Abstract

This dissertation consists of three chapters, all of them are self-contained works.

The first chapter, "Globalizing labor and the world economy: the role of human capital" is a joint work with Prof. Dr. Frédéric Docquier and Dr. Joël Machado. We develop a microfounded model of the world economy aiming to compare short- and long-run effects of migration restrictions on the world distribution of income. We find that a complete removal of migration barriers would increase the world average level of GDP per worker by 13% in the short run and by about 54% after one century. These results are very robust to our identification strategy and technological assumptions.

The second chapter, titled "Infrastructure Policy: the role of informality and brain drain" analyses the effectiveness of infrastructure policy in developing countries. I show that, at low level of development, the possibility to work informally has a detrimental impact on infrastructure accumulation. I find that increasing the tax rate or enlarging the tax base can reduce the macroeconomic performance in the short run, while inducing long-run gains. These effects are amplified when brain drain is endogenous.

The last chapter, titled "The role of fees in foreign education: evidence from Italy and the UK" is mainly empirical. Relying upon a discrete choice model, together with Prof. Dr. Michel Beine and Prof. Dr. Lionel Ragot I assess the determinants of international students mobility exploiting, for the first time in the literature, data at the university level. We focus on student inflows to Italy and the UK, countries on which tuition fees varies across universities. We obtain evidence for a clear and negative impact of tuition fees on international students inflows and confirm the positive impact of quality of education. The estimations find also support for an important role of additional destination-specific variables such as host capacity, expected return of education and cost of living in the vicinity of the university.

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Contents

Introduction

This thesis aims to provide contributions to the economics of international migration literature. Nowadays, immigration-related issues occupy the top of the policy-makers agenda in the developed world. Plenty of examples can be provided, it suffices to mention either the current political campaign for the US presidency or the recent vote in the UK for the "*Brexit*",[1] to get a quick understanding of the importance that the subject has gained. The large interest on migration issues in the political arena is reflected in the economics literature, where research on migration has grown sharply in volume emerging as a proper subfield as well (see Clemens et al. (2014)).

This manuscript is divided in three chapters, each one readable as a distinct paper. I present them following their chronological order of development. Chapter 1 and Chapter 2 follow a quantitative approach. Both chapters, set a theory which is then parametrized. Finally, counterfactual experiments are conducted to assess the effectiveness of different policies.

On the contrary, Chapter 3 exploits a newly developed dataset to (econometrically) assess the determinants of international students mobility.

Chapter 1, co-authored with Prof. Dr. Frédéric Docquier and Dr. Joël Machado, is titled "Globalizing labor and the world economy: the role of human capital". It provides new estimates on the economic impact of liberalizing migration borders. As Hatton (2014) reports, the majority of voters in most developed countries oppose immigration and this position is much more pronounced among low-skilled individuals. This chapter disregards the policy formation process or, in a clearer way, it does not study the process which leads to the implementation of one migration-policy in place of another one. On the contrary, it provides new estimates of the impact of opening borders on both efficiency (GDP per worker) and inequality.

This paper defines a microfounded model of the world economy able to highlight the link between immigration policies and human-capital accumulation. The literature has already shown that emigration prospects affect the incentives to acquire higher education. Additionally, our model also accounts for the fact that both fertility and education choices are location specific. Relying on this theoretical framework we evaluate the impact that opening borders would have on the trajectory of the two aforementioned individuals' (households) choices.

Our quantitative analysis reveals that the effects of liberalizing migration on human-capital accumu-

[1] The political debate is getting tougher, for instance the GOP candidate for the US presidency said that "I will build a great wall- and nobody builds better than me, believe me- and I'll build them very inexpensively. I will build a great, great wall on our southern border, and I will make Mexico pay for that wall. Mark my words".

lation, income and inequality are gradual and cumulative. In case of a complete removal of migration barriers, the world average level of GDP per worker increases by 13% in the short run, and by about 54% after one century. In addition, liberalizing migration gradually reduces the Theil index of inequality. These results are very robust to our identifying strategy and technological assumptions. Sizable differences are only obtained when we allow for an externality of schooling or cultural diversity on productivity, and when our baseline (pre-liberalization) scenario involves a rapid takeoff of sub-Saharan Africa or emerging countries.

Chapter 2 is titled "Infrastructure policy: the role of informality and brain drain". Its main focus is on the link between infrastructure accumulation and the informal economy in developing countries. It also highlights the links between these two factors and the emigration of the highly skilled, "*brain drain*". There is substantial evidence on the positive impact of infrastructure investments on development, (for instance see Calderon and Serven (2014)). However, in most developing countries a large fraction of individuals work in the informal economy not contributing to the implementation of massive infrastructure investments. Also, a low level of development incentivizes emigration, especially of high-skilled individuals. In this chapter, I develop a two-sector dynamic model with endogenous infrastructure and human capital accumulation in the presence of these two exit options. Then, I calibrate the model for a subset of 60 developing countries, and conduct numerical policy experiments. I show that, at a low level of development, the possibility to work informally has a detrimental impact on the infrastructure accumulation. Hence, increasing the tax rate or enlarging the tax base can reduce the macroeconomic performance in the short run, while inducing long-run gains. These short- and long-run effects are amplified when brain drain is endogenous, they are also greater where the initial level of infrastructure is low and the brain drain is large.

Chapter 3, "The role of fees in foreign education: evidence from Italy and the UK" is mainly empirical. This paper, co-authored with with Prof. Dr. Michel Beine and Prof. Dr. Lionel Ragot, aims to contribute at the literature devoted to the identification of factors influencing the location choice of foreign students. Foreign higher education is an important economic subject for several reasons. First, the number of international students has increased at a fast pace; while there were 0.6 millions international students in 1975, the OECD and UNESCO counted 4.5 millions of international students in 2012. Second, developed countries need to know which are the pull factors of international-students mobility when competing for attracting the best and the brightest talents. Importantly, Spilimbergo (2009) shows that foreign-educated individuals promote democracy in their home country, but only if education is acquired in democratic countries. We derive a gravity model based on a Random Utility Maximization model of location choice for international students. The last layer of the model is estimated using new data on students migration-flows at the university level for Italy and the UK. The particular institutional setting of the two destination countries allows to control for the potential endogeneity of tuition fees. We obtain evidence of a clear and negative effect of tuition fees on international-student mobility and confirm the positive impact of quality of education. The estimations find also support for an important role of additional destination-specific variables such as host capacity, expected return of education and cost of living in the vicinity of the university.

In summary, the main findings of this thesis are the following ones: first, it shows that the economic impact of opening borders is greater in the long run than in the short run; second it obtains that more restrictive fiscal policies leading to larger infrastructure investments may trigger development in the long run; finally it reports that controlling for all other factors, tuition fees have a repulsive impact on international students mobility.

1

Globalizing labor and the world economy: the role of human capital

This paper is a joint work with Prof. Dr. Frédéric Docquier and Dr. Joël Machado

Abstract

We develop a dynamic microfounded model of the world economy that jointly endogenizes income inequality and individual decisions about fertility, education and migration. We then use it to compare the short- and long-run effects of immigration restrictions on the world distribution of income. Our calibration strategy perfectly fits the economic and demographic characteristics of the world, and allows us to identify bilateral migration costs and visa costs for each pair of countries and two classes of workers. Our quantitative analysis reveals that the effects of liberalizing migration on human capital accumulation, income and inequality are gradual and cumulative. In case of a complete removal of migration barriers, the world average level of GDP per worker increases by 13 percent in the short run, and by about 54 percent after one century. In addition, liberalizing migration gradually reduces the Theil index of inequality. These results are very robust to our identifying strategy and technological assumptions. Sizeable differences are only obtained when we allow for an externality of schooling or cultural diversity on productivity, and when our baseline (pre-liberalization) scenario involves a rapid takeoff of sub-Saharan Africa or emerging countries.

1.1 Introduction

This paper provides a unified theory of bilateral migration, human capital formation, population growth and worldwide income inequality. We use it to investigate the short-run and long-run effects of immigration restrictions on the world economy. Our model is parametrized to match the recent evolution of the world economy, to fit the demographic projections of the United Nations for the 21^{st} century, and to match the numbers of actual migrants (those who have already migrated) and desiring migrants (those who have not yet migrated but express a desire to do so). Availability of bilateral data on actual and desired migration enables us to identify total migration costs and visa costs (i.e. policy-induced costs borne by migrants to overcome the legal hurdles set by national authorities in destination and origin countries) as residuals of the migration technology. Although we find limited gains from removing migration barriers in the short-run, we argue that long-run effects can be much greater. The reason is that relaxing migration barriers stimulates human capital formation and reduces the world population growth rate. These socio-demographic gains have been disregarded in the existing literature. Part of them are due to the well-known *brain gain* mechanism, i.e. the effect of emigration prospects on the expected returns to higher education. However, the main portion of these gains is purely mechanical and less disputable: new migrants from developing to industrialized countries face a policy environment conducive to reduce their fertility and increase investments in the basic education of their offspring. As basic education is a prerequisite for higher education, this gradually increases the worldwide level of human capital and shifts the world production frontier upwards.

The debate on the global efficiency and inequality implications of immigration barriers has been recently revived in the academic literature. Some economists argue that immigration restrictions are responsible for "trillion-dollar bills [left] on the sidewalk" (a summary of the existing literature is provided in Clemens (2011)). In particular, these regulations are perceived as carrying considerable economic costs for developing countries and preventing global inequality from declining Pritchett (2006). Most studies show that liberalizing migration displaces billions of people, mainly from developing to industrialized countries (i.e. from South to North). They find that liberalizing labor mobility induces an increase in the world GDP in the range of 50 to 150 percent, making labor mobility the greatest source of efficiency gains to expect from globalization.[1] These benefits would mainly accrue to the emigrants originating from poor countries. Still, aggregate gains can be obtained for the host population through the immigration surplus; however, the latter are unequally distributed among capitalists and workers, or among categories of workers.

A few recent contributions questioned the realism of the above-mentioned gains. On the one hand, Collier (2013) and Borjas (2015) emphasized the social and cultural challenges that such large movements of people may induce. The reasoning is the following: by importing their "bad"cultural, social and institutional models, migrants may contaminate the entire set of institutions in their country of adoption, levelling downwards the world distribution of technological capacity. Removing migration barriers can reduce the worldwide level of income per capita if such contagion spillovers are large enough. There is however no evidence that such contagion effects are important and unidirectional. On the contrary, at current migration levels, many studies evidenced a positive transfer of technological, political and behavioral norms from rich to poor countries (Spilimbergo (2009), Andersen and Dalgaard (2011), Beine et al. (2008), Beine et al. (2013), Bertoli and Marchetta (2015)). It is however legitimate to argue that displacing billions of workers from South to North could induce large spillovers of a different nature. On the other hand, Docquier et al. (2015) argued that removing migration barriers would generate much fewer

[1]In comparison, removing the remaining barriers to trade and capital flows would generate small increases in world GDP ranging from 0.5 to 4 percent for trade, and from 0.1 to 1.7 percent for capital (Clemens (2011)).

migrants than what existing studies predict. Using the Gallup World Poll survey, they estimate that the worldwide number of potential working-age migrants was around 386 million in 2000.[2] This is six times smaller than in previous studies and certainly tones down the risk of a massive technological or cultural contagion. As far as efficiency is concerned, they obtain efficiency gains in the neighborhood of 11.5 percent of the world GDP, in partial equilibrium or with a standard constant-elasticity-of-substitution technology. When various spillover effects are factored in, the gains remain limited, in the range of 7 percent (with congestion and schooling externalities in production) to 17 percent (with migration network effects).

The whole literature on the welfare implication of immigration restrictions has adopted a short-run or medium-run perspective, assuming a constant size and skill structure of the world population. Overall, it concludes that the uncertainty surrounding the size of the gains from globalization is large, both because the global income gains from letting workers move and the migration response to abolishing barriers are unclear. In line with Docquier et al. (2015), we admit that the short-run effects of immigration barriers might be limited. However, we argue here that the long-run effects are much more important. The reason is that the existing literature has largely disregarded the interdependences between migration decisions and the evolution of the world population.[3] Changes in migration flows are likely to affect education and fertility decisions. The majority of new migrants move from poor to rich countries and assimilate in terms of fertility and education. Compared to their home country, policies towards basic education in the North (such as mandatory education, generous subsidies, greater quality of education, etc.) make basic education much more accessible for the new migrants' offspring. This increases the pool of young adults who will be eligible for higher education in the future generation. Exposed to a new environment and different norms, migrants also change their fertility decisions. Many studies on internal migration have found that it leads to convergence of fertility rates between migrants and urban natives.[4] Convergence is also obtained in studies of international migration, including Stephen and Bean (1992) and Lindstrom and Saucedo (2002) for women of Mexican origin living in the US. [5] The effect of migration on fertility and education also operates ex-ante, i.e. before migration occurs. The recent literature has shown that emigration prospects stimulate incentives to acquire higher education in developing countries (see Stark et al. (1997), Mountford (1997), Beine et al. (2001); Beine et al. (2008), Easterly and Nyarko (2008), Docquier and Rapoport (2012)). This link between emigration prospects and human capital formation has been identified in the micro literature. Identification strategies rely on survey data on the student population, regional heterogeneity in emigration and education patterns, and quasi-natural emigration shocks. [6] Quasi-natural experiments are investigated in Chand and Clemens (2008) on Fiji, or Shrestha

[2]Potential migrants include those who have already migrated and current non migrants who express a desire to migrate. Data on desired emigration are described in Esipova et al. (2011).

[3]An exception is Mountford and Rapoport (2011), who developed a stylized model with endogenous education and fertility by individuals in the sending countries and in one representative receiving economy. They show that (exogenous) high-skilled migration shocks may improve the growth rate, and reduce the fertility rate of all the economies in the world. For the first time, we incorporate similar ingredients into a micro-founded macroeconomic model of the world economy including 195 receiving and sending countries, endogenize migration decisions, and then confront theory to data.

[4]See among others, Lee and Pol (1993) or Brockerhoff (1995).

[5]See also Chiswick and Miller (2012) and Fogli and Fernandez (2009).

[6]Survey data are used in Gibson and McKenzie (2011) on Tonga and Papua New Guinea or Kangasniemi et al. (2007) on medical doctors in the UK. Studies exploiting regional variations are Batista et al. (2012) on Cape Verde, McKenzie and

(2011) on Nepal.

Consequently, removing migration barriers reduces population growth and improves the skill structure of the world labor force. The implications for the world economy are cumulative and gradual.

Our contribution is two-fold. First, we build a fully microfounded model that encompasses all the channels aforementioned. Our framework is an abstract two-class overlapping-generations model (with college graduates and less educated workers), which highlights the major economic mechanisms underlying wage inequality and decisions about migration, fertility and education. Although the model is large (because 195 countries are included), the mechanisms are transparent. The model has only a few equations per country or country pair, uses consensus microfoundations, and can be parametrized using appropriate identification methods.

We then revisit the effects of a complete removal of migration barriers from 2000 onwards and investigate its impact on the world distribution of income, using our dynamical framework. This is an improvement with respect to the existing literature as the feedback effects from migration decisions on fertility and education decisions have so far been disregarded. Our quantitative analysis reveals that the long-run impact of migration restrictions exceeds by far the short-run impact. This is because liberalizing labor mobility reduces population growth and improves the skill structure of the world labor force. In line with Docquier et al. (2015) and the Gallup data in Esipova et al. (2011), a complete liberalization of labor mobility increases the proportion of international migrants from 3.5 to 12.3 percent in the short run. In our benchmark partial equilibrium scenario, the world average level of GDP per worker increases by 13.1 percent when the shock occurs.[7] The semi-elasticity of GDP to migration equals 1.5; this is slightly greater than the level obtained in previous studies because in our framework, better migration prospects stimulate the expected return to higher education and investments in college education. Moreover, additional migrants from poor to rich countries also face a new institutional environment which favors investments in the basic education of their offspring. This increases the pool of young adults who can access the higher education system among the next generation. Consequently, the rise in educational attainment and the changes in the world distribution of income are gradual and cumulative. By the year 2100, the effects are four times larger than in the short run (+53.8 percent in the worldwide level of GDP per capita). Our analysis shows that large efficiency gains can be expected from removing migration barriers, but these large gains mostly arise in the long run and will impact the welfare of future generations. As for inequality, the Theil index gradually decreases in all the scenarios. Again, the short-run effect is small (-1.6 percentage point) but the long-run effect is larger (-10.7 percentage points).

We also investigate the effects of partial liberalization reforms, i.e. cuts in legal migration restrictions by less than 100 percent. We show that the efficiency and inequality effects are roughly proportional to the "liberalization rate"; in other words, cutting legal moving costs by ϑ percent allows to realize slightly more than ϑ percent of the gains from a complete liberalization. We conduct a large set of robustness checks. Overall, our conclusions are very robust to our identifying strategy and to assumptions about the

Rapoport (2011) on Mexico, or Ha et al. (2016) on China.

[7]Throughout the paper, the GDP per adult worker is the income measure of interest.

technological environment. Results change only slightly when we use alternative interpretations of the Gallup data on desired migration, when we deactivate the *brain gain* mechanism, or when we consider many alternative specifications for the technologies of production and human capital formation. Sizeable differences are only obtained under three variants of the model. On the one hand, more optimistic results emerge when we consider the positive elasticity of productivity to birthplace diversity estimated in the macro literature (as in Ottaviano and Peri (2006) or Alesina et al. (2013)). On the other hand, more pessimistic results are found when we allow for schooling externalities in production, or when the baseline (pre-liberalization) trajectory of the world economy involves a rapid take off of sub-Saharan Africa or emerging countries.

The rest of this paper is organized as follows. A review of the literature on immigration barriers and income is provided in Section 1.2. In Section 1.3, we describe a micro-founded model that links income disparities and decisions about migration, education and fertility. The parametrization of the model is explained in Section 1.4. Partial equilibrium results are presented in Section 1.5. A large set of extensions and robustness checks are discussed in Section 1.6. Finally, Section 1.7 concludes.

1.2 Literature review

Many studies have highlighted the global benefits from removing immigration restrictions. Some treated migration as the outcome of a central planning problem (Benhabib and Jovanovic (2012); de la Croix and Docquier (2015)) and provided theoretical and numerical predictions, using a stylized representation of the world economy (one developing region and several destination countries, or a two-region framework) and a simple treatment of moving costs (neglected, or calibrated using US interstate transportation costs). Others investigated the economic impact of abolishing migration barriers using stylized models with two regions (Iranzo and Peri (2009a), Klein and Ventura (2009)) or with a single "preferred" location for the new migrants Kennan (2013). In these studies, the gains from removing migration restrictions arise from the differences in total factor productivity across countries. These differences are magnified by the mobility of physical capital, which "chases" labor.

Other recent studies evaluated the welfare impact of observed levels of migration. For example, Giovanni et al. (2015) found positive effects of existing migration flows for both receiving and sending countries. In their model, the gains in receiving countries arise from greater product variety available in consumption and intermediate inputs. The gains in sending countries are due to incoming remittances. Using a similar framework with market-size effects, Aubry et al. (2016) showed that most OECD countries benefit from South-North migration, while intra-OECD migration is a zero-sum game with many losers and only few winners. In the same vein, Battisti et al. (2014) also found positive effect of immigration to OECD countries in a model of search and matching in which native and immigrant workers differ with respect to job break-up risks and outside options. Although informative about the mechanisms at work, these models do not cover the whole world economy or do not deal with a worldwide liberalization of migration. Numerical illustrations provided in these studies are therefore too specific to be transposed to the world economy.

A second strand of literature uses multi-region models of the world economy to simulate the effect of exogenous migration shocks. In particular, Winters (2001) or Walmsley and Winters (2005) simulated the effect of an exogenous increase in developed countries' immigration quotas on both high-skilled and low-skilled migrants equivalent to 3 percent of the labor force (i.e. 0.45 percent of the world labor force). Using a global computational-general-equilibrium model with two skill levels, they predicted a $150 billion increase in the world GDP (+0.6 percent), i.e. a semi-elasticity of the world GDP to the share of migrants of about 1.3. Migration is treated as an exogenous variable and their model cannot be used to infer the effect of a complete removal of migration restrictions.

The endogeneity of migration decisions has been accounted for in a third strand of literature. Most of these studies use static models and assume that a complete liberalization would lead to (real) wage equalization across countries. On average, they predict that (i) at least 50 percent of the world population would live in a foreign country after a complete liberalization, and (ii) eliminating all restrictions to labor mobility would induce huge efficiency gains in the range of 50 to 150 percent of world GDP. A summary of these predictions is provided in Clemens (2011). More precisely, in a scenario assuming mobile physical capital and no differences in inherent productivity of people (i.e. a Mexican worker migrating to the US is as productive as a US citizen), liberalization increases the world GDP by 147.3 percent in Hamilton and Whalley (1984), 122.0 percent in Klein and Ventura (2007), 96.5 percent in Moses and Letnes (2004). Less optimistic results are obtained when foreign workers are assumed to be less productive than natives or when arbitrary migration costs are included. Iregui (2003) is the first to account for differences in workers' educational attainment (i.e. a low-skilled Mexican migrating to the US is as productive as a low-skilled US worker but less than the average American). Under the same set of hypotheses, she found that relocating people to equalize wages would increase the world GDP by 67.0 percent. In the latter study, the semi-elasticity of the world GDP to the share of international migrants in the world population is around 1.3.[8] Incidentally, this semi-elasticity is identical to that obtained in the exogenous migration framework of Winters (2001) or Walmsley and Winters (2005). Although the latter considers many sectors and a few regions, output in each industry is modeled using a technology with two types of workers as in Iregui (2003). In a world with exogenous total factor productivity levels and perfect mobility of physical capital, the responsiveness of the world income to migration is thus characterized by a semi-elasticity of 1.3 in the existing literature.

