*, forthcoming.
- [60] Pissarides, C. (2000). *Equilibrium Unemployment Theory*. Second edition. MIT Press, Cambridge, MA, pp. 252.
- [61] Robalino, D. & M. Weber (2013). Designing and implementing unemployment benefit systems in middle and low income countries: beyond risk-pooling vs savings. *IZA Journal of Labor Policy* 2(1), 1–20.
- [62] Rodriguez, C. (1975). On the Welfare Aspects of International Migration. *Journal of Political Economy* 83(5), 1065–1072.
- [63] Rodrik, D. (2013). Unconditional Convergence in Manufacturing, *Quarterly Journal of Economics* 128(1), 165–204.
- [64] Satchi, M. & Temple, J. (2009). Online Appendix for "Labor Markets and Productivity in Developing Countries". Technical Appendices 06-167, Review of Economic Dynamics.
- [65] Schneider, F. (2005). Shadow Economies around the World: What do we really know?. *European Journal of Political Economy* 21, 598–642.
- [66] Schneider, F. (2014). The Shadow Economy and Shadow Labor Force: A Survey of Recent Developments. IZA Discussion Paper 8278.
- [67] Shrestha, S.A (2017). No man left behind: Effects of emigration prospects on educational and labour outcomes of non-migrants. *Economic Journal* 127(600), 495–521.
- [68] Stark, O. & C. Helmenstein & A. Prskawetz (1997). A Brain Gain with a Brain Drain. *Economics Letters* 55(2), 227–34.
- [69] Stark, O. & C. Helmenstein & A. Prskawetz (1998). Human Capital Depletion, Human Capital Formation, and Migration: A Blessing or a 'Curse?'. *Economics Letters* 60(3), 363–67.

- [70] Theoharides, C. (2017). Manila to Malaysia, Quezon to Qatar: International Migration and its Effects on Origin-Country Human Capital. *Journal of Human Resources*, forthcoming.
- [71] United Nations (2015). UN Commission for Africa
- [72] Verick, S.(2008). The Impact of Globalization on the Informal Sector in Africa. Economic and Social Policy Division, UNECA, Addis Ababa.
- [73] Vodopivec, M. (2013). Introducing unemployment insurance to developing countries. *IZA Journal of Labor Policy* 2(1), 1–23.
- [74] Walther, R. (2006). Vocational Training in the Informal Sector: Report on the South Africa Field Survey. Working Paper No. 30, Department of Research, Agence Francaise de Developpement, Paris.
- [75] World Bank (2014). The State of Social Safety Nets. The World Bank, Washington, DC.
- [76] World Bank (2016). World Development Indicators. The World Bank, Washington, DC.
- [77] Yashiv, E. (2000). The Determinants of Equilibrium Unemployment. *American Economic Review* 90(5), 1297–1322
- [78] Zenou, Y. (2008). Job Search and Mobility in Developing ountries. Theory and Policy Implications. *Journal of Development Economics*. Vol.86, 336–355.

Supplementary Appendix

A Parameterization

Table A1 reports the descriptive stats for the sample.

Table A1. Descriptive stats				
Variable	Mean	St. dev.	Min	Max
Pop. growth differential	0.0531	0.0117	0.0205	0.0770
Informality rate	0.5423	0.1463	0.3390	0.8000
Informal Activities (as percentage of official GNP)	0.2538	0.0815	0.1540	0.4880
Official GDP per worker in PPP	3592.99	4939.64	459.19	24781.91
Proportion of college-educated (as % of labor force)	0.0218	0.0146	0.0040	0.0594
Brain drain (as % of college-educated labor force)	0.1790	0.1594	0.0256	0.6784
Share of low-skilled in informality	0.5480	0.1466	0.3481	0.8053
Share of high-skilled in informality	0.2740	0.0733	0.1740	0.4026

Table A2 reports the calibrated value of parameters with country-specific variations, i.e. the set $\{A_F, \alpha, \psi, p, \rho, g, \mu_L, \mu_H\}$.