In a recent essay, Borjas (2015) revisited the efficiency gains from open borders in a context with negative technological spillovers. The point of departure is a standard labor market model with fixed capital stock and exogenous total factor productivity. The model is then calibrated to match the demographic and income disparities between the developed and the developing world. Initially, Borjas (2015) disregards migration costs and predicts that a removal of migration barriers would displace 2.6 billion workers (i.e. 95 percent of the South population and 79 percent of the world population) and increase the

[8]The semi-elasticity is computed dividing the deviation in the world GDP by the change in the world proportion of migrants.

world GDP by 40 trillion dollars (i.e. +57 percent compared to the pre-reform level). The semi-elasticity of the world GDP to the share of international migrants (0.72) is lower than in previous studies for two reasons. First, physical capital is assumed to be immobile across countries, while it "chases" labor in previous studies. Second, the author assumes an income ratio of 4 between the North and the South.[9] Redistributive effects turn out to be important as wages increase by 143 percent in the South and decline by 40 percent in the North.[10] In a second step, Borjas (2015) considers a scenario with technological spillovers across countries, where migration levels down the distribution of productivity.

Echoing Collier (2013), the rationale is that migrants import their institutional model and contaminate the entire set of institutions in the destination country. Borjas (2015) assumes that the post-liberalization level of the total factor productivity in the North is a weighted average of the pre-liberalization levels in the origin and destination regions. The weight allocated to the South technology varies between 0 and 1, and is independent of the migration shock. Unsurprisingly, the global effect can become negative if the weight given to the South technology is large enough. This happens when the weight allocated to the South technology exceeds 0.5. Still, even in this scenario, the author predicts large migration responses (+2.3 billion workers, i.e. 85 percent of the South labor force).

In the above-mentioned studies, private (or non-visa) migration costs are disregarded or modeled in a simple way. This is an important shortcoming as the empirical literature on the determinants of migration has long emphasized the role of geographic, linguistic and cultural distances. For example, psychic and monetary moving costs explain why within-EU migration flows have been limited despite large income differences between EU member states and a free mobility agreement, or why large income disparities exist within countries.[11] The first study assessing the size of "incompressible" moving costs for all country pairs is Docquier et al. (2015). Using data on people's willingness to emigrate from the Gallup World Poll survey (see Esipova et al. (2011)), they identified a total number of potential migrant workers, i.e. actual plus desiring migrants aged 25 and over, equal to 386 million (i.e. about 15 percent of the figure predicted in Borjas (2015)). Accounting for network effects does not drastically change the picture, mainly because an important mechanism through which network effects operate (i.e. family reunification) becomes irrelevant if migration barriers were abolished. Using an upper-bound for the non-visa component of the network effect, they obtain a total number of 589.5 million potential migrants. They quantified the effect of liberalization on the world economy using a model jointly endogenizing migration decisions and economic performances. They use a "backsolving" calibration strategy to identify total migration costs and visa costs as residuals of the migration technology. In partial equilibrium or in general equilibrium with perfect capital mobility and without technological externalities, they obtain a 11.9 percent increase in the world GDP after a complete liberalization, and a semi-elasticity of the

[9] Assuming that migration costs are equal to 10 times the annual average income in the South, the number of migrants reduces to 2.46 billion (75 percent of the world population) and the gain falls to 28.1 trillion dollars (i.e. +40.1 percent). Hence, the semi-elasticity falls to 0.54.

[10] Despite fixed capital stock, the semi-elasticity of the world GDP to the share of migrants becomes 1.09 if the income ratio equals 6.

[11] In Germany, the average GDP per inhabitant in Hamburg (EUR 47,100) is 2.3 times greater than in Brandenburg (EUR 20.500). In Italy, GDP per inhabitant is twice as large in Lombardy (EUR 33,500) than in Campania or Calabria (EUR 16,400; values for 2008; see EUROSTAT (2011)). The same ratio is observed in the US between Connecticut (USD 68,167) and Mississippi (USD 32,348; values for 2008; see Bureau of Economic Analysis (2014)).

world GDP to the share of migrants of 1.3. This is in line with the existing studies accounting for skill differences across people (Iregui (2003), Winters (2001), Walmsley and Winters (2005)). Hence, their relatively small efficiency effect is entirely explained by the inclusion of incompressible migration costs, and not by the technological features of their model. Similar results are obtained when congestion is included or when migrants and natives are imperfect substitutes within each education category. When migration network effects are accounted for, the world income increase by 17 percent while the semi-elasticity remains unchanged. When country-specific levels of total factor productivity are affected by human capital, the semi-elasticity falls to 0.9 and the efficiency gains of a liberalization is much lower (+7 percent in the world income). The reason is that on average, new migrants are more educated than natives left behind (positive selection in emigration) but less educated than workers in destination countries (negative selection in immigration). Almost all regions therefore end up with a lower fraction of skilled workers among their workforce after a liberalization. In line with Borjas (2015), removing immigration barriers levels down the distribution of total factor productivity in the presence of schooling externalities, but to a much lesser extent and for different reasons.

Overall, this literature on the global effects of migration barriers mainly relies on static models that disregard the relationships between migration decisions and the evolution of the size and structure of the world population. This paper shows, both theoretically and numerically, that the efficiency and redistributive effects of immigration restrictions are gradually amplified when population growth and human capital accumulation are endogenized.

1.3 Theory

In this section, we develop an integrated model describing interdependencies between bilateral migration flows, human capital formation, population growth and worldwide income disparities. Our world economy model accounts for the technological and behavioral responses to migration policy reforms. It endogenizes migration flows across countries and encompasses three channels of transmission of migration shocks. First, as stated above, skill-biased changes in emigration prospects stimulate people to acquire tertiary education. Second, newly educated individuals left behind as well as new migrants moving from poor countries (where the access to and quality of the education system are low) to rich countries (where the access and quality are high) change their fertility and their investment in the basic education (primary and secondary levels) of their offspring. Third, movements of human capital can affect cross-country disparities in total factor productivity and wages. To the best of our knowledge, this is the first paper providing explicit microfoundations to the link between education, fertility and migration in a multi-country framework with many origin and destination countries.

Our model assumes two-period lived agents (adults and children). Adults are the only decision makers. They maximize their well-being and decide where to live, whether to invest in their own (higher) education, how much to consume, and how much to invest in the quantity and quality (i.e. basic education) of their children. We distinguish between college-educated adults and the less educated and assume that preferences are represented by a two-level nested utility function. Working-age individuals have heterogeneous abilities to acquire higher education, and heterogeneous preferences over destination countries.

The number of working-age natives from country k ($k = 1, ..., K$) at time t is denoted by $N_{k,t}$ which divides into $N^h_{k,t}$ college graduates and $N^l_{k,t}$ less educated. The proportion of college graduates in the native population equals $N_{k,t} \equiv N^h_{k,t} / \left(N^h_{k,t} + N^l_{k,t} \right)$. Each native decides whether to emigrate or not; $N^s_{kj,t} (s = h, l)$ denotes the number of emigrants from k to j. After migration, the resident labor force of type s is given by $L^s_{k,t} \equiv \sum_i N^s_{ik,t}$ and $h_{k,t} \equiv L^h_{k,t} / \left(L^h_{k,t} + L^l_{k,t} \right)$ denotes the proportion of college graduates among residents. The skill-specific proportion of emigrants from country k is denoted by $p^s_{k,t} \equiv \sum_{i \neq k} N^s_{ki,t} / N^s_{k,t}$.

The sections below describe the microfoundations of fertility, education and migration decisions, as well as income determination. Bilateral migration and higher education decisions are examined in Section 1.3.1. Fertility and basic education decisions are modeled in Section 1.3.2. Aggregates and population dynamics are characterized in Section 1.3.3. Section 1.3.4 describes the technology. The intertemporal equilibrium is defined in Section 1.3.5. Finally, our measure of worldwide income inequality is explained in Section 1.3.6.

1.3.1 Migration and higher education decisions

Individual decisions to emigrate and acquire higher education result from the comparison of discrete alternatives. To model them, we use a logarithmic *outer utility function* with a deterministic and a random component. The utility of an adult a of cohort t, born in country k, living in country i, and acquiring (higher) education type s is given by:

$$U^s_{ki,t} = \ln v^s_{i,t} + \ln(1 - x^s_{ki,t}) + \ln(1 - z^s_{a,k}) + \varepsilon^s_{a,ki}, \tag{1}$$

where $\ln v^s_{i,t} \in \Re$ is the deterministic level of utility that can be reached in the location i at period t (explained in Section 1.3.2), and $x^s_{ki,t} \in [0, 1]$ captures the effort required to migrate from country k to country i (such that $x^s_{kk,t} = 0$). Migration costs $x^s_{ki,t}$ vary across country pairs and education levels. We distinguish between visa costs and private costs. Private costs, denoted by $\underline{x}^s_{ki,t}$, cover a wide range of hurdles faced by migrants in finding employment, housing, living far from one's community, deciphering foreign cultural norms, adjusting to a new linguistic and economic environment, etc. Legal or visa costs $(x^s_{ki,t} - \underline{x}^s_{ki,t})$ represent policy-induced costs borne by the migrant to overcome the legal hurdles set by national authorities at destination and origin.

Individuals are heterogeneous in their ability to acquire higher education and in their preference for alternative locations. The individual-specific level of effort required to be of type $s = (h, l)$ in country k is denoted by $z^s_{a,k} \in [0, 1]$. Basic education is a prerequisite to invest in higher education. We have $z^l_k = 0$ for those who do not invest in higher education. For those who decide to invest, we assume that $\tau^h_{a,k} \equiv \left(1 - z^h_{a,k} \right)^{-1} \in [0, \infty]$, a monotonic and increasing function of $z^h_{a,k}$, follows a Pareto distribution.

The country-specific CDF is given by

$$G_k(\tau) = 1 - \left[\frac{\overline{\tau}_k}{\tau}\right]^{\alpha},$$

where $\overline{\tau}_k > 0$ is the country-specific lower bound of the distribution in country k and $\alpha > 0$ is a common shape parameter governing the responsiveness of higher education decisions to the expected returns to schooling. Parameter $\overline{\tau}_k$ features the access to higher education in country k.

The individual-specific random taste shock for moving from country k to i is denoted by $\varepsilon^s_{a,ki} \in \Re$ and follows an iid Type-I extreme value distribution,[12] also known as the double exponential distribution:

$$F(\varepsilon) = e^{\left[-e^{\left(-\frac{\varepsilon}{\mu}-\gamma\right)}\right]},$$

where $\mu > 0$ is a common scale parameter governing the responsiveness of migration decisions to income disparities, and $\gamma \approx 0.577$ is the Euler's constant.

The timing of decisions is the following. In the first stage, individuals who received basic education discover their education type, $(z^s_{a,k,t})$. They do not know their migration type $(\varepsilon^s_{a,ki,t})$ but know its distribution. Given their perfect expectations about $v^s_{i,t}$ and $x^s_{ki,t}$, they decide whether to acquire higher education or not. In the second stage, they discover their migration type $(\varepsilon^s_{a,ki,t})$ and decide whether to emigrate or to stay in the home country. The *third stage* of the utility maximization process determines $\ln v^s_{i,t}$ and is explained in Subsection 1.3.2.

First stage. Individuals acquire higher education if the expected utility gain from being college educated exceeds the effort cost. Under the Type I Extreme Value distribution, de Palma and Kilani (2007) derived the expression for the ex-ante expected utility. In our augmented framework with endogenous education, the expected utility, of individual a, of choosing education type s is given by

$$E\left(U^s_{a,k,t}\right) = \ln \sum_{i=1}^{I} e^{\left(\frac{\ln v^s_{i,t} + \ln(1-x^s_{ki,t})}{\mu}\right)} + \ln(1 - z^s_{a,k,t}).$$

An individual chooses to educate if the expected benefits from college education exceed the training effort, i.e. when $E\left(U^h_{a,k,t}\right) > E\left(U^l_{a,k,t}\right)$. This condition holds if

$$\tau^h_{k,t} \leq \frac{\sum_{i=1}^{I}(v^h_{i,t})^{1/\mu}(1-x^h_{ki,t})^{1/\mu}}{\sum_{i=1}^{I}(v^l_{i,t})^{1/\mu}(1-x^l_{ki,t})^{1/\mu}} \equiv \frac{(v^h_{k,t})^{1/\mu} + (V^h_{k,t})^{1/\mu}}{(v^l_{k,t})^{1/\mu} + (V^l_{k,t})^{1/\mu}}, \tag{2}$$

where $v^s_{k,t}$ determines the component of expected utility explained by the home country characteristics, and $(V^s_{k,t})^{1/\mu} \equiv \sum_{i \neq k}(v^s_{i,t})^{1/\mu}(1-x^s_{ki,t})^{1/\mu}$ is the component linked to emigration prospects.

In a closed economy framework $(x^s_{ki,t} = 1 \; \forall s, i \neq k)$, the critical level of effort below which college education is beneficial is determined locally $(\tau^h_{k,t} = (v^h_{k,t}/v^l_{k,t})^{1/\mu})$. In an open economy (i.e. when

[12] More general distributions were used in Bertoli and Moraga (2013), Bertoli and Marchetta (2015) or Ortega and Peri (2013), who allow for a positive correlation in the realization of the shock across similar countries. This can be helpful to derive micro-founded gravity models accounting for multilateral resistance to migration. This is less an issue in our "non-estimation" paper since our backsolving identification strategy described in Section 1.4 is such that we fit the data perfectly.

$V^s_{k,t} > 0$ for some s), the expected return to education is affected by emigration prospects. From Eq. (2), we have:

Proposition 1. *Emigration prospects increase incentives to acquire higher education if* $\frac{V^h_{k,t}}{V^l_{k,t}} > \frac{v^h_{k,t}}{v^l_{k,t}}$.

The skill structure of emigration costs is a key determinant of $V^h_{k,t}/V^l_{k,t}$; because of skill-selective immigration policies and the greater ability of educated workers to gather information about destination countries, many migration corridors are such that $x^h_{ki,t} < x^l_{ki,t}$ and exhibit positive selection.

As stated above, basic education is a prerequisite to invest in higher education. Let us denote the proportion of working-age individuals who received basic education when young (i.e. in the previous period) in country k by $q_{k,t-1}$. The critical level of ability in Eq. (2) determines the fraction of them who find it optimal to acquire higher education. Given the Pareto distribution of the ability to acquire education, the proportion of working-age adults deciding to invest in college education is given by:

$$H_{k,t} = q_{k,t-1}\left[1 - \left(\overline{\tau}_k \frac{(v^l_{k,t})^{1/\mu} + (V^l_{k,t})^{1/\mu}}{(v^h_{k,t})^{1/\mu} + (V^h_{k,t})^{1/\mu}}\right)^{\alpha}\right]. \tag{3}$$

It follows:

Proposition 2. *The average responsiveness of investment in college education to emigration prospects depends on past education levels ($q_{k,t-1}$) and access to higher education ($\overline{\tau}_k$).*

The effect of emigration prospects on the proportion of college graduates thus varies across countries with the lagged enrollment rate in basic education and with access to higher education ($\overline{\tau}_k$). The latter is likely to depend on the country's development level, urbanization rate, public spending on tertiary education, etc. In the next sub-section, we show that the enrollment rate in basic education depends itself on the lagged proportion of college graduates (i.e. college-educated invest more in the basic education of their offspring). This explains the strong persistence in human capital data and implies that a shock in emigration prospects induces gradual effects on the world economy.

Second stage. When education is determined, individual a chooses to emigrate to country i if $\ln v^s_{i,t} + \ln(1 - x^s_{ki,t}) + \varepsilon^s_{a,ki}$ exceeds the level attainable in any other location.[13] Under the Type I Extreme Value distribution, McFadden (1984) showed that the probability to emigrate is governed by a logit expression. The emigration rate is given by

$$\frac{N^s_{ki,t}}{N^s_{k,t}} = \frac{e^{\left(\frac{\ln v^s_{i,t} + \ln(1-x^s_{ki,t})}{\mu}\right)}}{\sum_{j=1}^{I} e^{\left(\frac{\ln v^s_{j,t} + \ln(1-x^s_{ji,t})}{\mu}\right)}} = \frac{(v^s_{i,t})^{1/\mu}(1 - x^s_{ki,t})^{1/\mu}}{\sum_{j=1}^{I}(v^s_{j,t})^{1/\mu}(1 - x^s_{kj,t})^{1/\mu}}.$$

Staying rates $\left(N^s_{kk,t}/N^s_{k,t}\right)$ are governed by the same logit model. It follows that the emigrant-to-

[13]Note that in the present framework, migration is permanent and irreversible. Kennan and Walker (2011) developed a framework which allows for sequential migration decisions (i.e. multiple moves). As noted by the authors, the addition of more dimensions complicates the computation exponentially. This is particularly true in a large multi-country framework as the one we develop here. Nevertheless, we account for temporary migrants in a robustness check.

stayer ratio is governed by the following expression:

$$\frac{N^s_{ki,t}}{N^s_{kk,t}} = \left(\frac{v^s_{i,t}}{v^s_{k,t}}\right)^{1/\mu} (1 - x^s_{ki,t})^{1/\mu}. \tag{4}$$

Skill-specific emigration rates are endogenous and comprised between 0 and 1. Eq. (4) states that the ratio of emigrants from country k to country i to stayers in country k (i.e. individuals born in k who remain in k), is an increasing function of the utility achievable in country i and a decreasing function of the utility in the country of origin k. The proportion of migrants from k to i also decreases with the bilateral migration cost $x^s_{ki,t}$. Heterogeneity in migration tastes implies that emigrants select all destinations such that $x^s_{ki,t} < 1$ (if $x^s_{ki,t}$=1, the corridor is empty), and all corridors such that $x^s_{ik,t}, x^s_{ki,t} < 1$ exhibit bidirectional migration flows, in line with existing data. In addition, the aggregate emigration rate $\left(p^s_{k,t}\right)$ and the skill ratio of emigration rates ($\rho_{k,t}$) from country k are jointly determined and given by the following expressions:

$$\begin{aligned} p^s_{k,t} &\equiv \frac{\sum_{i\neq k} N^s_{ki,t}}{N^s_{k,t}} = \frac{(V^s_{k,t})^{1/\mu}}{(v^s_{k,t})^{1/\mu} + (V^s_{k,t})^{1/\mu}}, \\ \rho_{k,t} &\equiv \frac{p^h_{k,t}}{p^l_{k,t}} = \frac{(V^h_{k,t})^{1/\mu}}{(V^l_{k,t})^{1/\mu}} \left[\frac{(v^h_{k,t})^{1/\mu} + (V^h_{k,t})^{1/\mu}}{(v^l_{k,t})^{1/\mu} + (V^l_{k,t})^{1/\mu}}\right]^{-1}. \end{aligned} \tag{5}$$

The skill ratio of emigration rates increases with $V^h_{k,t}$ and decreases with $V^l_{k,t}$. From Eqs. (3) and (5), we have $sgn\left(\frac{\partial H_{k,t}}{\partial V^s_{k,t}}\right) = sgn\left(\frac{\partial \rho_{k,t}}{\partial V^s_{k,t}}\right)$ and $sgn\left(\frac{\partial H_{k,t}}{\partial v^s_{k,t}}\right) \neq sgn\left(\frac{\partial \rho_{k,t}}{\partial v^s_{k,t}}\right)$. This implies:

Proposition 3. *Emigration-driven expected utility shocks* $\left(\Delta V^s_{k,t}\right)$ *induce a positive association between human capital formation* ($H_{k,t}$) *and the ratio of emigration rates* ($\rho_{k,t}$). *Local expected utility shocks* $\left(\Delta v^s_{k,t}\right)$ *induce a negative association between* $H_{k,t}$ *and* $\rho_{k,t}$.

In particular, shocks increasing the expected utility of college graduates abroad (e.g. greater skill selection in the major destination countries) have a positive effect on human capital formation ($H_{k,t}$) and on the positive selection of emigrants (as reflected by the ratio of emigration rates $\rho_{k,t}$). Shocks increasing the expected utility of the less educated abroad have a negative effect on both variables. Proposition 3 establishes the microfoundation of the link between emigration rates $\left(p^s_{k,t}\right)$ and pre-migration human capital formation ($H_{k,t}$) in a multi-destination framework (see Stark et al. (1997), Mountford (1997), Beine et al. (2001), Beine et al. (2008), Easterly and Nyarko (2008), Docquier and Rapoport (2012)).

1.3.2 Fertility and basic education decisions

We now endogenize $\ln v^s_{k,t}$ as resulting from the *third stage* of the utility maximization process. The *inner utility function* $v^s_{k,t}$ is a Cobb-Douglas function of consumption $\left(c^s_{k,t}\right)$, fertility $\left(n^s_{k,t}\right)$ and the proportion of children receiving basic (primary and secondary) education $\left(q^s_{k,t}\right)$. In logs, we have:

$$\ln v^s_{k,t} = (1-\theta)\ln c^s_{k,t} + \theta \ln n^s_{k,t} + \theta\lambda \ln q^s_{k,t}, \tag{6}$$

where $\theta \in [0,1]$ and $\lambda \in [0,1]$ are preference parameters for fertility and children's basic education.

Each adult receives a wage rate $w^s_{k,t}$ per unit of time worked. Raising a child requires a time cost ϕ, and providing a child with basic education induces a monetary education cost $e^s_{k,t}$. For the sake of tractability we do not explictly microfound $e^s_{k,t}$, we interpret this exogenous variable as a proxy of the country k development at time t, see also Section 1.4.[14] We allow non-educated children to work and earn a wage $w^c_{k,t}$ per unit of time spent on the labor market (reflecting country-specific, social and institutional norms towards child labor).

The budget constraint writes as:

$$c^s_{k,t} + n^s_{k,t} q^s_{k,t} e^s_{k,t} = w^s_{k,t}(1 - \phi n^s_{k,t}) + n^s_{k,t}(1 - q^s_{k,t}) w^c_{k,t}. \tag{7}$$

Each adult maximizes utility (6) subject to $q^s_{k,t} \leq 1$ and to the budget constraint (7). The first-order conditions are:

$$\frac{(1-\theta)\left[\phi w^s_{k,t} + q^s_{k,t} e^s_{k,t} - (1 - q^s_{k,t}) w^c_{k,t}\right]}{c^s_{k,t}} - \frac{\theta}{n^s_{k,t}} = 0, \tag{8}$$

$$\frac{(1-\theta)\, n^s_{k,t}\left[e^s_{k,t} + w^c_{k,t}\right]}{c^s_{k,t}} - \frac{\theta\lambda}{q^s_{k,t}} \geq 0. \tag{9}$$

From Eqs. (7) and (8), the total net cost of children is equal to a fraction θ of the wage rate, and the total consumption is equal to the remaining fraction, $1 - \theta$. It follows that

$$n^s_{k,t} = \frac{\theta w^s_{k,t}}{\phi w^s_{k,t} + q^s_{k,t} e^s_{k,t} - (1 - q^s_{k,t}) w^c_{k,t}},$$

in which $q^s_{k,t}$, the proportion of children receiving basic education, is endogenous.

Assume first that Eq. (9) holds with equality (*interior solution* with $q^s_{k,t} < 1$). Combining Eqs. (8) and (9) gives the optimal fertility rate and investment in basic education:

$$n^s_{k,t} = \frac{\theta(1-\lambda) w^s_{k,t}}{\phi w^s_{k,t} - w^c_{k,t}} \tag{10}$$

$$q^s_{k,t} = \frac{\lambda}{1-\lambda} \frac{\phi w^s_{k,t} - w^c_{k,t}}{e^s_{k,t} + w^c_{k,t}} \tag{11}$$

In line with intuition, the fertility rate decreases with the wage rate ($w^s_{k,t}$) and increases with the child's wage rate ($w^c_{k,t}$). Children's basic education increases with the adult's wage rate ($w^s_{k,t}$), decreases with the education cost ($e^s_{k,t}$) and with child's wage rate ($w^c_{k,t}$).

From Eq. (11), the condition under which such an interior solution emerges writes as:

$$w^s_{k,t} \leq \frac{(1-\lambda) e^s_{k,t} + w^c_{k,t}}{\phi\lambda}. \tag{12}$$

If Eq. (12) does not hold, we have a *corner solution* with $q^s_{k,t} = 1$. Substituting $q^s_{k,t} = 1$ in Eq. (8)

[14] Tanaka et al. (2014) study the effect of immigration-inflows on the quality of basic education in destination countries. They find that immigration may decrease quality due to congestion effects in public school and also lead natives to opt to private, and more expensive, schools.

determines the fertility rate:

$$n_{k,t}^{s}=\frac{\theta w_{k,t}^{s}}{\phi w_{k,t}^{s}+e_{k,t}^{s}}. \tag{13}$$

Countries differ in terms of technology and policies. The wage ratio between college graduates and the less educated can be denoted by $\sigma_{k,t}\equiv w_{k,t}^{h}/w_{k,t}^{l}$. The wage ratio between children and low-skilled adults is denoted by $\omega_{k,t}\equiv w_{k,t}^{c}/w_{k,t}^{l}$. The ratio of basic education costs to the high-skilled wage rate is denoted by $\xi_{k,t}^{s}\equiv e_{k,t}^{s}/w_{k,t}^{h}$. These country-specific "institutional" variables fully characterize the fertility and basic education levels/differentials. Indeed, dividing Eqs. (10), (11), (12) and Eq. (13) by $w_{k,t}^{l}$, we have

$$\left(n_{k,t}^{l},q_{k,t}^{l}\right)=\begin{cases}\left(\frac{\theta(1-\lambda)}{\phi-\omega_{k,t}},\frac{\lambda}{1-\lambda}\frac{\phi-\omega_{k,t}}{\xi_{k,t}^{l}\sigma_{k,t}+\omega_{k,t}}\right) & \text{if } 1\leq\frac{(1-\lambda)\xi_{k,t}^{l}\sigma_{k,t}+\omega_{k,t}}{\phi\lambda},\\ \left(\frac{\theta}{\phi+\xi_{k,t}^{l}\sigma_{k,t}},1\right) & \text{otherwise}\end{cases} \tag{14}$$

and

$$\left(n_{k,t}^{h},q_{k,t}^{h}\right)=\begin{cases}\left(\frac{\theta(1-\lambda)\sigma_{k,t}}{\phi\sigma_{k,t}-\omega_{k,t}},\frac{\lambda}{1-\lambda}\frac{\phi\sigma_{k,t}-\omega_{k,t}}{\xi_{k,t}^{h}\sigma_{k,t}+\omega_{k,t}}\right) & \text{if } \sigma_{k,t}\leq\frac{(1-\lambda)\xi_{k,t}^{h}\sigma_{k,t}+\omega_{k,t}}{\phi\lambda},\\ \left(\frac{\theta\sigma_{k,t}}{\phi\sigma_{k,t}+\xi_{k,t}^{h}\sigma_{k,t}},1\right) & \text{otherwise.}\end{cases} \tag{15}$$

Relocating people from poor countries (high fertility and low investment in basic education) to rich countries (low fertility and high investment in basic education) gradually changes the dynamics of the world population. Substituting the optimal levels of utility and basic education investment into (6) defines the optimal level of indirect utility, $\ln v_{k,t}^{s}$. We have

$$\ln v_{k,t}^{s}=(1-\theta)\ln w_{k,t}^{s}+\ln\Omega_{k,t}^{s}, \tag{16}$$

where $\ln\Omega_{k,t}^{s}\equiv\theta\ln n_{k,t}^{s}+\theta\lambda\ln q_{k,t}^{s}+(1-\theta)\ln(1-\theta)$ depends on the optimal levels of fertility and investment in basic education. Given Eqs. (14) and (15), the latter levels only depend on the trajectory of country-specific "institutional" characteristics, reflected by the vector $(\sigma_{k,t},\omega_{k,t},\xi_{k,t}^{h},\xi_{k,t}^{l})$. We thus have:

Proposition 4. *We define an EXogenous Institutional Trajectory (labeled as EXIT) as a scenario with exogenous "institutional" characteristics* $\left(\sigma_{k,t},\omega_{k,t},\xi_{k,t}^{s}\right)$ *for all k, t and s. In such an EXIT scenario, fertility rates* $\left(n_{k,t}^{s}\right)$*, basic education investments* $\left(q_{k,t}^{s}\right)$ *and the "institutional component" of utility* $\left(\Omega_{k,t}^{s}\right)$ *follow an exogenous time path.*

In the *EXIT* scenario, a migration policy reform only affects disparities in *inner utility* if low-skilled and high-skilled wages are endogenous. The elasticity of indirect utility to the wage rate is equal to $(1-\theta)$, and from Eq. (4), the elasticity of the migrant-to-stayer ratio to the ratio of indirect utility levels equals $1/\mu$. Hence, the elasticity of the migrant-to-stayer ratio to the ratio of wage rates equals $(1-\theta)/\mu$. Obviously, in a partial equilibrium context with exogenous wage rates, bilateral emigration rates are constant.

1.3.3 Aggregates and dynamics

The average fertility rate and proportion of children receiving basic education are given by

$$n_{k,t} \equiv h_{k,t}n^h_{k,t} + (1-h_{k,t})n^l_{k,t}, \tag{17}$$

$$q_{k,t} \equiv \frac{h_{k,t}q^h_{k,t}n^h_{k,t} + (1-h_{k,t})q^l_{k,t}n^l_{k,t}}{n_{k,t}}. \tag{18}$$

Labor is the only production input. Labor supply of type s, $\left(\ell^s_{k,t}\right)$, is determined by migration and fertility decisions, and we assume that low-skilled workers and employed children are perfect substitutes although their productivity or employability differs:

$$\ell^h_{k,t} = L^h_{k,t}\left(1-\phi n^h_{k,t}\right), \tag{19}$$

$$\ell^l_{k,t} = L^l_{k,t}\left(1-\phi n^l_{k,t}\right) + \omega_{k,t}\left(L^l_{k,t}n^l_{k,t}\left(1-q^s_{k,t}\right) + L^h_{k,t}n^h_{k,t}\left(1-q^h_{k,t}\right)\right). \tag{20}$$

The dynamics of the native population $(N_{k,t})$ and the proportion of college graduates in the adult population $(H_{k,t})$ are given by

$$N_{k,t} = L_{k,t-1}n_{k,t-1} \tag{21}$$

and by Eq. (3). It clearly appears that $N_{i,t}$ is a pre-determined variable, whereas $H_{k,t}$ is not because adults' investment in higher education is determined at time t.

1.3.4 Production technology

We assume that output is proportional to labor in efficiency units, equivalent to a model without slowly accumulating factors featuring a globalized economy with a common international interest rate. This hypothesis is in line with Klein and Ventura (2009) and Kennan (2013), both papers assume that capital "chases" labor. Also this assumption is in line with the evidence reported in Caselli and Feyrer (2007); they show that the marginal product of capital differ slightly across countries. The production function writes as:

$$Y_{k,t} = A_{k,t}(.)F\left(\ell^h_{k,t}, \ell^l_{k,t}\right)$$

where $A_{i,t}(.)$ denotes total factor productivity and $F(.)$ features the substitutability between high-skilled and low-skilled workers.

The wage rates are determined by the marginal productivity of labor:

$$w^h_{k,t} = A_{k,t}(.)F'_h\left(\ell^h_{k,t}, \ell^l_{k,t}\right) \tag{22}$$

$$w^l_{k,t} = A_{k,t}(.)F'_l\left(\ell^h_{k,t}, \ell^l_{k,t}\right) \tag{23}$$

$$w^c_{k,t} = \omega_{k,t}A_{k,t}(.)F'_l\left(\ell^h_{k,t}, \ell^l_{k,t}\right) \tag{24}$$

In our numerical analysis, we consider several variants of the production technology, with linear or CES specification for $F(.)$ and with exogenous or endogenous levels of total factor productivity $A_{k,t}(.)$. In the benchmark, we consider a partial equilibrium framework with exogenous wages, assuming that

$A_{k,t}(.)$ grows at the same rate in all countries and $F(.)$ is linear with an exogenous and constant relative productivity σ_k in each country k. We stick to the partial equilibrium scenario as a benchmark because there is not a consensual estimate for the elasticity of substitution between high-skilled and low-skilled workers, see Docquier et al. (2015). In the CES case, the wage ratio between high-skilled and low-skilled workers $\sigma_{k,t}$ (one plus the skill premium) becomes endogenous. In other variants, we account for schooling externalities, diversity spillovers or congestion effects, allowing $A_{k,t}(.)$ to vary with the proportion of high-skilled in the working-age population ($h_{k,t}$), with an indicator of birthplace diversity of workers ($Div_{k,t}$), or with the total working-age population $\left(L^h_{k,t}+L^l_{k,t}\right)$.

1.3.5 Intertemporal equilibrium

Our benchmark scenario assumes an *EXIT* trajectory of institutional characteristics and a linear production function with exogenous levels of total factor productivity (equivalent to a partial equilibrium framework).[15] In this context, an intertemporal equilibrium for the world economy can be defined as follows:

Definition 1. *For a set $\{\theta,\lambda,\phi,\mu,\alpha\}$ of structural parameters, a set $\left\{\sigma_{k,t},\omega_{k,t},\xi^s_{k,t},\overline{\tau}_{k,t},A_{k,t}\right\}_{\forall k,s,t}$ of country-specific institutional, educational and technological, exogenous characteristics, a set $\left\{x^s_{ki,t}\right\}_{\forall k,i,t,s}$ of bilateral migration costs, a functional form for $F(.)$, and a set $\{N_{k,t},q_{k,t-1}\}_{\forall k,t}$ of predetermined variables or initial conditions, an intertemporal equilibrium is a set of endogenous variables $\left\{w^s_{k,t},H_{k,t},n^s_{k,t},q^s_{k,t},N^s_{ki,t},L^s_{k,t},h_{k,t},\ell^s_{k,t}\right\}_{\forall k,i,t,s}$ such that (i) wages $w^s_{k,t}$ maximize profits, as depicted in Eqs. (22), (23) and (24), (ii) the proportion of college graduates in the native labor force $H_{k,t}$ satisfies Eq. (3), (iii) adults' fertility rates and investment in basic education maximize location-specific utility, as depicted in Eqs. (10) and (11), (iv) the allocation of the world labor force maximizes utility, as depicted in Eq. (4), (vi) aggregation constraints $L^s_{k,t}\equiv\sum_i N^s_{ik,t}$, $h_{k,t}\equiv L^h_{k,t}/(L^h_{k,t}+L^l_{k,t})$, Eqs. (17), (18) are satisfied, (vi) labor supply is determined by Eqs. (19) and (20), and (vii) the evolution of the native adult population is governed by Eq. (21).*

In Sections 1.4 and 1.5, we parametrize a baseline intertemporal equilibrium for the world economy and simulate the effects of liberalization shocks. For example, a complete removal of legal migration barriers means that $x^s_{ki,t}$ is decreased to $\underline{x}^s_{ki,t}$ for all k,i,s and t. In the robustness checks described in Section 1.6, we retain the *EXIT* hypothesis but consider scenarios with endogenous wages, i.e. endogenous wage ratios ($\sigma_{k,t}$) and total factor productivity levels ($A_{k,t}$).

1.3.6 World distribution of income

As a by-product of the intertemporal equilibrium, the model endogenizes the level of income inequality among the world citizens. We use the Theil index of inequality and compute it on adults' wage using the

[15] As Docquier et al. (2015) report there is no agreement in the literature about the value which characterizes the elasticity of substitution between high- and low-skilled workers. This leads us to consider as a benchmark the partial equilibrium scenario. Several variants with endogenous skill premia are considered in Section 1.6. We also assume that natives and migrants of the same education-type (low-and high-skilled) are equally productive. We acknowledge that following the results of Coulombe and Tremblay (2009) this assumption may be relaxed.

following expression:

$$T_t = \sum_{k \in K; s=l,h} SHW^s_{k,t} \ln \left(\frac{SHW^s_{k,t}}{SHN^s_{k,t}} \right)$$

where $SHW^s_{k,t}$ is the share of the world labor income earned by adults of type s living in country k at time t and $SHN^s_{k,t}$ is the share of the world adult population of individuals of type s.[16]

1.4 Parametrization

The model is calibrated on the year 2000, the last year for which comprehensive migration matrices by education level are available. The horizon of our simulations is 2100 and one period represents 25 years. Our parametrization strategy is designed to match the evolution of the world economy between 1975 and 2000, and to fit the demographic projections of the United Nations for individuals aged 25 and over for the period 2000-2100 (United Nations (2011)).[17] By implication "children" are the ones aged less than 25 while adults are the remaining ones. Our baseline scenario corresponds to the partial equilibrium *EXIT* scenario described in Definition 1. Hence, the time path of total factor productivity ($A_{k,t}$) is exogenous and workers are perfect substitutes in production, i.e. the technological function $F(.)$ is linear.

Structural parameters $\{\theta, \lambda, \phi, \mu, \alpha\}$ - Preferences are assumed to be identical across countries and time invariant. The set of structural parameters is calibrated using insights from the literature. As for parameter ϕ, the time-cost of having a child, evidence in Haveman and Wolfe (1995) suggests that the opportunity cost of a child is equivalent to about 15 percent of the parents' time endowment. This means that the maximal fertility rate equals 6.7 children per adult, or 13 per couple. As for the altruism parameter θ, the literature provides a range of values between 0.10 in de la Croix and Gosseries (2009), 0.17 in de la Croix and Doepke (2004), 0.27 in de la Croix and Doepke (2003). As for the preference for basic education λ, de la Croix and Doepke (2003) and de la Croix and Doepke (2004) used values of 0.635 and 0.6, respectively, while de la Croix and Gosseries (2009) used 0.578. In line with these papers, we use $(\theta, \lambda, \phi) = (0.3, 0.6, 0.15)$. In a robustness analysis, we decrease parameters θ and λ by 0.1.

As for the scale parameter of the distribution of migration tastes μ, Bertoli and Moraga (2013) found an elasticity of bilateral migration to the wage ratio $(w^s_{j,t}/w^s_{k,t})$ between 0.6 and 0.7. Given the values of the preference parameters and plugging the solution of the maximization problem given by Eq. (16) into Eq. (4), this elasticity equals $(1-\theta)/\mu$ in our model. By choosing $\mu = 1$, the responsiveness of migration to wage disparities in our model is thus in line with the empirical literature.

Parameter α, the common shape parameter of the Pareto distribution of the ability to acquire higher education, governs the responsiveness of higher education decisions to the expected returns to schooling, as appearing in Eq. (3). We iterated on α (and the vector of $\overline{\tau}_{k,t}$, as explained below) in order to match the elasticity of human capital formation to the high-skilled emigration rate found in the empirical

[16] The Theil index can be decomposed in within-country and across-country components. However, as shown in a previous version of this paper, the within-country component is marginally affected as we only consider two different categories of workers. Moreover, in a setup with constant wages the changes in the Theil index are driven by the evolution of the workers' distribution.

[17] This assumption implies that individuals live for 50 years and allows us to use jointly the Defoort (2008) and Artuç et al. (2015) datasets.

literature. To conduct this exercise, we simulate several liberalization shocks of high-skilled migration for all country pairs and select α in order to match the average long-run elasticity of the pre-migration proportion of college graduates to the high-skilled emigration rate equal to 0.20 in developing countries, as in Beine et al. (2008). Setting $\alpha = 0.4$, we obtain an elasticity of 0.21.

Exogenous country characteristics $\left\{\sigma_{k,t}, \omega_{k,t}, \xi^s_{k,t}, A_{k,t}, \overline{\tau}_{k,t}\right\}_{\forall k,s,t}$ - Mincerian returns to schooling, MR_i, are available for 54 countries around the year 2000 in Hendricks (2004). For the same countries, we use Barro and Lee (2013) data and compute the difference in years of schooling in 2000, $DY_{k,2000}$, between college graduates and the less educated workers. The wage ratio between college graduates and less educated adult workers is then computed as $\sigma_{k,2000} = (1 + MR_{k,2000})^{DY_{k,2000}}$. For countries where data is not available, we predict the wage ratio using a log-linear function of the skill ratio in the resident labor force.[18] For subsequent periods, our baseline trajectory assumes exogenous and constant returns to schooling, $\sigma_{k,t} = \sigma_{k,2000} \forall k, t$.

As for the characteristics affecting fertility and basic education decisions $\left(\omega_{k,t}, \xi^s_{k,t}\right)$, we first use cross-country data on the skill structure of the resident labor force in 1975 ($L_{i,1975}$) from Defoort (2008) and of the native labor force in 2000 ($N_{i,2000}$) from Artuç et al. (2015). Under the identifying assumptions that $n^h_{k,t} = q^h_{k,t} = 1$, we calibrate $n^l_{k,t}$ and $q^l_{k,t-1}$ to perfectly match the average fertility rate ($n_{i,1975} = N_{i,2000}/L_{i,1975}$) and proportion of natives with secondary education ($q_{k,1975}$) in 1975. We calibrate $\left(\omega_{k,1975}, \xi^l_{k,1975}\right)$ so that the optimal fertility rates of less educated parents match the level observed in 1975, $\left(n^l_{k,1975}, q^l_{k,1975}\right)$. It is worth noticing that our worldwide average level of differential fertility $n^h_{k,1975}/n^l_{k,1975}$ is around 0.6, which corresponds to the average level reported in Kremer and Chen (1999). Using Eq. (13), $\xi^h_{k,1975}$ is calibrated to be compatible with $n^h_{k,1975} = 1$. For subsequent periods, $n^l_{k,t}$ and q^l_k are adjusted to match the medium variant of the UN demographic projections (United Nations (2011)). We then calibrate the trajectory of $\omega_{k,t}$ to match the time path for $n^l_{k,t} \forall k, t$.[19] Hence, $\omega_{k,t}$ is 3, 24.8, 44.8 and 44.8 percent lower than $\omega_{k,1975}$ in the years 2000, 2025, 2050 and 2075 respectively. With this time path for $\omega_{k,t}$, our labor force projections are in line with the medium demographic projections of the United Nations (4.903, 6.370 and 7.202 billion in 2025, 2050 and 2075, respectively). We also assume $\xi^s_{k,t} = \xi^s_{k,1975} \forall k, s, t$. Note that this determines the trajectory of $\ln \Omega^s_{k,t}$ in (16) as well as the trajectory of the supply of labor $\left(\ell^s_{k,t}\right)$ from Eqs. (19) and (20).

Under the linear technology assumption, the level of total factor productivity in 2000 can be identified to match the observed gross domestic product: $A_{k,2000} = Y_{k,2000}/(\sigma_{k,2000}\ell^h_{k,2000} + \ell^l_{k,2000})$. Data on gross domestic product are obtained from the World Development Indicators World Bank (2010). Using Eqs. (22), (23) and (24), this determines the wage structure in all countries. For subsequent periods, total factor productivity $A_{k,t}$ grows at a constant and homogeneous rate of 1.5 percent per year (i.e. 45 percent per period) in all the countries, $A_{k,t} = A_{k,t-1}(1 + 0.015)^{25}$. This determines the baseline trajectory of $v^s_{k,t}$ in (16). Alternative geopolitical scenarios are considered in Section 1.6.

[18] A simple OLS regression gives $\ln \sigma_{i,2000} = 0.25 - 0.31 \ln \frac{h_{i,00}}{1-h_{i,00}}$ with $R^2 = 0.57$.

[19] The United Nations forecast do not provide any endogenous mechanism for their predicted decrease in the fertility rate. We match their forecasts varying accordingly $\omega_{k,t}$.

Finally, decisions about higher education are governed by the Pareto distribution of the effort cost to acquire tertiary education. Although α is assumed to be common to all the countries, the lower bound of the distribution, parameter $\overline{\tau}_{k,t}$, is allowed to vary across countries. For a given α, $\overline{\tau}_{k,2000}$ is calibrated so as to match the proportion of college graduates in the labor force of country k in 2000. For subsequent periods we assume that $\overline{\tau}_{k,t} = \overline{\tau}_{k,2000}$ are constant for all k and t.

Bilateral migration costs $\left\{x^s_{ki,t}, \underline{x}^s_{ki,t}\right\}_{\forall k,i,t,s}$ - As for bilateral migration costs $\left(x^s_{ki,t}\right)$, we use the data set in Artuç et al. (2015), which documents bilateral migration stocks in 2000 for all pairs of countries $\left(N^s_{ki,2000}\right)$ and stocks of native stayers $\left(N^s_{kk,2000}\right)$ by education level. Once $v^s_{k,t}$ is identified for each country, bilateral migration costs $\left(1 - x^s_{ki,2000}\right)$ can then be recovered for each pair of countries as residuals of Eq. (4). For subsequent periods, our baseline scenario assumes that $x^s_{ki,t} = x^s_{ki,2000}$ are constant for all k, i, s, and t.