Table A2. Parameters with country-specific variations

Country	ISO	A_F	α	ψ	p	ρ	g	μ_L	μ_H
Angola	AGO	2000.7	0.458	0.096	1.98E-04	1.06E-04	5.35E-03	0.175	0.325
Benin	BEN	2854.0	0.445	0.032	3.88E-04	3.94E-05	4.43E-03	0.041	0.127
Bostwana	BWA	9243.8	0.394	0.065	1.28E-04	4.46E-05	2.44E-03	0.120	0.238
Burkina Faso	BFA	1488.7	0.437	0.049	1.29E-04	4.30E-05	4.99E-03	0.064	0.159
Cameroon	CMR	2166.2	0.502	0.052	7.47E-04	4.83E-05	4.28E-03	0.069	0.168
Chad	TCD	317.0	0.783	0.198	5.16E-04	1.35E-05	5.61E-03	0.161	0.314
Congo, Dem Rep	COD	639.4	0.495	0.027	6.15E-04	2.97E-05	4.09E-03	0.036	0.119
Congo, Rep	COG	3488.1	0.389	0.061	1.54E-03	1.69E-04	5.40E-03	0.104	0.216
Cote d'Ivoire	CIV	1966.4	0.466	0.053	2.75E-04	7.20E-05	4.42E-03	0.071	0.172
Ethiopia	ETH	661.1	0.492	0.054	4.49E-04	4.57E-05	4.52E-03	0.071	0.171
Gabon	GAB	10927.53	0.600	0.094	5.04E-04	4.95E-05	3.42E-03	0.078	0.183
Gambia	GMB	1633.8	0.685	0.053	3.21E-03	2.02E-05	4.68E-03	0.037	0.120
Ghana	GHA	1226.4	0.631	0.059	1.61E-03	3.35E-05	3.56E-03	0.048	0.137
Guinea	GIN	2295.9	0.400	0.028	2.15E-04	4.56E-05	4.57E-03	0.038	0.122
Kenya	KEN	933.65	0.552	0.114	1.53E-03	3.85E-05	3.92E-03	0.146	0.276
Lesotho	LSO	677.23	0.620	0.106	1.20E-04	1.30E-05	2.88E-03	0.144	0.288
Liberia	LBR	325.1	0.501	0.110	1.95E-03	9.40E-05	4.36E-03	0.182	0.329
Madagascar	MDG	1089.2	0.462	0.064	3.15E-04	5.01E-05	4.04E-03	0.081	0.183
Malawi	MWI	483.7	0.462	0.064	1.00E-03	1.55E-05	4.75E-03	0.097	0.211
Mali	MLI	449.0	0.656	0.144	8.09E-04	1.86E-05	5.41E-03	0.173	0.325
Mauritania	MRT	1178.7	0.514	0.101	3.57E-04	3.94E-05	4.10E-03	0.144	0.275
Namibia	NAM	4269.7	0.430	0.070	1.02E-04	5.31E-05	2.99E-03	0.111	0.227
Niger	NER	433.9	0.656	0.114	3.41E-04	1.40E-05	6.16E-03	0.103	0.220
Nigeria	NGA	1496.9	0.433	0.151	5.08E-04	7.59E-05	4.80E-03	0.155	0.231
Rwanda	RWA	936.5	0.643	0.059	1.30E-03	1.40E-05	4.07E-03	0.045	0.131
Senegal	SEN	1911.9	0.480	0.055	7.36E-04	5.19E-05	4.24E-03	0.068	0.166
Sierra Leone	SLE	525.8	0.587	0.046	2.28E-03	4.04E-05	4.60E-03	0.052	0.143
Sudan	SDN	1005.4	0.519	0.077	2.78E-04	3.70E-05	4.03E-03	0.128	0.261
Tanzania	TZA	716.7	0.510	0.101	5.50E-04	4.63E-05	4.50E-03	0.139	0.267
Togo	TGO	703.4	0.451	0.072	6.90E-04	4.84E-05	4.14E-03	0.150	0.288
Tunisia	TUN	5271.3	0.391	0.051	2.14E-04	5.36E-05	1.65E-03	0.076	0.175
Uganda	UGA	784.4	0.603	0.091	1.90E-03	3.57E-05	5.23E-03	0.085	0.191
Zimbabwe	ZWE	202.3	0.393	0.088	4.30E-04	9.22E-05	3.25E-03	0.189	0.332
Mean	-	1947.5	0.522	0.080	7.86E-04	4.82E-05	4.27E-03	0.103	0.214
St. Dev.	-	2407.7	0.103	0.036	7.38E-04	3.17E-05	9.36E-04	0.048	0.069
Coeff. Var.	-	1.236	0.196	0.470	0.939	0.657	0.219	0.467	0.322