Figure 1.a depicts the identified levels of migration cost obtained for the 200 largest migration corridors (representing about 70 percent of the world migration stock). Bubble sizes are proportional to the bilateral stock of migrants in the year 2000. On average, mobility costs are smaller for college graduates (vertical axis) than for the less educated (horizontal axis). We obtain mean levels equal 0.935 for college graduates (standard error of 0.136), and to 0.973 for the less educated (standard error of 0.062). Considering the 1000 largest corridors (representing 92 percent of the world migration stocks), the mean levels increase to 0.965 and 0.988, respectively. The data reveal that 61 percent of bilateral migration corridors are empty; these corridors are characterized by $x^s_{ki,2000} = 1$ in our model.

Our calibration strategy thus perfectly fits migration data. In the benchmark trajectory of the world economy, we assume that migration costs are constant. Migration costs sum up the legal costs incurred to obtain a visa and the private costs incurred by migrants to move and assimilate in the destination country. We aggregate four waves of the Gallup World Poll survey data on desired migration to identify the magnitude of private migration costs in 2000 ($\underline{x}^s_{ki,2000}$). The survey includes two relevant questions on intentions to emigrate: "Ideally, if you had the opportunity, would you like to move permanently to another country, or would you prefer to continue living in this country?", and "To which country would you like to move?" As in Docquier et al. (2015), we consider that "having the opportunity" is interpreted by the respondents as the complete absence of policy restrictions to movement. On the one hand, this interpretation is likely to overestimate the importance of legal costs and thereby the effect of a complete liberalization. On the other hand, our baseline scenario disregards migration multiplier effects induced by networks. We identify incompressible private costs ($1 - \underline{x}^s_{ki,2000}$) as a residual of Eq. (4) after adding the skill-specific number of individuals who express a desire to emigrate to the actual migration stocks. As for total migration costs, we assume that $\underline{x}^s_{ki,t} = \underline{x}^s_{ki,2000}$ are constant for all k, i, s, and t. In Section 1.6, we allow private migration costs to decrease with the size of the bilateral migration stock.

Figure 1.b depicts the share of total migration costs explained by legal immigration restrictions. The structure is identical to that of Figure 1.a. On average, legal costs represent a greater proportion of the total for college graduates (vertical axis) than for the less educated (horizontal axis). We obtain a mean share of 0.113 percent for college graduates (and a standard error of 0.125), and of 0.018 for the

less educated (standard error of 0.034). This confirms that legal costs account for a small proportion of total migration costs. Private (psychic and monetary) moving costs are important and explain why labor mobility is relatively limited despite large income disparities within and between countries. These private costs are more important for the less educated, who usually contemplate a smaller number of potential destinations. Considering the 1000 largest corridors, the mean levels fall to 0.049 and 0.014, respectively.

Validation - Our parametrization strategy uses all the degrees of freedom of the data to identify the structural parameters and country characteristics. Hence, our model cannot produce a test of its assumptions. In order to establish the relevance of our identification method, we examine whether our identified country-specific parameters exhibit realistic correlations with observations for related variables that are not matched by our model but viewed as traditional determinants in the empirical literature. Correlation rates are presented in Table 1.

The first column shows that the calibrated relative income of children is negatively correlated with development, the quality of institutions, the level of public expenditure per student in secondary education, and positively correlated with the share of the population living in rural areas. More importantly, the correlation with the proportion of economically active children is large (58 percent). Variable $\omega_{i,1975}$ captures well parents' incentives to rely on child labor. The second column shows that the calibrated cost of basic education decreases with development and increases with the share of population living in urban areas, where access to schooling is more limited. Finally, the effort required to acquire higher education is negatively correlated with development, the quality of institutions, the level of public expenditure per student in secondary and tertiary education, and positively correlated with the share of the population living in rural areas.

Table 1: Correlation between identified country characteristics and data

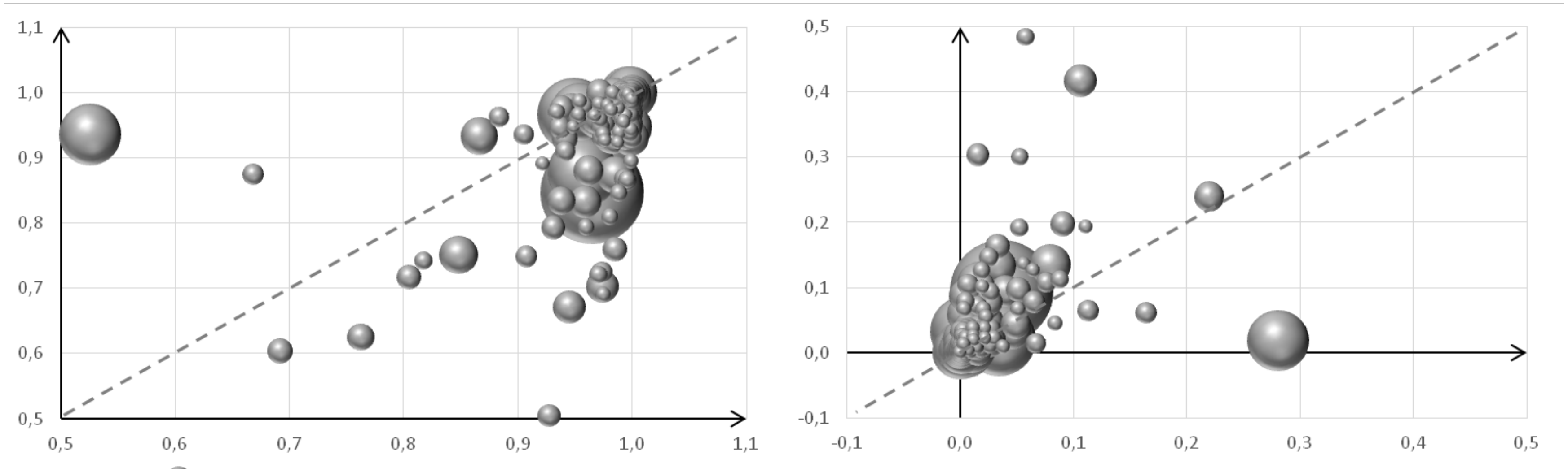
	ω_i	ε_i^l	$\overline{\tau}_i$
GNI per capita[a]	-0.49	-0.28	-0.63
Government effectiveness[b]	-0.48	-0.08	-0.54
Political stability[b]	-0.33	-0.12	-0.45
Share of rural population[a]	0.42	0.36	0.63
Economically active children (percentage of 7-14)[a]	0.58	0.32	0.61
Public education expend. per student (secondary level)[a]	-0.59	-0.01	-0.52
Public education expend. per student (tertiary level)[a]	-0.08	-0.11	-0.16

Data sources: [a] World Bank (2010) and [b] Kaufmann et al. (2008)

Figure 1: Identified migration costs incurred by college graduates (y-axis) and the less educated (x-axis) over the 200 largest corridors

1.a Total migration costs

1.b Share of legal migration costs (as % of the total)



Notes. Vertical axis: migration costs incurred by college-educated migrants. Horizontal axis: migration costs incurred by less educated migrants. Figure 1.a gives the level of $x^s_{ki,2000}$ for the 200 largest corridors in the year 2000. Figure 1.b gives the share of legal costs , $\left(x^s_{ki,2000} - x^s_{ki,t}\right)/x^s_{ki,t}$ for the 200 largest corridors (after excluding a few outliers). Bubble sizes are proportional to the bilateral stock of migrants (both college graduates and the less educated) in the year 2000.

1.5 Opening borders: partial equilibrium

We use our model to simulate the effects of a permanent removal of migration barriers, i.e. a shift in legal migration costs, assuming that the shock occurs in 2000. Results for the year 2000 are therefore fully comparable to those obtained in the static framework with exogenous population size and structure of Docquier et al. (2015). In this section, we assume that the production function is linear and that productivity growth is identical across countries. Hence, removing migration restrictions has no effect on wages. The income distribution across countries (as measured by the Theil index) is however affected by the changes in the workers' skill distribution. This partial equilibrium scenario corresponds to the *EXIT* set of hypotheses described in Proposition 4 and Definition 1. Extensions with endogenous wages are amply discussed in Section 1.6.

We first consider liberalization variants in which, for each pair of countries, the legal costs of migration are reduced by ϑ percent. Hence, ϑ can be interpreted as the liberalization rate. The change in legal migration costs writes as:

$$x^s_{ki,t} \longrightarrow x^s_{ki,t} - \vartheta(x^s_{ki,t} - \underline{x}^s_{ki,t}) \;\; \forall s, k, i, t$$

Four values of ϑ are considered, 25, 50, 75 and 100 percent. The latter scenario corresponds to a complete removal of legal migration restrictions. Figure 2.a to 2.d describe the effect of these shocks on the proportion of migrants in the world population, the worldwide level of GDP per worker, the semi-elasticity of the world GDP to the proportion of migrants, and the Theil index of income inequality.[20] The liberalization rate is measured on the horizontal axis, and each curve corresponds to a time period.

Figure 2.a shows that the change in the worldwide proportion of international migrants is almost proportional to the liberalization rate. The greatest effect is obtained in 2000, the period at which the shock occurs. Then, it slightly decreases over time because the population living in developing countries gradually falls relative to the baseline trajectory. In the year 2000, a 25 percent cut in migration barriers increases the worldwide proportion of immigrants from 3.5 percent to 6 percent (+2.5 percentage points) while a complete liberalization raises it to 12.3 percent (+8.7 percentage points). By 2100, a 25 percent cut in migration barriers increases the average proportion of immigrants by 2.4 percentage points while a complete liberalization raises it by 7.1 percentage points.

A key finding of our analysis is that removing migration barriers stimulates the acquisition of human capital. There are three reasons for this. First, in line with the *brain gain* literature (see Stark et al. (1997), Mountford (1997), Beine et al. (2001); Beine et al. (2008), Easterly and Nyarko (2008), Docquier and Rapoport (2012)), increased emigration prospects stimulate the expected return to education; the fraction of young adults acquiring higher education increases as from the year 2000. As shown in Table 2.a, the worldwide proportion of college graduates increases from 11.2 to 12 percent (+ 0.8 percentage points) under the full liberalization scenario. Second, wherever they live, newly educated parents have higher propensities to educate their children. Third, newcomers in rich countries, educated or not, face a better

[20] In the Appendix (Section 1.8.1), we discuss (and provide tables) on the impact of liberalization-shocks on the size and the distribution of the world population.

environment (lower education costs, no child labor) for providing basic education to their offspring. The latter two effects are dynamic by nature. Enrollment in basic education increases as from 2000, and the pool of young adults who can access the higher education system gets larger as from 2025. Consequently, the rise in educational attainment is gradual and cumulative. In 2100, the world proportion of college graduates increases by about 6.7 percentage points as compared to the baseline (from 17.7 percent in the baseline to 24.4 percent under the complete liberalization scenario). In parallel, the world average fertility rate and the world population size decrease gradually (i.e. -4.3 % in the year 2100 as compared to the baseline scenario). These socio-demographic changes exert a strong influence on the efficiency gains from removing migration barriers.

Figure 2.b reveals that the efficiency gains are slightly concave in the liberalization rate: reducing migration barriers by 50 percent allows the realization of slightly more than 50 percent of the gains that can be achieved under a full liberalization. In the year 2000 (the short run), reducing migration barriers by 25 percent increases the world average level of GDP per worker by 3.8 percent as compared to the baseline scenario. A complete liberalization increases GDP per worker by 13.1 percent. The concentration of workers in higher productivity countries and the gradual changes in the accumulation of human capital imply that the economic gains of liberalizing migration flows are cumulative. Hence, by the year 2100, the effects are four times larger than in the short run: the worldwide level of GDP per worker increases by 19.1 and 53.8 percent when migration barriers are reduced by 25 and 100 percent, respectively.

Figure 2.c reveals that the semi-elasticity of the world GDP to the proportion of migrants is almost independent of the liberalization rate. In the year 2000, it is around 1.5, which is slightly above the 1.33 semi-elasticity obtained in the static frameworks of Docquier et al. (2015), Iregui (2003), Winters (2001) or Walmsley and Winters (2005). This is because our model endogenizes the decision to acquire college education. As from the year 2000, removing migration barriers increases expected returns to schooling and the worldwide proportion of college graduates.[21] In addition, given the gradual and cumulative changes in human capital accumulation, the semi-elasticity increases over time. In 2100, the semi-elasticity lies between 7.5 and 8 depending on the liberalization rate. Figure 2.d shows that the distribution of income is less unequal in a world with lower mobility restrictions. Removing migration barriers relocate workers from poor countries (where inequality is high) to rich countries (where inequality is lower). In the short run, the Theil index decreases by 0.4 percentage points if migration costs are reduced by 25 percent, and by 1.6 percentage points if migration is fully liberalized. By the year 2100, deviations from the baseline scenario are equal to -2.9 and -10.7 percentage points for a 25 and 100 percent reduction in migration costs, respectively.

Focusing on the complete liberalization scenario, Tables 2.a and 2.b give the changes in the average proportion of college-educated adults and in the average level of GDP per worker in 11 regions: USA (the United States), EU15 (the 15 initial members of the European Union), CANZ (Canada, Australia, and New Zealand), GCC (countries of the Gulf Cooperation Council), MENA (Middle East and North-

[21] As it appears in the robustness section, simulating the model without this *brain gain* effect reduces the semi-elasticity to 1.4 in 2000 (see Section 1.6.2), in line with previous studies.

ern Africa), SSA (Sub-Saharan Africa), CIS (Commonwealth of Independent States, ex-Soviet Union), CHIND (China and India), ASIA (Rest of Asia), LAC (Latin American and Caribbean countries), and OTHERS (remaining countries).[22]

In the short run, GDP per worker decreases in all developed regions. The effect ranges from -0.5 percent in the EU15 to -6.1 percent in the USA and -7.1 percent in GCC. On the contrary, GDP per worker increases in the developing regions. The effect ranges from +0.6 percent in CHIND and CIS to +10.2 percent in SSA. Given that wages are exogenous in the partial equilibrium scenario, these results are entirely driven by the change in the skill composition of the regional labor force. Human capital decreases in developed regions due to massive inflows of immigrants who are on average less educated than natives. In the long run, the world average proportion of educated workers increases from 17.7 to 24.4 percent (i.e. by 6.7 percentage points). Human capital accumulation gradually reduces the negative impact of the immigration shock in developed regions (i.e. in 2100, the decrease in average GDP per worker is around -2.0 percent in the USA, and -0.1 percent in the EU15).

In developing regions, emigrants are generally positively selected (i.e. emigrants are on average slightly more educated than non migrants). For this reason, removing migration barriers induces a short-run decrease in human capital in all developing regions in the static context of Docquier et al. (2015). In our framework with endogenous formation of human capital, the proportion of college-educated natives in 2000 increases in most regions due to greater incentives to acquire higher education (see the discussion in section 1.6.2). In the long run, further human capital accumulation and decreases in the average fertility imply cumulative gains in all developing regions. In 2100, the change in GDP per worker reaches 21.9 percent in Asia and 40.8 percent in SSA as compared to the baseline scenario.

1.6 Opening borders: extensions

In this section, we assess the robustness of our results to various identifying and technological assumptions. We first use alternative interpretations of the Gallup data in Section 1.6.1. The sensitivity to the technology of human capital formation is assessed in Section 1.6.2. We then simulate our model assuming technological non linearities or externalities associated with cultural diversity in Sections 1.6.3 and 1.6.4. Finally, we consider scenarios with smaller or greater growth rates for African countries and the BRICs in Section 1.6.5. For these robustness checks, we focus on the complete liberalization scenario ($\vartheta = 100$ percent), and provide results for the worldwide level of GDP per worker and the Theil index of inequality only (see Figure 3).

1.6.1 Potential migration

In the benchmark scenario, we computed the stock of potential migrants (i.e. effective + desired migrants) and its bilateral structure, assuming that current migrants do not relocate to another destination, disregarding potential temporary migration, and disregarding network effects. In a first set of robustness

[22] Our simulations provide country-specific results, which are available upon request. We have aggregated them at the regional level for the sake of clarity and comparability with other studies.

Figure 2: Effect of a partial or complete liberalization on world aggregate values

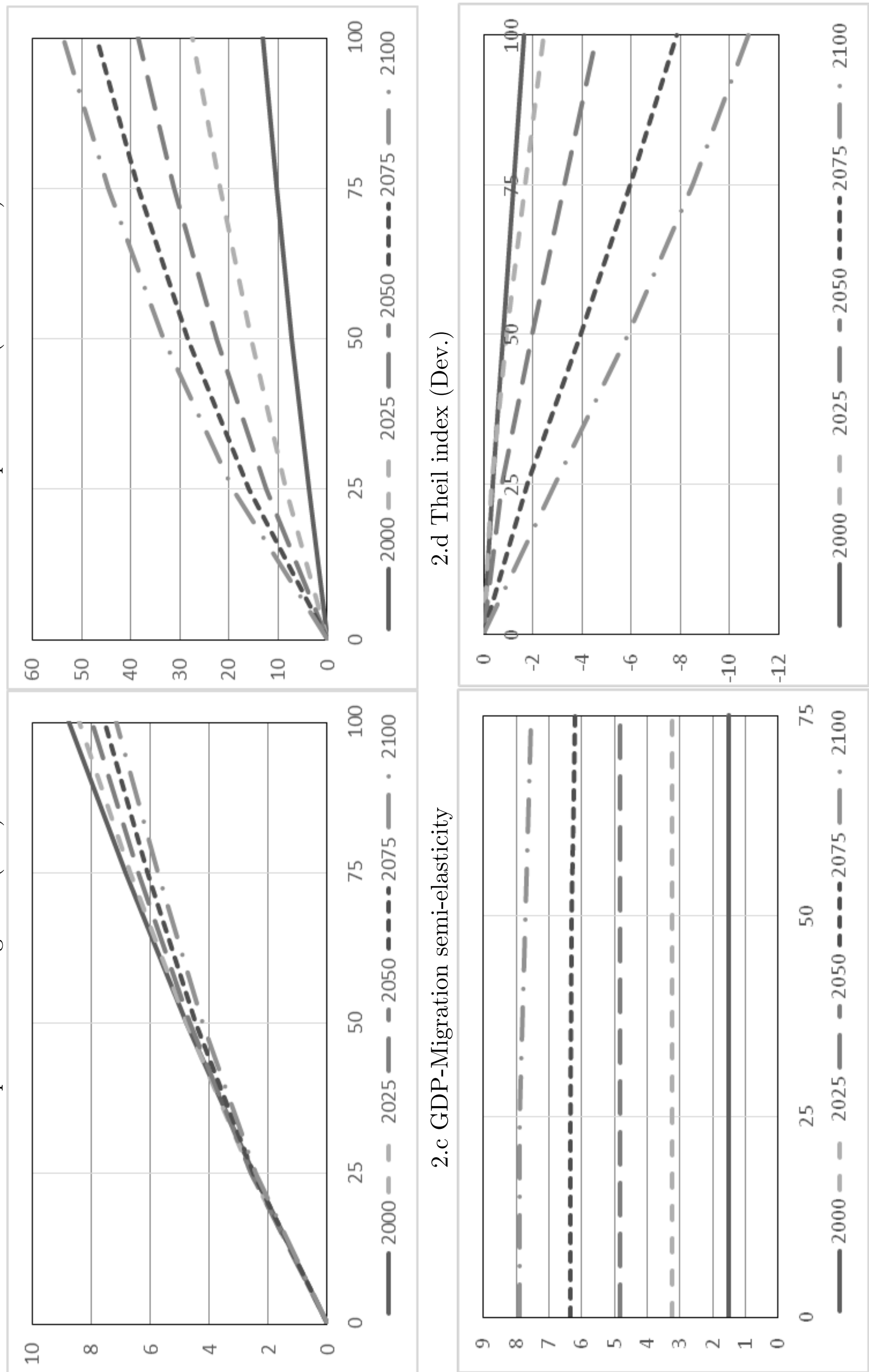


Table 2: Regional effects of a complete liberalization

2.a. Proportion of college graduates in the population aged 25 and over

	Baseline (as percent)					Liberalization (dev. in perc. points)				
	2000	2025	2050	2075	2100	2000	2025	2050	2075	2100
WORLD	11.2	11.5	14.0	17.0	17.7	+0.8	+2.3	+3.9	+5.4	+6.7
USA	51.3	53.4	55.8	56.8	56.8	-11.3	-9.3	-6.8	-4.9	-3.8
EU15	21.2	23.4	27.2	30.5	31.2	-1.0	-1.3	-0.9	-0.4	-0.2
CANZ	43.6	46.0	50.7	52.9	52.7	-10.1	-8.4	-7.3	-6.4	-5.9
GCC	12.8	13.1	18.2	21.8	21.3	-3.7	-3.2	-3.4	-3.1	-2.5
MENA	7.8	8.8	13.3	18.0	18.4	+0.3	+0.5	+1.1	+1.9	+2.6
SSA	3.1	3.3	4.5	5.7	5.8	+0.4	+0.6	+0.9	+1.4	+1.7
CIS	17.7	19.1	22.4	25.6	25.7	+0.4	+0.4	+0.4	+0.5	+0.5
CHIND	3.4	4.0	5.5	7.0	7.3	+0.6	+0.6	+0.6	+0.7	+0.7
ASIA	10.2	10.1	12.7	15.4	15.6	+0.1	+0.4	+0.9	+1.6	+2.1
LAC	11.4	13.0	18.4	24.1	25.0	+0.3	+0.3	+0.1	-0.1	-0.1
OTHERS	12.2	13.0	15.6	18.2	18.7	+2.2	+3.8	+5.7	+7.5	+9.1
HIGH	30.1	32.3	36.8	40.2	41.2	-3.3	-2.5	-1.8	-1.2	-0.9
DEV	5.9	6.6	9.0	11.5	11.8	+0.4	+0.4	+0.4	+0.5	+0.6

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

Table 2: Regional effects of a complete liberalization (continued)

2.b. GDP per adult worker

	Baseline (in USD)					Liberalization (Perc. of dev.)				
	2000	2025	2050	2075	2100	2000	2025	2050	2075	2100
WORLD	13.578	19.235	29.271	45.621	68.660	+13.1	+27.4	+38.6	+46.9	+53.8
USA	52.067	76.553	112.442	164.043	238.070	-6.1	-4.9	-3.5	-2.5	-2.0
EU15	32.095	47.740	71.291	105.428	153.908	-0.5	-0.5	-0.2	-0.1	+0.0
CANZ	38.496	56.877	83.911	122.364	177.366	-3.3	-2.6	-2.3	-2.0	-1.8
GCC	35.359	55.489	89.289	136.256	196.408	-7.1	-5.5	-5.1	-4.4	-3.6
MENA	9.442	15.068	24.819	39.240	57.183	+2.8	+3.8	+4.1	+4.0	+3.6
SSA	4.114	5.988	9.170	13.837	20.030	+10.2	+17.9	+25.7	+34.1	+40.8
CIS	11.649	17.381	26.181	38.958	56.869	+0.6	+0.9	+1.2	+1.4	+1.4
CHIND	5.760	8.607	13.035	19.359	28.096	+0.6	+0.6	+0.8	+0.9	+1.0
ASIA	12.669	17.536	25.977	39.046	56.461	+4.0	+8.6	+13.6	+18.2	+21.9
LAC	13.184	20.550	34.005	54.903	81.142	+2.4	+3.9	+5.0	+6.0	+6.8
OTHERS	14.570	21.764	33.223	50.557	75.720	+19.2	+35.6	+49.7	+61.3	+69.5
HIGH	36.425	54.798	83.562	126.069	186.911	+0.2	+2.1	+2.9	+3.0	+2.5
DEV	7.207	10.998	17.318	26.647	38.886	+1.2	+2.0	+2.9	+3.8	+4.9

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

checks, we follow Docquier et al. (2015) and consider three variants of the potential migration stock, starting from the partial equilibrium scenario:

- First, we use the same size and structure of desired migration, but consider that current migrants do relocate proportionally to the bilateral structure of desired migration. This scenario is labeled as "*Reloc*".
- Second, we use the Gallup World Survey and identify the proportion of non-migrants expressing a desire to emigrate temporarily to another country.[23] We include the latter in the set of potential migrants and assume that each temporary migrant stays almost 30 percent of a whole career in the destination country, i.e. about 8 years. We use the same bilateral structure as for permanent migration. This scenario is labeled as "*Temp*".[24]
- Third, we account for network externalities that allow private migration costs to be compressed when the size of the bilateral diaspora increases. We use the same elasticities of incompressible migration costs to the total diaspora size as in Docquier et al. (2015), i.e. -0.05 for college graduates and -0.20 for the less educated. This scenario is labeled as "*Network*".