Table A3 gives the cross-country correlation between these calibrated parameters.

Table A3. Correlation between country-specific parameters

	A_F	α	A_I/A_F	p	ρ	g	μ_L	μ_H
A_F	1.000	-0.286	-0.190	-0.234	0.169	0.493	-0.167	-0.175
α	-	1.000	0.492	0.423	-0.641	0.369	-0.019	-0.040
A_I/A_F	-	-	1.000	-0.056	-0.111	0.320	0.755	0.736
p	-	-	-	1.000	0.001	0.237	-0.208	-0.210
ρ	-	-	-	-	1.000	0.048	0.269	0.221
g	-	-	-	-	-	1.000	0.058	0.064
μ_L	-	-	-	-	-	-	1.000	0.986
μ_H	-	-	-	-	-	-	-	1.000

B Decomposition of baseline results

Table A4 gives the results of the decomposition of the expected income response for the low-skilled.

Table A4. Decomposition of $\Delta \bar{w}_L / \bar{w}_L$

Country	R	R^A	R/R^A	$R - R^A$	$R - R^Z$	$R - R^M$	$R - R^T$
Angola	-1.0%	-0.8%	1.153	-0.1%	-0.1%	-0.1%	-0.1%
Benin	-2.0%	-1.5%	1.330	-0.5%	0.1%	-0.1%	-1.1%
Bostwana	-1.6%	-0.6%	2.806	-1.0%	-0.8%	0.0%	-0.6%
Burkina Faso	-0.6%	-0.6%	1.044	0.0%	0.1%	0.0%	-0.2%
Cameroon	-3.0%	-2.6%	1.151	-0.4%	-0.2%	0.0%	-0.6%
Chad	-0.2%	-2.1%	0.118	1.7%	0.3%	0.0%	0.6%
Congo, Dem Rep	-2.8%	-2.3%	1.249	-0.6%	0.2%	-0.3%	-0.8%
Congo, Rep	-7.9%	-4.4%	1.798	-3.5%	-2.0%	0.0%	-2.3%
Cote d'Ivoire	-1.6%	-1.1%	1.429	-0.5%	-0.3%	0.0%	-0.3%
Ethiopia	-1.9%	-1.7%	1.066	-0.1%	0.1%	0.0%	-0.1%
Gabon	-1.9%	-1.9%	1.015	0.0%	-0.6%	0.0%	-0.7%
Gambia	-2.8%	-6.6%	0.430	3.8%	1.3%	-0.4%	-0.1%
Ghana	-3.7%	-4.5%	0.816	0.8%	-0.3%	-0.2%	0.6%
Guinea	-1.4%	-0.9%	1.502	-0.5%	0.1%	0.0%	-0.8%
Kenya	-3.5%	-4.4%	0.802	0.9%	-0.2%	-0.1%	1.0%
Lesotho	-0.3%	-0.5%	0.646	0.2%	0.0%	0.0%	0.2%
Liberia	-6.2%	-5.1%	1.231	-1.2%	-1.7%	-0.3%	0.3%
Madagascar	-1.7%	-1.3%	1.297	-0.4%	-0.2%	0.0%	-0.2%
Malawi	-1.0%	-3.3%	0.314	2.2%	0.7%	0.0%	0.9%
Mali	-0.8%	-2.8%	0.269	2.0%	0.7%	0.0%	0.7%
Mauritania	-1.4%	-1.3%	0.907	0.1%	0.0%	0.0%	0.2%
Namibia	-1.0%	-0.4%	2.130	-0.5%	-0.4%	0.0%	-0.2%
Niger	-0.3%	-1.4%	0.207	1.1%	0.4%	0.0%	0.3%
Nigeria	-1.8%	-1.9%	0.940	0.1%	-0.2%	-0.2%	0.2%
Rwanda	-1.8%	-3.9%	0.459	2.1%	0.8%	-0.1%	0.5%
Senegal	-3.2%	-2.6%	1.244	-0.6%	-0.3%	0.0%	-0.6%
Sierra Leone	-4.6%	-5.5%	0.829	0.9%	0.4%	-0.4%	0.6%
Sudan	-1.1%	-1.1%	0.954	0.1%	0.0%	0.0%	0.1%
Tanzania	-1.8%	-2.1%	0.870	0.3%	0.0%	0.0%	0.2%
Togo	-3.0%	-2.5%	1.230	-0.6%	-0.3%	0.0%	-0.4%
Tunisia	-4.5%	-0.9%	5.025	-3.6%	-3.3%	0.1%	-2.0%
Uganda	-2.6%	-5.0%	0.526	2.4%	0.8%	0.0%	1.2%
Zimbabwe	-4.0%	-1.7%	2.381	-2.3%	-1.9%	-0.3%	-0.9%