Results of the potential migration variants are depicted in Figures 3.a and 3.b. Overall, the order of magnitude of the efficiency and inequality effects of liberalizing migration are very similar to those obtained in the partial equilibrium scenario.

Under the "*Reloc*" variant, desired migration is much more concentrated in high-income countries than effective migration. The proportion of immigrants in high-income countries reaches 37.0 percent in 2000 (compared to 35.1 percent in the partial equilibrium scenario). Figure 3.a shows that efficiency gains are therefore greater in this scenario. In the short run, the worldwide average level of GDP per worker increases by 14.4 percent while long run efficiency gains amount to 57.4 percent (compared to 13.1 and 53.8 percent in the partial equilibrium scenario). As migrants concentrate in richer regions, fertility decreases slightly more and human capital formation is amplified. The higher concentration of less educated immigrants slightly reduces the level of income per worker in the most developed countries. Hence, this scenario also implies a stronger decrease in income inequality, as shown in Figure 3.b.

Accounting for temporary migration increases the number of additional migrants by 61.4 million in the short run and 106.9 million in the long run compared to the partial equilibrium scenario (this represents an increase of 10.7 percent in the short run, and 12.7 percent in the long run). In the short run, the proportion of immigrants reaches 38.2 percent in developed countries and 3.8 percent in developing countries. In 2100, these immigration rates are equal to 21.7 and 4.4 percent, respectively. The higher number of migrants reinforces the positive effects of liberalization. Education increases and a higher number of people move to countries with lower fertility such that the world population is slightly smaller

[23]The Gallup Survey identified temporary migrants making the same questions reported in Section 1.4 but with permanently being replaced by temporary. As Docquier et al. (2015) notice there is a large overlap between the two types of questions and we follow them by considering temporary migrants only the ones who declared that they would like to migrate only temporary.

[24]Similarly to Docquier et al. (2015) we assume that 30% of temporary migrants move abroad for the full period while the remaining ones (70%) stay put.

than in the partial equilibrium scenario. As shown in Figure 3.a, world GDP per capita increases by 15 percent in the short run (compared to 13.1 percent in the partial equilibrium scenario), and the long-run effect reaches 59.2 percent (compared to 53.8 percent in the benchmark). Accounting for temporary migrants also reinforces the effect on inequality.

As for network externalities, they raise the number of global migrants by 58.7 percent in the short run, and by 40.1 percent in the long run as compared to the partial equilibrium scenario. In the short-run, the proportion of foreign-born workers increases to 47.6 and 6.4 percent in developed and developing regions, respectively. The size of global efficiency gains increases as shown in Figure 3.a. Changes in the average level of GDP per worker now amount to 20.2 percent in the short run and 67.8 percent in the long run. Network effects have a stronger impact on the private migration costs of the less educated; this negatively affects the proportion of educated workers in the richest countries. However, lowering emigration costs also triggers greater incentives to acquire education in developing countries. The rise in the worldwide proportion of college educated adults in 2100 is greater (+7.2 percentage points) than in the partial equilibrium scenario (+6.7 percentage points). Overall, we observe a sharper decline in the average level of GDP per worker of developed countries, whereas higher incentives to educate increase the gains observed in developing regions. The decrease in the Theil index is thus larger than in the partial equilibrium scenario, and is reinforced by the fact that the demographic weight of developing countries decreases in this scenario.

1.6.2 Human capital

In this section, we evaluate the robustness of our results to some identifying assumptions. The endogeneity of education and fertility decisions has strong implications for our results. We thus assess whether our efficiency and inequality responses are robust to the inclusion of the *brain gain* mechanism and to the levels of the preference parameters affecting basic education decisions. We simulate the model using the partial equilibrium environment and the three following variants:

- First, we assume a constant proportion of college graduates among those who received basic education when young. This means that we consider the second term as constant in Eq. (3). This scenario is labeled as "*No brain gain*".
- Second, we use an altruism parameter, θ, equal to 0.2 (instead of 0.3 in the benchmark). This scenario is labeled as "*Low altr*".
- Third, we use a preference for basic education, λ, equal to 0.5 (instead of 0.6 in the benchmark). This scenario is labeled as "*Low educ*".

Results of the potential migration variants are depicted in Figures 3.c and 3.d. Again, the order of magnitude of the efficiency and inequality effects are very similar to those obtained in the partial equilibrium, benchmark scenario.

Under the "*No brain gain*" variant, the proportion of college graduates is fixed in the short run and the gradual changes in human capital accumulation are smaller compared to the benchmark. The worldwide proportion of college-educated workers increases in only 55 and 69 countries in the short and long run, respectively (against 118 and 126 in the partial equilibrium scenario, respectively). This robustness check evidences that the global rise in education is mainly triggered by the improved access to basic education (i.e. the concentration and assimilation of new migrants in countries where the access to basic and tertiary education is better and fertility is lower). While the long-run fraction of college-educated workers reaches 24.4 percent in the partial equilibrium scenario, it now reaches 23.3 percent (+5.6 percentage points relative to the baseline scenario). This means that the *brain gain* mechanism explains about one sixth of the long-run increase in human capital. When *brain gain* effects are deactivated, changes in the world average level of GDP per worker and in the Theil index of inequality are slightly lower than those obtained in the benchmark scenario.

Using a smaller altruism parameter in the "*Low altr*" scenario changes the baseline trajectory of the world economy. It reduces the worldwide average fertility rate to a value slightly below unity in the long run (as compared to 1.14 in the benchmark scenario). Compared to the benchmark scenario, pre-liberalization population growth rates are smaller and the worldwide proportion of college-educated workers is greater. The latter reaches 24.5 percent in the long run, compared to 17.7 percent in the benchmark scenario. Nevertheless, the size of the efficiency gains from removing migration barriers decrease a little. As far as inequality is concerned, liberalization has a greater effect on the average fertility of developing countries. By reducing the demographic weight of these countries, it leads to a stronger decline in inequality.

In the "*Low educ*" scenario, decreasing the preference parameter for basic education increases fertility and reduces the proportion of college graduates. These changes also affect the pre-liberalization trajectory of the world economy. By 2100, the proportion of college-educated workers in the new baseline equals 15.5 percent, as compared to 17.7 percent in the partial equilibrium case. In the long run, liberalization increases the worldwide level of GDP per worker by 56 percent (compared to 53.8 percent in the benchmark scenario). While the global proportion of migrants is virtually unchanged with respect to the benchmark scenario, migrants tend to be more concentrated in developed countries. This is particularly true for high-skilled migrants from poor countries. Overall, opening borders is less beneficial for developing countries, which lose more talented workers and exhibit greater population growth rates. The decrease in inequality implied by a liberalization is thus slightly less pronounced than in the benchmark scenario.

1.6.3 Technological non linearities

Our benchmark scenario assumes a linear technology (constant skill premium), exogenous TFP levels, and an unconstrained absorption capacity by the receiving countries. Three alternative scenarios are considered here:

- First, we assume a CES specification for $F(.)$. As in Docquier et al. (2015), we set the elasticity of substitution to 3.0 in all the countries, and calibrate the country-specific preference parameters for college-educated workers so as to match the wage ratios $\sigma_{k,t}$ observed in 2000. This scenario is labeled as "*CES*".

- Second, we consider the possibility of a positive schooling externality on TFP (see Peri et al. (2013)). We assume that the elasticity of TFP to the proportion of college graduates in the labor force equals 0.32. We use $A_{k,t} = A_{k,t}^{Base}\left(h_{k,t}/h_{k,t}^{Base}\right)^{0.32}$ where $A_{k,t}^{Base}$ and $h_{k,t}^{Base}$ stand for the TFP levels and proportion of college graduates in the baseline scenario. This scenario is labeled as "*Schooling*".

- Third, we account for limited absorption capacity and allow TFP to decrease with the size of the labor force. Ciccone and Hall (1996) recommended using an elasticity of -0.03, representing the share of land in production. We use $A_{k,t} = A_{k,t}^{Base}\left(L_{k,t}/L_{k,t}^{Base}\right)^{0.03}$ where $L_{k,t}^{Base}$ stands for the total adult population in the baseline scenario. This scenario is labeled as "*Congest*".

Results of the potential migration variants are depicted in Figures 3.e and 3.f. In the "*CES*" and "*Congest*" scenarios, the order of magnitude of the efficiency and inequality effects is very similar to those obtained in the partial equilibrium scenario. Adding schooling externalities reduces the efficiency gains from liberalizing migration, but induces larger effects on inequality.

Under the CES technology, the skill premia becomes endogenous. Low-skilled wages increase and high-skilled wages decrease with the proportion of college graduates in the workforce. This change in the production function only marginally impacts our results. Efficiency gains increase slightly less than under the partial equilibrium scenario. Average GDP per worker increases by 12.7 percent in the short run and 53.0 percent in the long run. Efficiency gains are slightly higher in developed countries while marginally lower in developing countries. The decrease in inequality is less marked than in the partial equilibrium scenario because returns to schooling increase in high-income countries.

Under the "*Schooling*" scenario, productivity decreases in high-income countries due to the immigration-driven change in the proportion of college graduates. Lower economic performances in developed countries reduce incentives to emigrate and to acquire college education. For these reasons, the global efficiency gains from removing migration barriers are smaller than those obtained in the partial equilibrium scenario. They amount to 10.2 and 49.5 percent in the short and long run, respectively. The inequality effect also changes because productivity decreases in developed countries (due to a decline in human capital) and increases in developing countries (due to the *brain gain* mechanism). Consequently, we observe a stronger decline in inequality compared the partial equilibrium scenario, especially in the short run.

Accounting for congestion has a negligible impact on our results. Productivity in traditional immigration countries is negatively affected by congestion whereas productivity increases in emigration countries due to the lower pressure on their resources. The global efficiency gains are slightly smaller than those obtained in the partial equilibrium scenario (12.3 and 49.8 percent in the short and long run, respectively). As congestion implies a decrease in the average income per worker in developed countries and an increase in developing countries. Hence, the Theil response to a liberalization is slightly more important than in the partial equilibrium scenario.

1.6.4 Cultural diversity

In this section, we account for potential gains and costs from cultural diversity. Although cultural diversity may directly impact utility, acting as an amenity or a disamenity, we only treat its effect as a shift in TFP. We proxy cultural diversity using a birthplace diversity index of the labor force ($Div_{k,t}$) for each country and period. Our index measures the probability that two randomly drawn individuals in a country originate from two different birthplaces. We then allow TFP to vary positively or negatively with this index. The empirical literature has provided ambiguous results on the sign and magnitude of this effect. We consider three scenarios and assume that the diversity effect on TFP is only observed in high-income OECD destination countries:

- Our first variant assumes a negative effect of cultural diversity on TFP. We follow Parrotta et al. (2014) who found a negative effect of workers' diversity by nationality on the productivity of Danish firms, using a matched employer-employee database. Linearizing their specification gives $A_{k,t} = A_{k,t}^{Base} - 0.075\left(Div_{k,t} - Div_{k,t}^{Base}\right)$. This negative externality can be due to negative effects on communication or cooperation among workers. Another channel of transmission advocated by Collier (2013) is trust (or mutual regard). The effect of trust on the log of TFP has been identified in Knack and Keefer (1997); their long-run coefficient is around 0.30. At the same time, Alesina and La Ferrara (2002) showed that diversity by race reduces trust by 0.24. Although the latter effect pertains exclusively to race, not national origin, combining these effects and linearizing at the current level of diversity gives an effect of diversity on TFP which is exactly equivalent to the effect of birthplace diversity identified in Parrotta et al. (2014). We thus assume a negative elasticity of -0.075 in our first variant, labeled as "*Low cult*".

- Our second variant is even more pessimistic and arbitrarily assumes a negative coefficient of -0.15, twice as high as in the previous scenario. This scenario is labeled as "*High cult*".

- On the contrary, in our third variant, we consider a positive effect of birthplace diversity on TFP. Such a positive effect has been identified in empirical studies based on aggregate data by country (see Alesina et al. (2013)) or US metropolitan areas (see Ottaviano and Peri (2006)). Here we linearize the IV, state-effect specification for wages estimated by Ottaviano and Peri (2006). This gives $A_{k,t} = A_{k,t}^{Base} + 0.68\left(Div_{k,t} - Div_{k,t}^{Base}\right)$. This scenario is labeled as "*Cult benefits*".

Results of the cultural diversity variants are depicted in Figures 3.g and 3.h. Under the two scenarios considering the negative elasticities of productivity to diversity, the order of magnitude of the efficiency and inequality effects are very similar to those obtained in the partial equilibrium scenario. However, at the level of the positive elasticity obtained in the macro literature, birthplace diversity sharply increases the efficiency gains from removing migration barriers, but also changes the inequality response, leading to more inequality in the short run.

After removing migration barriers, birthplace diversity increases in almost all the countries of the world (i.e. 190 countries in the short run, and 180 countries in the long run). Exceptions are to be found mainly among small island developing states. Therefore, under the "*Low cult*" scenario, the TFP level decreases in most countries. Benefits accruing from liberalization are thus lower than in the partial equilibrium scenario. In the short run, average GDP per worker increases by 11 percent (compared to 13.1 percent in the partial equilibrium case) while it rises by 52.4 percent in the long run (compared to 53 percent in the partial equilibrium). The inequality response is similar to that obtained in the partial equilibrium scenario. Inequality decreases slightly more in the short run, but the difference with respect to the benchmark almost disappears in the long run. The same patterns are obtained under the "*High cult*" scenario, although they are amplified. Efficiency gains are further reduced in the short run (+8.9 percent) and in the long run (+51 percent).

Results are different if we consider the positive elasticity of productivity to birthplace diversity estimated in the macro literature. Since developed countries host the majority of potential migrants, a positive externality means that the level of TFP increases in the richest countries of the world. This reinforces the efficiency gains from removing migration barriers. In the short run, the average level of GDP per worker increases by 36.1 percent (three times more than in the partial equilibrium scenario), and the long run gains reach 65.8 percent. In addition, if rich countries benefit from birthplace diversity, a complete liberalization of migration increases cross-country disparities in productivity. In the short run and after 25 years, liberalizing migration makes the world distribution of income more unequal. This effect disappears in the long-run because of the gradual changes in human capital accumulation.

1.6.5 Geopolitics

In our benchmark scenario, TFP growth (1.5 percent per year) is assumed to be homogeneous across countries. We consider here three geopolitical variants:

- The first assumes that the BRICs (Brazil, Russia, India and China) grow by 3 percent per year from 2000 to 2100. This means that by 2100, the BRICs will be 4.3 times as rich as in the baseline scenario. This scenario is labeled as "*High BRIC*s".
- The second variant assumes that Africa (both Northern and sub-Saharan African countries) grows by 3 percent per year from 2000 to 2100. This means that by 2100, Africa will be 4.3 times as rich as in the baseline scenario. This scenario is labeled as "*High Africa*".
- On the contrary, the third variant assumes that Africa grows by 1 percent per year from 2000 to 2100. This means that by 2100, Africa will be 40 percent poorer than in the baseline scenario. This scenario is labeled as "*Low Africa*".

Results of the potential migration variants are depicted in Figures 3.i and 3.j. Assuming that the BRICs grow faster than the rest of the world implies that these countries catch up with the developed countries in the baseline. This implies that workers from this countries have less incentives to emigrate, and that the BRICs become more attractive for foreign migrants. The first effect dominates. Hence, the world migration stock after liberalization now amounts to 741 million in 2100, as compared to 844 million in the partial equilibrium scenario. The world average proportion of migrants reaches 12.3 and 9.5 percent in the short and long run, respectively. This reduces the scope of efficiency gains, as reflected in Figure 3.i. The effect on the world GDP peaks at 27.5 in 2050 and then decreases to 25 percent in the long run. As BRICs countries converge towards developed countries but diverge with respect to developing countries, the Theil index decreases slightly less than in the partial equilibrium.

Under the "*High Africa*" variant, the effects are similar to those of the previous scenario. The convergence of Africa reduces the incentives for Africans to emigrate. The impact of a liberalization on efficiency gains follows the pattern observed in the "*High BRIC*" scenario. In the long run, efficiency gains amounts to 34.2 percent in 2100; this is much lower than the gains obtained in partial equilibrium (53.8 percent). The effect on the Theil index is virtually identical of the partial equilibrium scenario. On the contrary, under the "*Low Africa*" variant, greater income disparities between Africa and the rest of the world stimulate emigration flows. Efficiency gains are identical to those of the benchmark whereas the change in inequality is more pronounced.

1.6.6 Accounting for remittances

Our benchmark simulation does not account for remittances that migrants send back to their home country. The average ratio of remittances to GDP is low in developing countries (3 percent), and 135 countries exhibit a lower ratio than the mean. However, this ratio is much greater in some countries (36 percent in Tonga, 34 in Lesotho, 29 in Bosnia, 22 in Jordan, 20 in Samoa, 17 in West Bank and Gaza, 16 in Albania, 15 in Haiti, Yemen and Cape Verde). In many of these countries, the after-liberalization ratio of emigrants to stayers is three to six times larger than in the baseline. This can induce huge changes in the level of remittances and income. Hence, accounting for remittances is likely to affect the size of our effects.

It is however difficult to include remittances for different reasons. First, the literature has emphasized different motives to remit (altruism, exchange of services, risk diversification, reimbursement of loans, etc.) and the weights of these motives vary across countries or country pairs. Second, there is no consensus about who remits more and who receives more (college graduates or the less educated). Survey data collected in Bollard et al. (2011) show that the correlation between the amount remitted and the level of education of emigrants is also country-specific. Third, in a fully micro-founded model, individuals should anticipate remittances in their migration and education decisions, and the amount remitted would itself depend on the size of migration flows. The properties of our model would be much more complex while the literature has not identified robust and general effects of remittances on education decisions and other types of investment. In other words, there is no consensual strategy to include remittances in such a model and to parametrize remittance patterns.