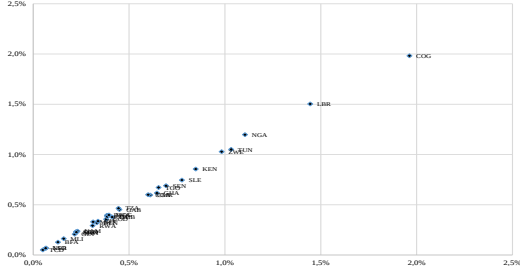
C Robustness analysis

Robustness to parameter values. – Before explaining these cross-country differences in the labor market responses for the low-skilled, let us demonstrate that such heterogeneous responses are not driven by our calibration strategy. Most of our common parameters are calibrated in line with the existing literature, and the country-specific parameters are calibrated to match some moments. However, by using $\beta = 0.7$, we deviate from the vast majority of studies conducted for developed economies. In addition, in the absence of data on informal employment by education level, our baseline calibration arbitrarily assumes that $i_H/i_L = 0.5$ (i.e., the share of informal employment of the high-skilled is half of the low-skilled). Finally, when simulating the no-migration counterfactual, we assume that the absolute cost of posting a vacancy remains constant. On Figure A1, we consider three alternative scenarios: (i) one with $\beta = 0.5$, (ii) one assuming $i_H/i_L = 0.25$ in the pre-shock economy, and (iii) one assuming $k_s = 0.4\omega_S$ in both pre-shock and counterfactual equilibria. Focusing on the employment and wage responses of the low-skilled, Figure A1 compares the baseline results from Figure 2 (on the horizontal axis) with the alternative results (on the vertical axis). All other country-specific parameters are recalibrated to match the moments, in line with the last column of Table 1.