To assess the role of remittances, we adopt here an *ad hoc* strategy. Although we acknowledge the fact that remittances could affect the size of our efficiency gains (through their impact on education, fertility and migration), we assume that these efficiency effects are of second-order importance and only focus on inequality responses. We compute the after-transfer inequality index considering that remittances have

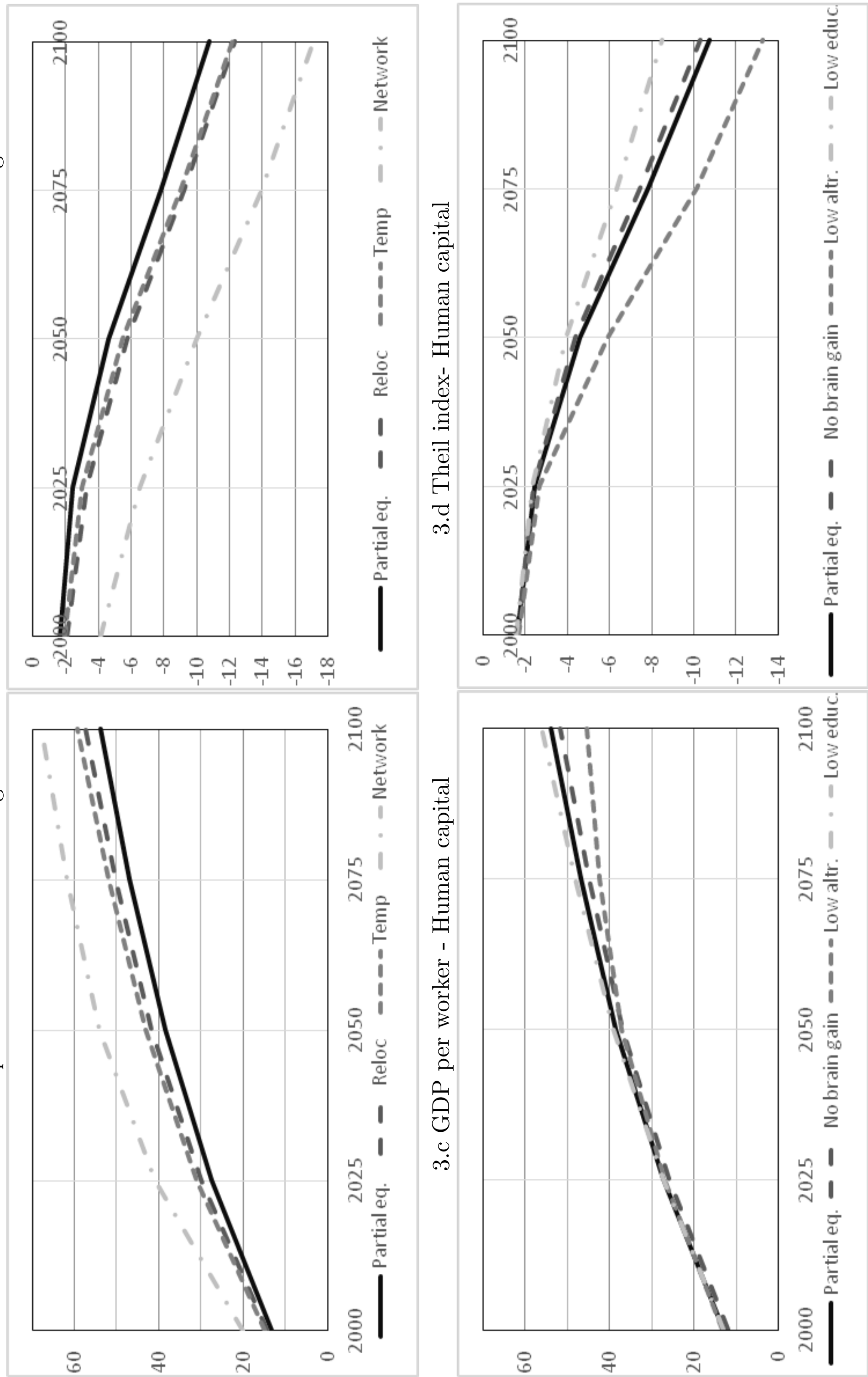


Figure 3: Robustness of the efficiency and inequality effects of liberalizing migration

Figure 3: Robustness of the efficiency and inequality effects of liberalizing migration (continued)

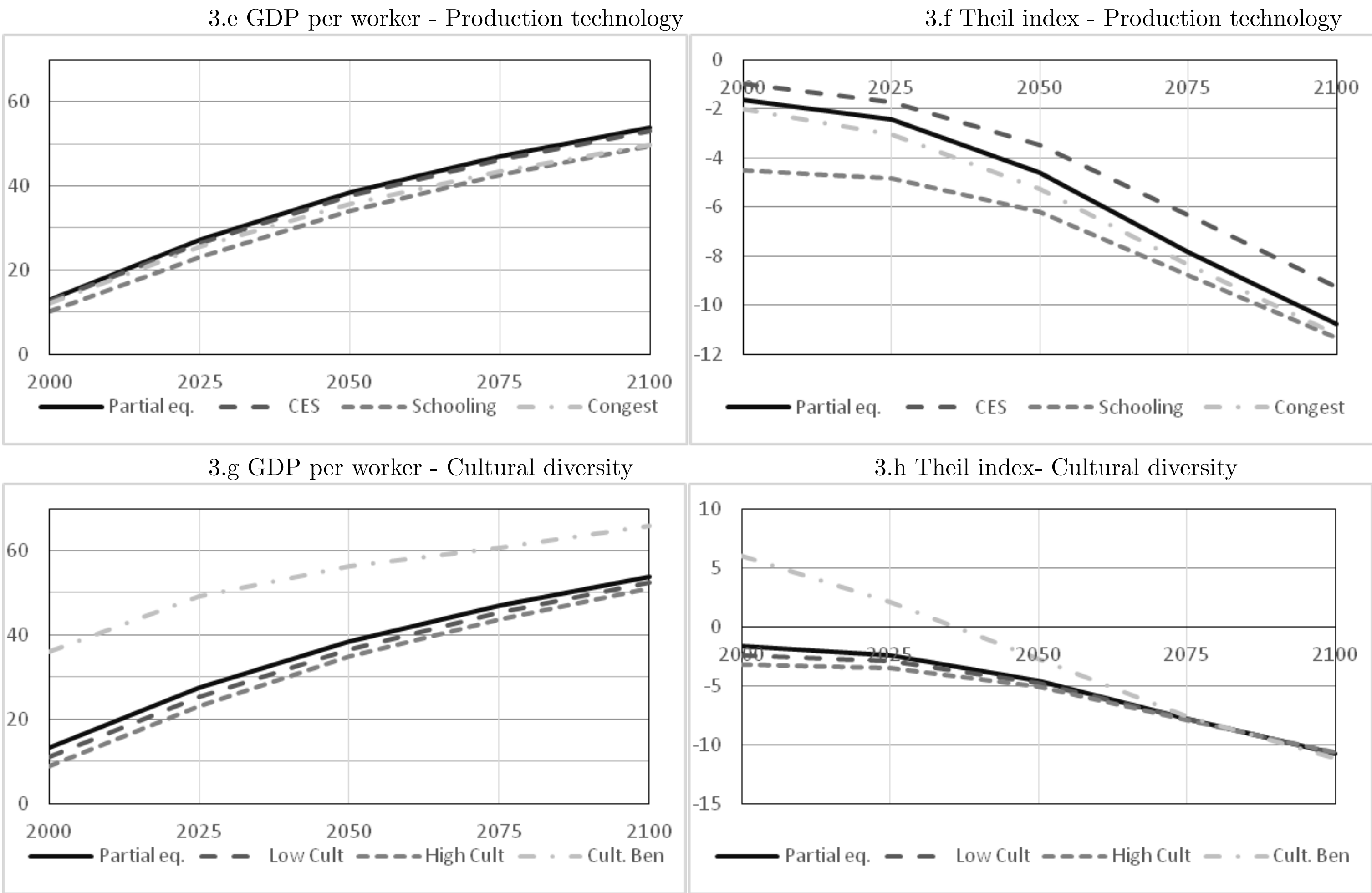
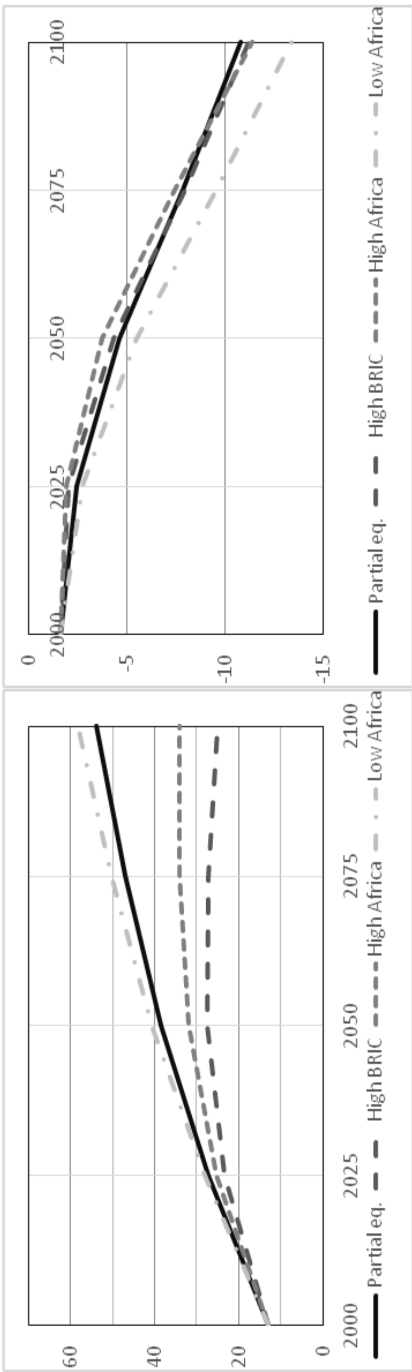


Figure 3: Robustness of the efficiency and inequality effects of liberalizing migration (continued)

3.i GDP per worker - Geopolitics

3.j Theil index - Geopolitics



no effect on education, fertility and migration.

Our model endogenizes the level of pre-transfer income of all migrants and non migrants. In 2000, we can easily compute the aggregate labor income of all emigrants from any country i ($EMW_{i,2000}$), the aggregate income generated in country i ($Y_{i,2000}$), and calibrate the propensity to remit of emigrants from country i (r_i) that perfectly fits the observed ratio of remittances to GDP ($REM_{i,2000}$) in 2000. This gives $r_i = REM_{i,2000}Y_{i,2000}/EMW_{i,2000}$. Then we simulate the income distribution after a complete liberalization and in all subsequent periods, assuming that r_i is constant (high-remittance variant) or that the elasticity of r_i to the emigrant/stayer ratio equals -0.5 (low-remittance variant):[25] we obtain a new ratio of remittances to GDP, $REM_{i,t} = r_{i,t}EMW_{i,t}/Y_{i,t}$. Results for the average remittances/GDP ratio in developing countries, and for the after-remittance Theil index of inequality are depicted in Figures 4.a and 4.b.

Figure 4.a provides the changes in the remittances/GDP ratio in developing countries, expressed in percentage point of deviation from the baseline. Under a constant propensity to remit, a full liberalization increases the remittances/GDP ratio in developing countries by 6 percentage points in 2000, and by 5.5 percentage points in 2100. As shown in Figure 4.b, the decrease in the after-remittance Theil index ('High Rem' curve) is much more pronounced than in the before-remittance index ('No Rem.' curve). However, if the propensity to remit is elastic to the emigrant-to-stayer ratio, the remittances/GDP ratio only increases by 1.4 to 1.9 percentage points in all the years. The decrease in the after-remittance Theil index ('Low Rem' curve) is then much closer to that obtained for the before-remittance index. In sum, the fall in inequality induced by a liberalization can be accentuated by remittances, but this is the case if and only if the propensity to remit of emigrants is sufficiently inelastic to the emigrant-to-stayer ratio.

1.7 Conclusion

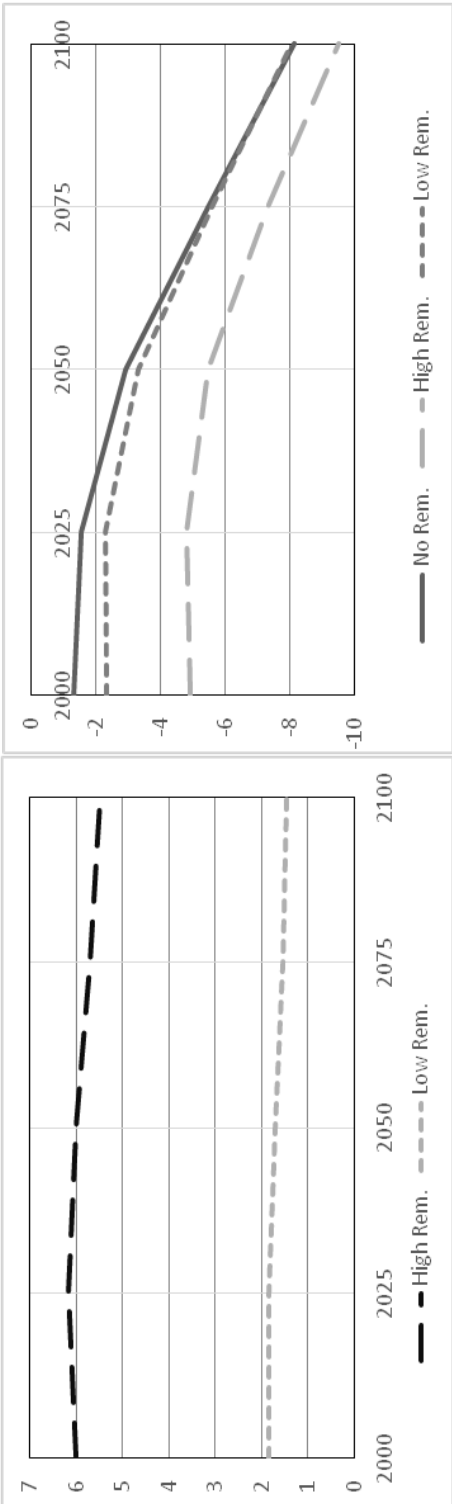
This paper studies the effect of immigration barriers on the world distribution of income. We develop a theoretical framework that accounts for education and fertility responses to migration policy reforms. Quantitatively, we show that the efficiency and redistributive effects of immigration restrictions gradually increase over time when population growth and human capital accumulation are endogenized. In a partial equilibrium framework, a complete liberalization of labor mobility increases the world average level of GDP per worker by 13 percent in the short run, and by about 54 percent after one century. The main reason is that new migrants moving from developing to developed countries face a favorable environment (lower education costs, no child labor) for providing basic education to their children and decreasing their fertility. This increases the pool of young adults who are eligible for higher education in the future generation. Some of them will invest in college education and will have a greater propensity to provide education to their own offspring. Hence, the effects on human capital accumulation, income and inequality are cumulative: liberalizing migration gradually increases the world proportion of college educated and reduces population growth.

[25] This elasticity is compatible with Faini (2007) and Niimi et al. (2010), who found an elasticity of remittances to the stock of emigrants of 0.5. Freund and Spatafora (2008) found an elasticity between 0.65 and 0.75.

Figure 4: Remittances and the inequality effects of a complete liberalization

4.a Remittances/GDP in developing countries (Dev.)

4.b Theil index with remittances



These mechanisms are robust to our identifying assumptions and are also valid in the case of a partial liberalization, provided that the cut in migration restrictions is global (i.e. identical for all the country pairs and educational groups). We thus demonstrate that the long-run gain from liberalizing cross-border migration exceeds by far the short-run effect, although the magnitude of these effects varies when we allow for an externality of schooling or cultural diversity on productivity, and when our baseline (pre-liberalization) scenario involves a rapid takeoff of sub-Saharan Africa or emerging countries. Nevertheless, in the most likely scenarios, large efficiency gains can be expected from removing migration barriers, but these large gains mostly arise in the long run and will impact the welfare of future generations. This makes it difficult to find redistributive policies to compensate the losers, mainly the current cohorts of low-skilled nationals residing in high-income countries.

1.8 Appendix

1.8.1 Regional Effects of a liberalization on the distribution and the size of the world population.

In this section we analyze the effect of a liberalization on the size and the distribution of the world population. This discussion and the tables refer to the partial equilibrium scenario. Total population is the sum of the adults (people aged 25+) and children (people older less than 25). This definition makes our population numbers different from the UN data. This discrepancy is due to the fact that, in our parametrization, the living population between year 2000-2025 is equal to the sum of the labor force at year 2000 plus the labor force at year 2025. On the contrary, our parametrization is set to match UN labor force projections. However, comparing the baseline and the liberalization scenarios gives valuable information on how the distribution of people across countries would be affected by less stringent or none migration-restriction policy. Intuitively, and as confirmed by Tables 3.a, 3.b, 3.c, 3.d and 3.e a liberalization would increase the population size of the world's developed regions. This effect is substantial already at year 2000, for instance in the full liberalization scenario we estimate a 28.3 percent larger population in the developed regions. The estimated increase is lower for partial liberalization liberalization policies, see Table 3.a. Even if migrants assimilate in terms of education- and fertility-choices the population increase gets larger in the long-run; population in developed region would be more than twice larger in the full liberalization scenario, see Table 3.e. The developed regions that would face the largest population increase are GCC (the countries of the Gulf Cooperation Council), for which we estimate 126.9 increase in the short run, and a population more than twice larger in the long run. On the contrary, population size would fall sharply in the developing regions. The effect is stronger in the SSA (sub-Saharan Africa) and MENA (Middle East and African Countries). Finally we find that the net effect, namely on the world population as a whole, is slightly negative both in the short run and in the long run.

Table 3: Effect of a partial or complete liberalization on the distribution of the worldwide population

3.a Effects at year 2000

		Liberalization (Perc.of dev.)			
Regions	Baseline	↓ 25% *	↓50% *	↓ 75% *	↓ 100%*
WORLD	8084653742	-0.3	-0.6	-0.8	-1.0
USA	400924717	11.8	22.2	31.6	40.1
EU15	587694698	5.4	10.2	14.4	18.2
CANZ	78558106	35.7	68.4	98.7	126.9
GCC	40714591	48.6	92.0	131.4	167.3
MENA	413961014	-3.6	-6.9	-9.8	-12.5
SSA	651305520	-5.4	-9.9	-13.6	-16.9
CIS	384899620	-2.1	-4,1	-5.9	-7.7
CHIND	3071682337	-0.9	-1.8	-2.6	-3.5
ASIA	1534243972	-2.4	-4.6	-6.5	-8.2
LAC	703066222	-3.8	-7.0	-9.8	-12.2
OTHERS	217602944	-0.9	-1.6	-2.2	-2.6
HIGH	1546216046	8.2	15.5	22.2	28.3
DEV	6538437696	-2.3	-4.4	-6.2	-7.9

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

*Liberalization rate

Table 3: Effect of a partial or complete liberalization on the distribution of the worldwide population (continued)

3.b Effects at year 2025

		Liberalization (Perc.of dev.)			
Regions	Baseline	↓ 25% *	↓50% *	↓ 75% *	↓ 100%*
WORLD	11274060494	-0.8	-1.5	-2.0	-2.5
USA	546045433	23.9	43.9	60.9	75.9
EU15	693483367	12.6	22.8	31.2	38.3
CANZ	113893040	62.6	118.7	169.5	216.1
GCC	87793367	68.9	127.0	176.9	220.3
MENA	688235722	-7.3	-13.5	-18.9	-23.6
SSA	1035743079	-10.7	-18.9	-25.3	-30.5
CIS	439651191	-4.0	-7.8	-11.2	-14.4
CHIND	4110704481	-1.8	-3.6	-5.4	-7.1
ASIA	2266303421	-4.7	-8.7	-12.1	-15.1
LAC	1042048717	-7.3	-12.9	-17.5	-21.3
OTHERS	250158676	-1.4	-2.3	-2.8	-3.0
HIGH	1971181909	17.9	33.0	46.0	57.4
DEV	9302878585	-4.8	-8.8	-12.2	-15.2

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

*Liberalization rate

Table 3: Effect of a partial or complete liberalization on the distribution of the worldwide population (continued)

3.c Effects at year 2050

		Liberalization (Perc.of dev.)			
Regions	Baseline	↓ 25% *	↓50% *	↓ 75% *	↓ 100%*
WORLD	13571996707	-1.1	-2.0	-2.8	-3.5
USA	738024480	33.2	59.2	80.5	98.4
EU15	772380610	20.0	34.7	46.2	55.3
CANZ	157583905	80.6	151.0	213.6	270.0
GCC	146675639	77.7	139.4	189.5	231.0
MENA	893308486	-10.9	-19.7	-26.9	-32.9
SSA	1328625381	-15.7	-26.7	-34.9	-41.2
CIS	457635739	-5.9	-11.2	-16.0	-20.4
CHIND	4769395201	-2.8	-5.6	-8.3	-10.9
ASIA	2778984173	-6.8	-12.4	-17.0	-20.9
LAC	1269283750	-10.3	-17.7	-23.4	-27.9
OTHERS	260099343	-1.1	-1.4	-1.0	-0.3
HIGH	2403538291	26.9	48.3	66.0	80.9
DEV	11168458416	-7.1	-12.9	-17.6	-21.6

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

*Liberalization rate

Table 3: Effect of a partial or complete liberalization on the distribution of the worldwide population (continued)

3.d Effects at year 2075

		Liberalization (Perc.of dev.)			
Regions	Baseline	↓ 25% *	↓50% *	↓ 75% *	↓ 100%*
WORLD	15345146570	-1.3	-2.4	-3.2	-4.0
USA	976406551	38.8	67.6	90.2	108.8
EU15	840689730	26.1	44.0	57.1	67.1
CANZ	210179644	91.4	169.1	237.0	297.2
GCC	216971559	80.8	141.2	187.7	224.3
MENA	1046378873	-14.3	-25.2	-33.8	-40.6
SSA	1561930728	-20.3	-33.5	-42.7	-49.4
CIS	457260008	-7.6	-14.4	-20.4	-25.7
CHIND	5201755195	-3.9	-7.7	-11.3	-14.7
ASIA	3152365762	-8.9	-15.7	-21.3	-25.8
LAC	1421921545	-12.8	-21.5	-27.9	-32.7
OTHERS	259286975	-0.1	0.9	2.7	5.0
HIGH	2880402447	33.9	59.5	79.8	96.5
DEV	12464744123	-9.5	-16.7	-22.4	-27.2

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

*Liberalization rate

Table 3: Effect of a partial or complete liberalization on the distribution of the worldwide population (continued)

3.e Effects at year 2100

Regions	Total Population Baseline	Liberalization (Perc.of dev.) ↓ 25% *	↓50% *	↓ 75% *	↓ 100%*
WORLD	17384771131	-1.6	-2.8	-3.8	-4.6
USA	1259805845	42.4	72.3	95.1	113.3
EU15	918108118	31.1	50.9	64.7	74.9
CANZ	271159391	98.4	180.1	250.0	311.1
GCC	307384063	81.8	139.2	181.1	212.5
MENA	1220954535	-17.4	-30.1	-39.5	-46.6
SSA	1836428528	-24.5	-39.4	-49.1	-55.9
CIS	456930231	-9.3	-17.4	-24.4	-30.5
CHIND	5691620994	-5.0	-9.8	-14.3	-18.6
ASIA	3570127820	-10.7	-18.8	-25.0	-30.0
LAC	1591813859	-15.0	-24.6	-31.3	-36.3
OTHERS	260437747	1.4	4.2	7.7	11.8
HIGH	3444186614	39.4	67.5	89.1	106.4
DEV	13940584517	-11.7	-20.2	-26.7	-32.0

Note: USA = United States, EU15 = 15 members of the European Union; CANZ = Canada, Australia and New Zealand; GCC = countries of the Gulf Cooperation Council; MENA = Middle East and Northern Africa; SSA = Sub-Saharan Africa; CIS = Commonwealth of Independent States (ex-Soviet Union); CHIND = China and India; ASIA = Rest of Asia; LAC = Latin American and Caribbean countries; OTHERS = Other countries; HIGH = High-income countries; DEV = Developing countries (World Bank classification in 2014).

*Liberalization rate

2

Infrastructure policy: the role of informality and brain drain

abstract

This paper analyzes the effectiveness of infrastructure policy in developing countries. In these countries public infrastructure is mainly funded by local taxes and individuals can evade taxation either by moving to the informal sector or by emigrating abroad. I develop a two-sector, dynamic model with endogenous infrastructure and human capital accumulation in the presence of these two exit options. Then, I calibrate the model for a subset of 60 developing countries, and conduct numerical policy experiments. I show that, at low level of development, the possibility to work informally has a detrimental impact on infrastructure accumulation. Hence, increasing the tax rate or enlarging the tax base can reduce the macroeconomic performance in the short run, while inducing long-run gains. These short- and long-run effects are amplified when brain drain is endogenous, they are also greater where the initial level of infrastructure is low and the brain drain is large.

2.1 Introduction

There is compelling empirical evidence that public infrastructure matters for development, and that the level of infrastructure is critically low in developing countries. For instance, Lin and Doemeland (2012) report that almost one billion and a half people have no access to electricity; Foster et al. (2010) report that the per-capita production of electricity is so low in sub-Saharan Africa (excluding South Africa) that the average household cannot power one light bulb for six hours a day. In this context, increasing the level of infrastructure is essential to achieve development, as Figure 5 suggests by illustrating the positive correlation between GDP per capita and two proxies of infrastructure. Although the raw correlation illustrated in Figure 5 does not necessarily involve a causal relationship, I shall review the abundant literature on the causal impact of infrastructure on development in Section 2.2.

In this paper, I argue that the difficulty to raise fiscal revenues is one of the main reasons why investments in infrastructure are small in developing countries. To investigate and quantify the effectiveness of infrastructure policy, I develop a two-sector dynamic model with endogenous infrastructure and human capital accumulation. The rationale is that developing countries need to accumulate both factors to achieve development, and the infrastructure policy affects their speed of accumulation. The formal sector represents the official economy and uses low-skilled and high-skilled workers; the total factor productivity of formal firms is positively affected by the levels of public infrastructure and human capital. On the contrary, the informal sector only uses low-skilled labor, and is characterized by an exogenous total factor productivity. It serves as a subsistence sector for the less educated workers. The government finances infrastructure by taxing the income of workers employed in the formal economy; taxation affects low-skilled workers' decision to work formally or informally. As far as international migration is concerned, I develop two variants of the model. The first one considers brain drain as an exogenous phenomenon; in the second one, brain drain is endogenous and decreases with the domestic high-skilled wage rate. The interplay between informality and brain drain, two important exit options in developing countries, limits the tax base and the capacity of the government to finance infrastructure.

The assumptions of my model are in line with the existing literature. First, I assume that public infrastructure is mainly funded by local taxes. This is in line with Foster et al. (2010), who report that the African taxpayer finances as much as two thirds of the overall spending in infrastructure investments. Second, taxpayers can evade taxation by moving to the informal sector or by emigrating abroad. In poor countries, the productivity gap between the informal and formal sector is small, and the informal sector drains a large proportion of the low-skilled labor force. Jütting and de Laiglesia (2009) and Schneider (2012) report that half of the workforce in developing countries could be considered as informal. Increasing the tax rate makes informality relatively more attractive for the low-skilled. I thus consider the size of the informal sector as endogenous, in line with the "dual economy" theory of Lewis (1954). La Porta and Shleifer (2014) provide supporting evidence of this theory by showing its ability to replicate five critical stylized facts about the informal economy in developing countries.[1] Building on the data used in La Porta and Shleifer (2014), Figure 6 shows the negative correlation between informality and development. Besley and Persson (2014) report that low-income countries have small tax rates (varying between 10 and 20% of GDP), while in developed countries the average level of taxation is close to the 40% of GDP; they argue that this discrepancy is due by the larger size of the informal sector which makes the sensitivity of taxable income to the tax rate much greater than in developing countries.[2] Finally, when low-skilled workers become informal, the skill premium decreases in the formal sector, thereby increasing the brain drain and restraining human capital accumulation.[3] A large fraction of high-skilled

[1] First, the informal sector has a huge relative size in developing countries. Second, its productivity is extremely low compared with the formal firms. Third, the productivity of informal firms is too low for them to be incorporated in the formal sector. Fourth, the informal economy is largely disconnected from the formal one economy. Fifth, as a country develops, the size of the informal sector shrinks.

[2] The same paper argues that the most striking difference between formal and informal firms is the level of education of their managers. 7% of the managers of informal firms have a college degree compared with 76% for formal firms. Skill differences between workers across sectors are considerably smaller. Gennaioli et al. (2014) estimate a 30% increase in returns per extra year of education of managers, while an extra year of worker education would increase average returns only by 7%.

[3] Many papers focus only on brain drain, considering low-skilled emigration rates as exogenous or negligible. Examples are: de la Croix and Docquier (2012), Grossmann and Stadelmann (2011) and Cellini (2007).

individuals emigrate from developing countries.[4] My assumptions are in line with Docquier et al. (2016), who demonstrate that the informal sector compresses the skill premium. In my model, this encourages high-skilled individuals to leave their home country. I use the model to analyze the short-run and long-run effects of infrastructure policy reforms. In the variant with exogenous brain drain, I can characterize the intertemporal equilibrium of the economy, show it is unique, and derive the theoretical conditions under which an expansive infrastructure policy (implying an increase in the tax rate) is beneficial or detrimental for the economy. In line with the Laffer curve, an expansive reform is beneficial if the tax rate does not exceed a threshold, which depends on the elasticity of formal sector production to human capital. Above the threshold, the reform reduces the level of infrastructure and the high-skilled wage. In the second variant, the brain drain becomes endogenous and this reduces the tractability of the model, although I can prove the uniqueness of the equilibrium. I calibrate the two variants of the model for 60 developing countries, and conduct various numerical experiments. This allows me to compare the effectiveness of infrastructure policy in the developing world. I consider three numerical experiments.

The first experiment should only be seen as a thought experiment. I simulate a ban of the informality, as if total productivity would fall to zero in this sector. Banning informality is clearly neither a feasible option (as part of it involves home production) nor a desirable option (informality serves as a subsistence sector for many workers) in developing countries. Nevertheless, this experiment helps illustrating the role of the informal sector at low levels of development. My results show that informality is responsible for huge losses in public infrastructure;[5] in addition "banning" the informal sector would substantially reduce brain drain flows.[6] The ban of informality has sizable effects on the brain drain in both the short and long run, and on infrastructure accumulation in the long run. Indeed, bringing low-skilled workers back to the formal sector has an immediate effect on high-skilled wages and emigration rates. This gradually increases the stock of public infrastructure, human capital accumulation, and total factor productivity. However, the income of low-skilled workers decreases in the short-run. Despite the large infrastructure gains, for most countries these losses are persistent even 75 years after the shock and the average income is found lower in the counterfactual. In the second experiment, I assume that informal workers can be taxed at the same rate as formal workers. Taxing informal activities mechanically increases the tax base, and also generates multiplier effects in the long-run (the same qualitative effects as the ban of informality). It reduces the size of the informal sector, increases the high-skilled wage rate, and decreases the brain drain. On the contrary, low-skilled wages fall proportionately to the tax rate. At the current level of taxation, I predict that the informal sector can totally disappear in some countries (what is referred to as a "regime switching"). This is the case of China, Kenya, Liberia, Chad and Gambia. In all countries the GDP per capita decreases in the short run while in the long run, for most of the countries, I predict an increase of this variable. In the last set of experiments, I consider moderate changes in the tax rate and assess the country-specific effects on macroeconomic performance. In most cases, high-skilled workers suffer a

[4] Docquier and Rapoport (2012) provide a review of the literature that studies the link between development and high skilled migration.

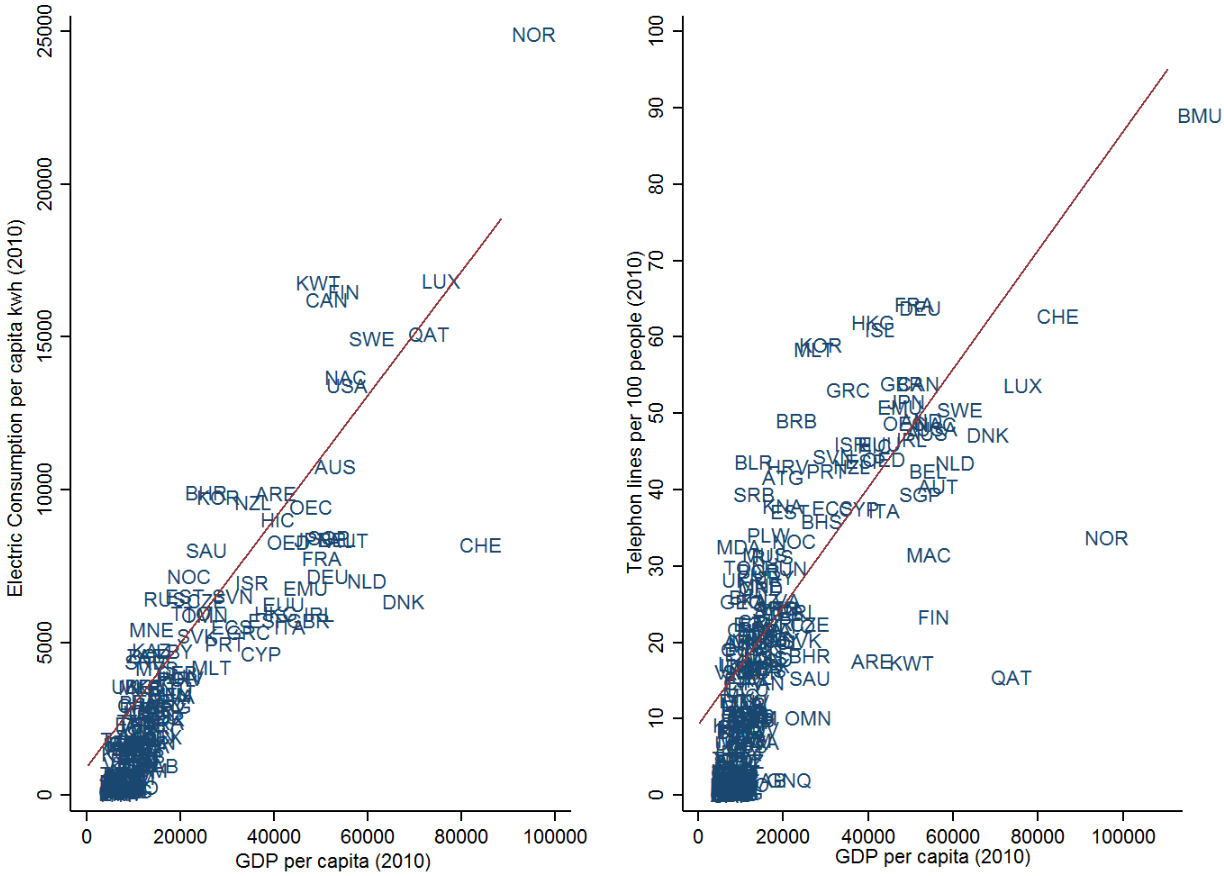
[5] In the long run I estimate an increase of the public stock of infrastructure between 5% (Peru) to 400% (Gambia).

[6] The largest effect of informality on brain drain is found for Gambia, for this country I predict a ample drop from 70% to 30%.

short-run welfare loss, due to the greater tax-rate and to the fall in the skill premium. However, 75 years after the shock, the policy becomes effective; the welfare gain is substantial for the high-skilled, whereas low-skilled workers are unaffected (at least if the informal sector does not disappear). These short-run and long-run effects are amplified when brain drain is endogenous. In the short-run, the GDP per capita decreases in all countries. In the long run, due to the larger infrastructure investments, the GDP per capita will be larger in all countries.

The rest of this paper is organized as following. Section 2.2 provides a summary of the related literature. Section 2.3 depicts the model, distinguishing between exogenous and endogenous brain drain. The quantitative analysis is described in Section 2.4. Section 2.4.1 explains the parametrization for the models. Section 2.4.2 discusses the results of my numerical experiments, and Section 2.4.3 assesses the robustness of the results to the choice of parameter values. Section 2.5 concludes.

Figure 5: Infrastructure and Development



The left panel shows the correlation between electric consumption per capita and GDP per capita in year 2010. The right panel shows the correlation between telephone lines per 100 people and GDP per capita in year 2010. Data on GDP and infrastructure indicators are taken from the World Bank.

Figure 6: Informality and Development

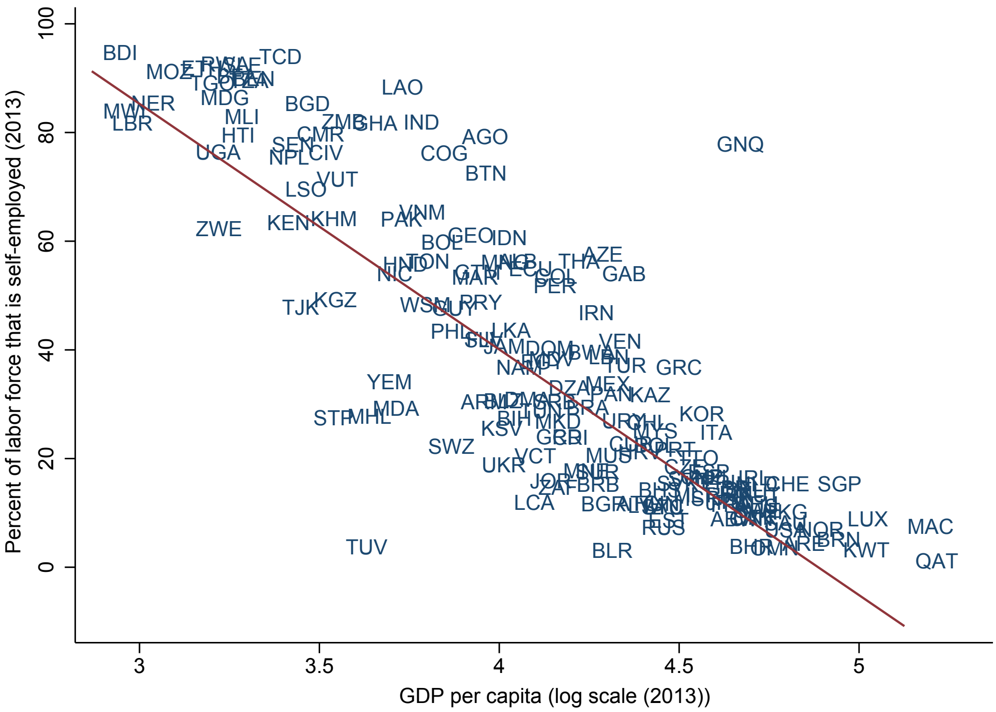


Figure 6 comes from La Porta and Shleifer (2014). Data on the percent of labor force employed in the informal sector and GDP comes from World Bank.

2.2 Related Literature

The role of infrastructure in economic development has been investigated in a large number of studies. Building on Gramlich (1994), infrastructure can be defined as "natural monopolies such as highways, other transportation facilities, water and sewer lines, and communication systems". In some studies, education, sanitation and electricity facilities are considered as infrastructure as well. Although part of the infrastructure can be privately owned I shall consider that is entirely funded by public taxes in my model.

There is a theoretical literature analyzing the optimal level of infrastructure, hypothesizing that infrastructure influences the level of total factor productivity (see Bougheas et al. (2000)).[7] The seminal paper of Barro (1990) treats productive public expenditure as a flow variable, and demonstrates that the optimal tax rate to finance infrastructure is equal to the elasticity of aggregate output with respect to public capital; this result is known as the *"Barro rule"*. Contrary to Barro (1990), Futagami et al. (1993) consider that it is the stock of infrastructure that affects the national output, and this stock accumulates slowly. In this context, the welfare-maximizing tax rate is lower than the one computed by Barro; this is due to the fact that public investments are not immediately productive. Similarly, but in

[7] For a comprehensive review of continuous time, dynastic models addressing the long-run impact on economic growth of infrastructure investments, see Irmen and Kuehnel (2009). Calderon and Serven (2014) also provide a more succinct review of both theoretical and empirical literatures.

discrete time, Glomm and Ravikumar (1994) determine the optimal tax rate in a dynamic model; the optimal tax rate is equal to the *"Barro rule"* divided by the representative agent's discount factor.[8] The literature has also demonstrated that some categories of public infrastructure can show different degrees of congestion. This arises when infrastructures are partially rival, i.e. when the use of the infrastructure by one firm decreases its availability for the other firms. In line with Futagami et al. (1993) and Glomm and Ravikumar (1994), my model assumes that it takes one period for infrastructure investments to increase total factor productivity, and accounts for congestion effects defining infrastructure in per capita terms.

Several types of methods have been used to quantify the effect on infrastructure on productivity, growth and income. Some exploit quasi-natural experiments to identify the economic impact of particular infrastructure projects. For example, Duflo and Pande (2007) investigate the impact of the construction of dams in India over the period 1971-1999. They find that constructing a dam makes the downstream populations better-off, while leaving the welfare of people living in the vicinity of the dam unchanged. This study provides evidence that the construction of large infrastructure facilities deeply affects the income distribution between districts within a country. Wang and Wu (2015) study the economic effects of the Quinzang railway construction on local development in Tibet and China. This massive project was almost entirely funded by the central government, and the authors predict an average 33% increase in GDP per capita in the counties served by the railway. However, these results cannot be generalized to other infrastructure projects or to other regions. Asturias et al. (2016) use a static general equilibrium model of internal trade to assess the welfare impact of the construction of the Golden Quadrilateral in India, a large road infrastructure project in India, that connects the four major cities in the country. They find that gains largely overcome costs,[9] estimating welfare gains equal to \$3.1 billion dollar per year while the government invested \$5.2 billion dollar.[10]

Hundreds of papers have estimated the elasticity of aggregate output (usually proxied by the GDP per capita or by measures of private output) to public infrastructure using cross-country regressions. One of the first papers is that of Aschauer (1989), which uses a measure of private output as dependent variable. Aschauer (1989) finds that a 1% increase in the stock of public capital increases private output by 0.39%. Calderon and Serven (2014) build a synthetic index of infrastructure to assess its impact on GDP. They employ a principal component analysis to aggregate various types of infrastructure (i.e. telecommunications, electric power and roads); the dependent variable is the GDP per capita of 88 countries, and the time span is the 1960-2000 period. They obtain a long-run elasticity varying between 0.07 and 0.10. Studies focusing on developing countries find additional evidence of a positive impact of infrastructure. For instance, Estache et al. (2005) estimate a growth regression on sub-Saharan countries considering five types of infrastructure (telecoms, electricity, roads, sanitation and water) in the set of covariates. They

[8] In the absence of informality and endogenous brain drain I obtain the same result in my model. See appendix, Subsection 2.6.2.

[9] Their framework also accounts for pro-competitive gains.

[10] Interestingly the authors exploit firm level data on both formal and informal Indian firms. This data report huge differences in productivity between formal and informal plants. The last ones while accounting for 89% of employment and around 20% of total value added.

obtain positive and significant estimates for the infrastructure elasticities, but heterogeneous effects by infrastructure type. Electricity-related facilities induce an elasticity of 0.50. On the contrary, infrastructures linked to sanitation have no significant impact on GDP growth. Calderón and Servén (2010) using their own estimate on the impact of infrastructure on growth determine the contribution of infrastructure investments by multiplying the coefficients with the change in average stocks between 2001-2005 and 1991-1995. They find that the largest contribution of infrastructure development to growth was attained in South-Asia, where they estimate that infrastructure investments led to a 2.7% larger yearly growth rate. In sub-Saharan countries, the contribution of infrastructure was smaller, 0.7% per annum, due to deterioration of the quality of infrastructure. Straub and Terada-Hagiwara (2011) focus on Asian Countries for the period between 1990-2007. In spite of the fact that infrastructure investments correlate well with positive growth performances, the authors do not find evidence for a positive effect of infrastructure investments on productivity.

Overall, Straub (2011) and Calderon and Serven (2014) provide reviews of the empirical literature, showing that the range of estimates is very large. In the same vein, Bom and Ligthart (2014) conduct a meta-analysis of existing estimates of the elasticity of private output to public capital. The authors consider 68 papers over the period 1983-2008, and combine 578 regression results. They only consider studies that proxy infrastructure with monetary values, contrary to other studies such as the previously cited Calderon and Serven (2014) who use data on physical proxies (for instance, electricity, telecommunication and roads). Estimated values of the elasticity markedly differ across studies, and range between -0.17 and 2.04. The simple average is equal to 0.188. The meta-analysis of Bom and Ligthart (2014) reveals an average long run elasticity of GDP to core infrastructure of 0.17. This is the value that I shall use in my model (see Section 2.4.1).

In a one-sector dynamic model with endogenous infrastructure accumulation, a series of papers by Rioja quantitatively assess the effect of infrastructure investments on GDP. After calibrating the model on seven Latin American countries,[11] Rioja (2003a) shows that infrastructure investments have sizable effects on GDP. This analysis recommends that around 10% of GDP should be devoted to increasing infrastructure. However, when investments exceed a threshold of 14% of GDP, they imply welfare losses. The author splits infrastructure expenditures into two components, construction and maintenance investments. The optimal level of maintenance investments equals 2% of GDP. In a similar framework, Rioja (2003b) estimates the welfare losses due to an ineffective stock of infrastructure, namely the cost borne by having infrastructure not in good condition. He finds that Latin American countries pay a steady-state penalty of about 40% of real GDP per capita for under-using their infrastructure (i.e. using it 74% as effectively as industrial countries do).