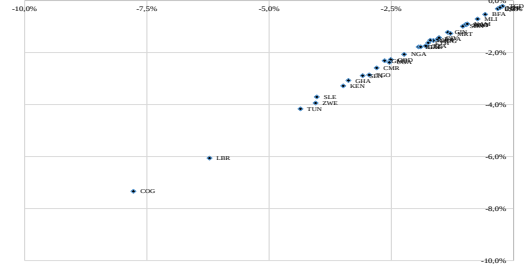
Figures A1.b, A1.d and A1.f show that our results for the wage effects are highly robust to our three identifying assumptions (the baseline and alternative responses are remarkably close to the 45° line). Similarly, Figure A1.a and A1.c shows that our results for the employment effects are highly robust to the choice of β and i_H/i_L . Smaller employment responses are obtained when $k_s = 0.4\omega_S$ in the after-shock economy: this is because the decrease in ω_S negatively impacts the cost of posting a vacancy, therefore attenuating the employment response. However, the results are qualitatively similar.

Fig A1. Sensitivity of Δi_L and $\frac{\Delta \omega_L}{\omega_L}$ to identifying assumptions; (Horizontal axis: baseline; Vertical axis: Alternative identifying assumptions)

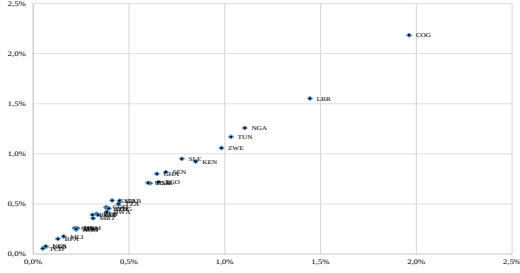
A1.a. Calibration with $\beta = 0.5(\Delta i_L)$



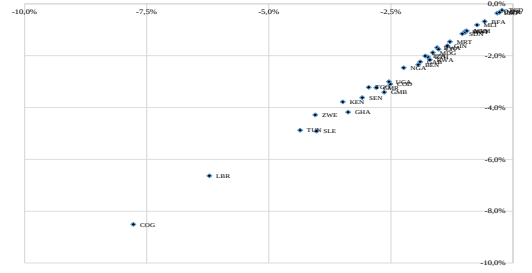
A1.b. Calibration with $\beta = 0.5(\frac{\Delta \omega_L}{\omega_L})$



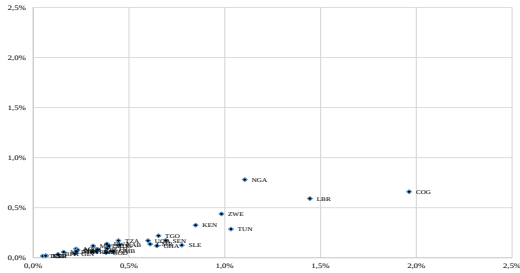
A1.c. Calibration with $\frac{i_H}{i_L} = 0.25(\Delta i_L)$



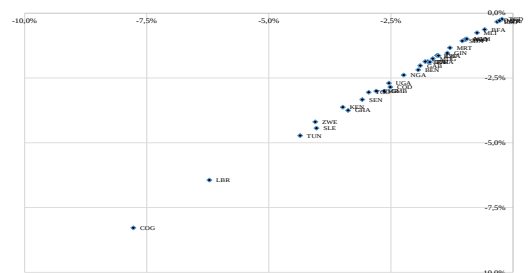
A1.d. Calibration with $\frac{i_H}{i_L} = 0.25(\frac{\Delta \omega_L}{\omega_L})$



A1.e. Calibration with $k_s = 0.4w_s(\Delta i_L)$



A1.f. Calibration with $k_s = 0.4w_s(\frac{\Delta \omega_L}{\omega_L})$



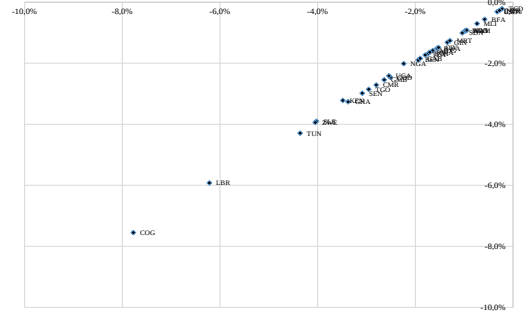
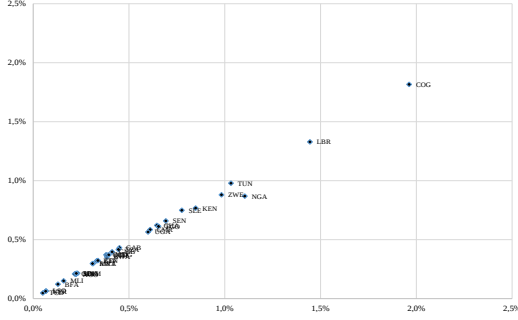
Robustness to the technological environment. – In line with Murphy et al. (1989, 1991), Brezis et al. (1993), Mookherjee and Ray (2010) and Docquier et al. (2017), our benchmark model assumes a linear technology in the informal economy. There is, however, a big deal of uncertainty about the way to model the technology of the informal sector. Heterogeneity in informal firms' productivity has been documented in Fields (1990, 2005) and Gunther and Launov (2012), who identify the existence of an upper-tier and a lower-tier (or easy-entry) parts of the informal economy. The latter consists of employment that is free-entry, low wage, and undesirable relative to formal sector employment. The former consists of employment (either wage or self-employment) that is limited-entry and closer to formal sector employment. Still, the upper-tier sector mainly comprises small-scale, low-productivity, frequently family-based enterprises employing low-skilled workers (Maloney 2004). To assess the sensitivity of our results to the technological environment, we consider three alternative production functions for informal firms: (i) the first one is a linear production function with a constant productivity gap between high-skilled and low-skilled workers; (ii) the second one is a CES production function with an

elasticity of substitution equal to 4 (σ_I); the third one is a CES function with $\sigma_I = 2$. In all cases, the parameters are re-calibrated to match the average productivity of informal firms as well as the skill premium of the formal economy.

Figure A2 compares the employment and wage responses of the low-skilled under the benchmark model (on the horizontal axis) and under the technological variants (on the vertical axis). Figure A2.a, A2.c and A2.e shows that the employment responses are highly robust to the technological environment. Figure A2.b, A2.d and A2.f shows that the wage effects are also highly robust. The heterogeneous responses to the brain drain are not driven by our technological specifications.

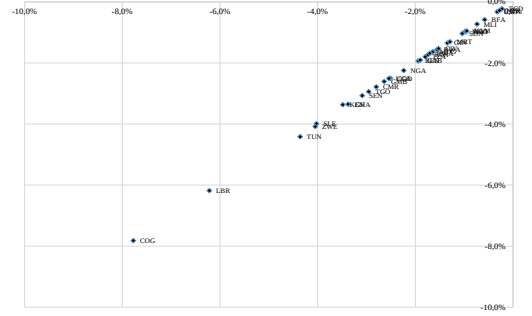
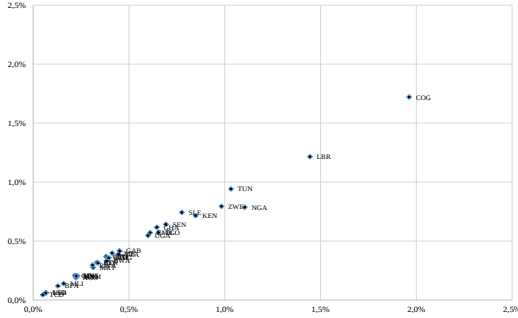
Fig A2. Sensitivity of Δi_L and $\frac{\Delta \omega_L}{\omega_L}$ to the technological environment

A2.a. Linear techn. with skill premium Δi_L A2.b. Linear techn. with skill premium $\frac{\Delta \omega_L}{\omega_L}$



A2.c. CES with $\sigma = 4(i_L)$

A2.d. CES with $\sigma = 4(\frac{\Delta \omega_L}{\omega_L})$



A2.e. CES with $\sigma = 2(i_L)$

A2.f. CES with $\sigma = 2(\frac{\Delta \omega_L}{\omega_L})$