My model also endogenizes infrastructure accumulation but distinguishes between two production sectors, the formal and the informal economies. This allows me to examine the effect of infrastructure on the productivity gap between these sectors, and the effect of informality on the government capacity to finance infrastructure investments. The interaction between the accumulation of a public infrastructure

[11] Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela.

and the informal sector is analyzed in Loayza (1996). He theoretically shows that, due to a lower available amount of public capital, a larger informal sector negatively affects GDP growth. I assume that public infrastructure influences the productivity of formal firms, but not the productivity of informal firms, hence assuming that escaping taxation prevents the use of public infrastructure. In addition, the stock of educated workers also affects the productivity of formal firms (through a schooling externality), as well as the wage of low-skilled workers employed in these firms (through labor complementarity). Hence, the level of infrastructure and the level of human capital influence the incentives of (low-skilled) workers to work informally. Simultaneously, when low-skilled workers leave the formal sector, this decreases the wage of high-skilled workers in formal firms. These mechanisms are similar to Docquier et al. (2016), who study the relation between development and the informal sector, and analyze the impact of the latter on education. Contrary to Docquier et al. (2016), I assume exogenous school enrollment rates, but I allow high-skilled workers to emigrate abroad when high-skilled wages are low. It is widely recognized that the emigration rate of high-skilled workers is sensitive to economic and institutional conditions in the home country (see Grogger and Hanson (2011)); and the brain drain is particularly large in small, low-income countries (see Docquier and Rapoport (2012)). The conjunction of low infrastructure and informality are important factors reducing high-skilled wages and causing the emigration of talented workers. My model thus accounts for the negative effects of the brain drain on human capital accumulation, in line with Bhagwati and Hamada (1974).[12] It formalizes the complex links between informality, infrastructure and human capital accumulation, which can be the source of multiplicity of equilibria, in line with de la Croix and Docquier (2012).

[12] A strand of the literature shows that a positive level of high-skilled migration may be beneficial to the source country due to the positive feedback effects on education decisions. See Mountford (1997), Stark et al. (1997) and Beine et al. (2001). However, the growth-maximizing rate of emigration is much smaller than the emigration rate observed in most developing countries.

2.3 Theory

I model an economy where two productive sectors, labeled as the formal and the informal sectors, produce a homogeneous good according to two different production technologies. The formal sector represents the official (or recorded) economy. On the contrary, in line with Docquier et al. (2016), I define the informal economy as "the part of the economy that is not taxed, monitored by any form of government or included in gross national product".[13] It is worth noticing that unrecorded activities exist in countries from all income groups. However, the nature of informality differs between developing and developed countries. In developed countries, the informal sector consists of firms' activities that are hidden from the State for tax, social and labor reasons; informal/unreported and formal/declared activities are governed by the same production technology. In developing countries, informal and formal firms are inherently different and use different technologies. For example, La Porta and Shleifer (2014) describe the differences between formal and informal firms in the developing world using a *dual perspective*.[14] According to the dual theory, the informal sector uses a low-skill intensive technology, and serves as a subsistence sector for many individuals. The decision of low-skilled workers to operate in this sector is made by necessity, to escape extreme poverty. A direct implication of the dual theory is that above a certain level of development, the subsistence part of the informal sector disappears and the only motive to act informally is to elude taxes. The discrete time model developed in this paper is consistent with the *dual perspective*, and views informality as a subsistence sector; however, taxation of formal activities influences the size of the informal sector.

More precisely, I assume that firms acting in the formal sector are characterized by a Cobb-Douglas technology that uses both high-skilled and low-skilled workers as inputs. Moreover, the total factor productivity of formal firms is endogenous; it is positively affected by the stock of public infrastructure and by the level of human capital of formal workers. The government finances infrastructure investments by levying taxes on formal workers' wages. Conversely, informal firms produce according to a linear technology using low-skilled labor only. The total factor productivity of informal firms is constant and independent on the level of infrastructure.[15] Informality thus serves as a subsistence sector and plays the same role as a minimum-income scheme.

Docquier et al. (2016) use similar technological assumptions to study the dynamic implications of informality, through its impact on human capital accumulation and long-run-growth. I extend their productive sector by including infrastructure and taxation; this allows me to study the impact of informality

[13]Gerxhani (2004) gives several definitions of the informal sector. The closest to the one used in this paper and in Docquier et al. (2016) dates back to Feige (1981), who argue that the main distinctive feature of the informal economy is that its output is omitted from the official national accounts. Specifically, he defines the informal economy as "all economic activities which because of accounting conventions, non-reporting or under-reporting, escape the social measurement apparatus, most notably the national accounts".

[14]In line with La Porta and Shleifer (2014), there exists competing theories explaining the informal economy. For instance, De Soto (1990) considers the informal sector as a reservoir of entrepreneurial energy held back by government regulations; inciting these firms to become formal would be beneficial for development. Instead, Farrell (2004) recommends a suppression of the informal sector; he defines informal firms as those violating the government regulations and unfairly competing with formal firms.

[15]The qualitative results of the model are not affected if the elasticity total factor productivity of informal firms to the stock of infrastructure is smaller than the elasticity of the productivity of formal firms. In line with Docquier et al. (2016), my model does not account for brain waste, namely high-skilled workers employed in low-skilled jobs provided by informal firms.

on human capital and infrastructure accumulation. In my framework, the size of the informal sector does not only depend on human capital and on the productivity gap between sectors; it also depends on the tax rate imposed by the government. Another difference is that Docquier et al. (2016) focus on the interplay between informality, returns to schooling, child labor and education choices. In my model, I simplify the treatment of education but I account for high-skilled emigration rates. Human capital accumulation depends on the intensity of the brain drain. My baseline model assumes exogenous high-skilled emigration flows. In a second variant of my model, I endogenize high-skilled emigration decisions. In both cases, I show that the dynamics of infrastructure depends on the prevailing regime, with or without informal firms.

2.3.1 Production

As already mentioned, the formal and the informal sectors produce the same homogeneous good. Formal firms produce according to a Cobb-Douglas technology using high- and low-skilled workers as inputs. H_t denotes the quantity of high-skilled workers, while $L_{f,t}$ is the quantity of low-skilled workers acting in the formal sector. The output of formal firms is given by:

$$Y_{f,t} = A_{f,t} H_t^{\alpha} L_{f,t}^{1-\alpha}, \tag{25}$$

where α is the elasticity of formal-sector output with respect to high-skilled labor, and $A_{f,t}$ stands for the level of total factor productivity in the formal sector at time t. I assume $\alpha > 0$.

Total factor productivity (TFP) in the formal sector is a function of the stock of infrastructure per worker, k_t (this variable is defined below), and of the skill ratio in the formal sector, $\left(z_{f,t} = \frac{H_t}{L_{f,t}}\right)$. We have:

$$A_{f,t} = A_0 z_{f,t}^{\phi} k_t^{\varepsilon}, \tag{26}$$

where A_0, which I assume larger than zero, is an exogenous productivity scale factor. The elasticity of TFP to infrastructure is denoted by ε. The parameter ϕ, which I assume larger than zero, denotes the elasticity of TFP to the skill ratio (this is a special case of Lucas (1988)). I assume that $0 < \varepsilon < 1$ and that $\alpha + \phi < 1$.

The labor market is competitive and formal firms maximize profits:

$$Y_{f,t} - w_{h,t} H_t - w_{l,t} L_t, \tag{27}$$

The profit-maximizing level of employment equalizes the marginal productivity of high-skilled and low-skilled workers with their gross wage rates. It follows that the after-tax wage rates, $w_{h,t}$ and $w_{l,t}$, are given by:[16]

[16] I assume that the high-skilled wage rate is always greater than the low-skilled one. At the end of Section 2.3.4, I discuss the condition required to have $\left(w_{h,t} > w_{l,t}\right)$.

$$w_{h,t} = (1-\tau)\,\alpha A_0 z_{f,t}^{\alpha+\phi-1} k_t^{\varepsilon}, \tag{28}$$

$$w_{l,t} = (1-\tau)\,(1-\alpha)\,A_0 z_{f,t}^{\alpha+\phi} k_t^{\varepsilon}. \tag{29}$$

where τ is the tax rate on formal income. I also assume that $0 < \tau < 1$.

By assumption, the production technology of informal firms is a linear function of the quantity of low-skilled labor.[17]

$$Y_{i,t} = BL_{i,t}, \tag{30}$$

where $L_{i,t}$ denotes the quantity of low-skilled workers employed in the informal sector. As in the formal sector, the labor market is competitive. Consequently, the wage of low-skilled workers in the informal sector is equal to their marginal productivity.[18]

The scale factor B characterizes the exogenous level of total factor productivity in the informal sector. Without loss of generality, it can be expressed as a fraction of A_0:

$$B = A_0\gamma. \tag{31}$$

In line with the definition of informality, low-skilled workers employed by informal firms are not subject to the government control and to taxation. Hence, they simply earn a net salary equal to B.

Low-skilled workers are perfectly mobile across sectors. They decide to join the informal sector if and only if informal sector firm offers a salary that is greater or equal to the after-tax salary offered by the formal firms. The following complementary slackness condition defines output and employment in the informal sector:

$$\frac{w_{l,t}}{B} \geq 1,\; Y_{i,t} \geq 0,\; \left(\frac{w_{l,t}}{B} - 1\right) Y_{i,t} = 0.$$

Two different equilibrium regimes can be obtained for our economy:[19]

- *Informal regime*: Some informal firms produce, and some low-skilled workers are employed by informal firms. Hence, the equilibrium net salary of low-skilled workers is equal to B (the marginal productivity of labor in the informal sector) in both sectors.

- *Formal regime*: Only formal firms produce. The after-tax salary of low-skilled workers exceeds the marginal productivity of labor in the informal sector.

The total workforce, after migration, of the economy is equal to:

[17] The tax rate is one of the key variable that determine the size of the informal sector, hence the model accounts for tax-based informality as well.

[18] If a production function such as $Y_{i,t} = BL_{i,t}k_t^{\underline{\varepsilon}}$ with $\underline{\varepsilon} < \varepsilon$ was considered, the qualitative results of our model would be similar.

[19] The condition which sets the prevailing regime will be discussed below.

$$N_t \equiv H_t + (L_{f,t} + L_{i,t}) .$$

For the sake of clarity, I distinguish between two measures of the skill ratio:

$$\begin{cases} \text{Skill ratio in the whole economy} & z_t = \frac{H_t}{L_{f,t}+L_{i,t}}, \\ \text{Skill ratio in the formal economy} & z_{f,t} = \frac{H_t}{L_{f,t}}. \end{cases} \tag{32}$$

2.3.2 Individuals

At each period of time, two types of working-age individuals populate the economy. High-skilled individuals have higher education whereas low-skilled individuals represent the remaining part of the workforce. I label these two categories respectively by $\{h, l\}$. Low-skilled workers, by comparing the net wages offered by formal and informal firms, decide to work formally or informally.

The evolution of the population is governed by education, fertility and emigration decisions. For simplicity, the first variant of my model follows de la Croix and Docquier (2012) and considers exogenous school enrollment rates, fertility rates, and emigration rates by education level. First, I assume that high-skilled workers educate all their children; on the contrary, low-skilled workers have more children and only educate a fraction q of them. It is natural to consider that q, reflecting education policy, urbanization and other country characteristics, varies across countries. As policy is not endogenized here, I treat q as exogenous. Second, I denote by n_h and n_l the exogenous fertility rates of high-skilled and low-skilled individuals (I assume $n_h < n_l$). Third, emigration rates depends on education as well. I denoted by $\overline{m}$ and $\underline{m}$ the emigration rates of high-skilled and low-skilled adults. These emigration rates are considered as exogenous in the first variant of the model; I shall endogenize the high-skilled migration rate in the second variant.

2.3.3 Infrastructure

At each period, the government taxes the income of formal workers at an exogenous rate τ. These resources are used to finance the stock of infrastructure that will be available in the next period. The model is calibrated under the assumption that the length of one period is 25 years. I assume a full depreciation of the infrastructure stock after one period. This corresponds to a depreciation rate of about 4% per year. I assume infrastructure is not immediately productive to match the fact that massive infrastructure projects become productive only on a long-time horizon perspective, similarly to Futagami et al. (1993) and Glomm and Ravikumar (1994). For instance, the OECD reports that it takes an average of 4-6 years to build a nuclear plant, to which the time for planning should be added. Another example is the construction of the Assuan Dam in Egypt, which became fully productive 16 years after the beginning of the construction.

The model specifies infrastructure in per capita terms. I interpret it as a monetary index proxying the available stock of infrastructure per worker, in the country. For instance, I assume that what matters is the amount of usable electricity, clean water, roads and telecoms lines per worker. Eq. (33) defines the evolution of the stock of infrastructure:

$$k_{t+1} = \frac{\tau Y_{f,t}}{N_{t+1}}. \tag{33}$$

2.3.4 Formal and Informal Regimes

The informal regime arises when the pair of skill ratio and stock of infrastructure, (k_t, z_t), is such that in case of full employment in the formal sector, the wage paid by the formal firms to low-skilled workers would be smaller than the one paid by the informal firms. I refer to this regime as the informal regime. Under this regime, a fraction of the low-skilled labor force finds it optimal to become informal, and we have $(z_{f,t} > z_t)$. Exit to informality stops when both sectors offer the same after-tax salary. I can write:

Lemma 1. *The informal regime arises when the level of infrastructure, k_t, is below an endogenous critical level $\tilde{k}(z_t)$ that decreases with the skill ratio of the whole economy. Otherwise, the formal regime arises.*

Proof. Replacing z_t to $z_{f,t}$ in Eq. (28) gives the low skilled wage under the formal regime. If the following is true:

$$w_{l,i,t} > w_{l,f,t}.$$

The infrastructure available at time t is lower than the endogenous critical level given by:

$$k_t < \tilde{k}(z_t) = \left(\frac{\Psi}{z_t^{\alpha+\phi}} \right)^{\frac{1}{\varepsilon}}. \tag{34}$$

where $\Psi \equiv \frac{\gamma}{(1-\tau)(1-\alpha)}$.

■

It follows that:

Corollary 1. *Under the informal regime Eq. (35) defines the skill ratio in the formal sector.*

$$z_{f,t} = \left(\Psi k_t^{-\varepsilon} \right)^{\frac{1}{\alpha+\phi}}. \tag{35}$$

Proof. By equalizing Eqs. (29) and (31) and then solving for $z_{f,t}$ I obtain the skill ratio in the formal sector prevailing under the informal regime. Corollary 1 implies that the after-tax, low-skilled wages are equalized under the informal regime.

■

Amaral and Quintin (2006) provide evidence that identical workers earn similar wages across sectors. Finally, I determine the conditions under which the salary of high-skilled workers exceeds the salary of the low-skilled, whatever the equilibrium regime.

Under the formal regime the high-skilled wage is greater than the low-skilled wage if the following condition on parameter is satisfied:

$$z_{f,t} \equiv z_t < \frac{\alpha}{1-\alpha}. \tag{36}$$

This condition is obtained by replacing $z_{f,t}$ with z_t in the wages paid by formal firms, given by Eqs. (28) and (29), and by assuming the former is larger than the latter. Instead, under the informal regime, Eq. (35) defines the skill ratio in the formal sector. Assuming that the high-skilled wage is greater than the low skilled one under the informal regime requires a level of infrastructure, k_t, larger than a critical level defined as:

$$\underline{k} \equiv \left(\frac{1}{\alpha}\right)^{\left(\frac{\alpha+\phi}{\varepsilon}\right)} (1-\alpha)^{\left(\frac{\alpha+\phi+\varepsilon}{\varepsilon}\right)} \left(\frac{\gamma}{(1-\tau)}\right)^{\left(\frac{1}{\varepsilon}\right)}. \tag{37}$$

This critical level is obtained from Eq. (35) and from the condition reported in Eq. (36) to the informal regime.

2.3.5 Dynamics

In the variant with exogenous migration, the evolution of the economy is regime-specific and is characterized by three equations.

The first one determines the evolution of the skill ratio in the whole population. Denoting by $n = \frac{n_h}{n_l}$ the differential fertility, we have:

$$z_{t+1} = \frac{H_{t+1}}{L_{t+1}} = \frac{(1-\overline{m})(nz_t+q)}{(1-q)(1-\underline{m})}. \tag{38}$$

Eq. (38) exhibits an interior fixed point under the following condition:

$$\frac{(1-\overline{m})\,n}{(1-q)(1-\underline{m})} < 1. \tag{39}$$

The second equation governs the growth rate of workforce:

$$g_t = \frac{n_h(1-\overline{m})\,z_t + \Theta}{1+z_t}, \tag{40}$$

where $\Theta \equiv n_l\left((1-\underline{m})(1-q) + (1-\overline{m})\,q\right)$.

Third, two equations determine the dynamic of infrastructure depending on the prevailing regime (formal or informal). The stock of infrastructure depends on the tax rate raised by the government. Exploiting Eqs. (25), (33), (38) and (40), I obtain the two possible cases below:

- Infrastructure dynamics under the *Formal Regime*:

$$k_{t+1} = \frac{\tau A_0 z_t^{(\alpha+\phi)} k_t^{\varepsilon}}{n_h(1-\overline{m})\,z_t + \Theta}, \tag{41}$$

- Infrastructure dynamics under the *Informal Regime*:

$$k_{t+1} = \frac{\tau A_0 z_{f,t}^{(\alpha+\phi-1)} k_t^{\varepsilon} z_t}{n_h(1-\overline{m})\,z_t + \Theta}. \tag{42}$$

Eqs. (38), (40) and (42) define the dynamic system that characterizes the informal regime; in this system, Eq. (41) must be replaced by Eq. (42) to characterize the formal regime.

2.3.6 Intertemporal Equilibrium

The labor market equilibrium condition requires:

$$\begin{aligned} H_t &= \overline{H_t}, \\ L_{f,t} + L_{i,t} &= \overline{L_t}. \end{aligned} \tag{43}$$

Hence, the intertemporal equilibrium of my economy can be defined as following:

Definition 2. *Given an initial workforce of size N_0, an initial number H_0 of high-skilled workers, and an initial level of infrastructure k_0, an intertemporal equilibrium consists in a sequence of wages $\{w_{h,t}, w_{l,t}\}$, a sequence of skill ratio in the economy $\{z_t\}$, a sequence of skill ratio in the formal sector $\{z_{f,t}\}$, and a sequence of infrastructure levels $\{k_t\}$ such that: (i) formal and informal firms maximize profits and wages are determined by Eqs (28), (29) and (31), (ii) wages $\{w_{h,t}, w_{l,t}\}$ and aggregate quantities $\{\overline{H}_t, \overline{L}_t\}$ are such that the labor markets clear (namely (43) holds), (iii) the skill ratio evolves according to (38); (iv) depending on (34) either Eq. (35) or $z_{f,t} = z_t$ define the skill ratio in the formal sector, (v) depending on (34), the stock of infrastructure evolves according either to (41) or (42), and (vi) the government balances its budget, (33) is satisfied.*

I can the prove the existence and uniqueness of a temporary equilibrium:

Proposition 5. *Given z_{t-1} the temporary equilibrium of period t exists and is unique. For any $\bar{z}_t$ there exists a unique intertemporal equilibrium.*

Proof. Let consider an economy at a given period $\bar{t}$ with a given amount of workers $(H_{\bar{t}}, L_{\bar{t}})$ and a given stock of infrastructure $k_{\bar{t}}$. Depending on Eq. (34) at period t the economy is either under the formal or the informal regime. It suffices to notice that the equations which set the wages, (28), (29) and (31) are single valued to prove both the existence and uniqueness of the temporary equilibrium. To prove the second statement, consider an economy at time $\bar{t}$ characterized by a given value of the skill ratio, $\overline{z_t}$. The subsequent level of the skill ratio is uniquely determined by Eq. (38). Moreover, the level of infrastructure per capita at period $t+1$ is uniquely determined (depending on the prevailing economy regime) by either Eqs. (41) or (42). It follows that for a given initial pair of skill ratio and infrastructure levels $\{z_{\bar{t}}, k_{\bar{t}}\}$ the sequence $\{z_t, k_t\}_{t=\bar{t}}^{\infty}$ is uniquely determined.

■

2.3.7 Steady State

A steady state of this economy is a fixed point, (z, k) of the dynamical system defined by Eqs. (38) and (41) for the formal regime, or by Eqs. (38) and (42) for the informal regime.[20]

Proposition 6. *The economy has a unique and locally stable steady state.*

[20] In Section 2.6.1.1 of the technical appendix, I report the equations that determine the skill ratio and infrastructure loci in the (k_t, z_t). I also show that the two curves which make up the infrastructure loci cross each other at the informality frontier.

Proof. The assumption on parameters stated in Eq. (39) assures that the discrete dynamic equation defined by Eq. (38) has one positive fixed point in the space (z_t, z_{t+1}). This fixed point does not depend on the level of infrastructure. Consequently, the skill ratio loci in the space (z_t, k_t) is a parallel line of the x-axis, see Figure (7). Differently, the infrastructure loci is defined by two upward sloping curve,[21] which cross each other only at the informality frontier.[22] Consequently, depending on the position of the skill ratio loci, the steady state lies either in the formal or in the informal region. This suffices to prove the uniqueness of the steady state for such economy. The technical appendix provides the equations which set the skill ratio and the infrastructure steady state levels (depending on the economic regime), see Subsection 2.6.1.1. As to check the stability of the steady state I study the direction field of the dynamical system. The technical appendix reports such analysis, which suggests the stability of the steady state. Anyhow, both Eqs. (41) and (42) are non-linear in k_t. Consequently I examine the stability of the steady state by computing the eigenvalues of the respective Jacobian Matrix evaluated at the steady state. For the informal regime I label this matrix J_i. Skill ratio dynamics, see Eq. (38), does not depend on the amount of infrastructure hence in order to obtain the trace and the determinant of J_i it suffices to derive Eq. (38) w.r.t. z_t and Eq. (42) w.r.t. k_t. I label with λ_1 and λ_2 the eigenvalues of J_i evaluated at the steady state. I also assume that no eigenvalue of J_i has modulus exactly equal to 1. Under these assumptions I can exploit the Hartman-Grobman theorem, see Azariadis (1993). Then

$$Det\,(J_i) = \lambda_1\lambda_2 = \left(\frac{dz_{t+1}(z)}{dz_t}\right)\left(\frac{dk_{t+1}(k)}{dk_t}\right) = \left(\frac{(1-\overline{m})\,(n)}{(1-q)\,(1-\underline{m})}\right)\left(\frac{\varepsilon}{\alpha+\phi}\right)$$

and

$$T\,(J_i) = \lambda_1 + \lambda_2 = \left(\frac{(1-\overline{m})\,(n)}{(1-q)\,(1-\underline{m})}\right) + \left(\frac{\varepsilon}{\alpha+\phi}\right).$$

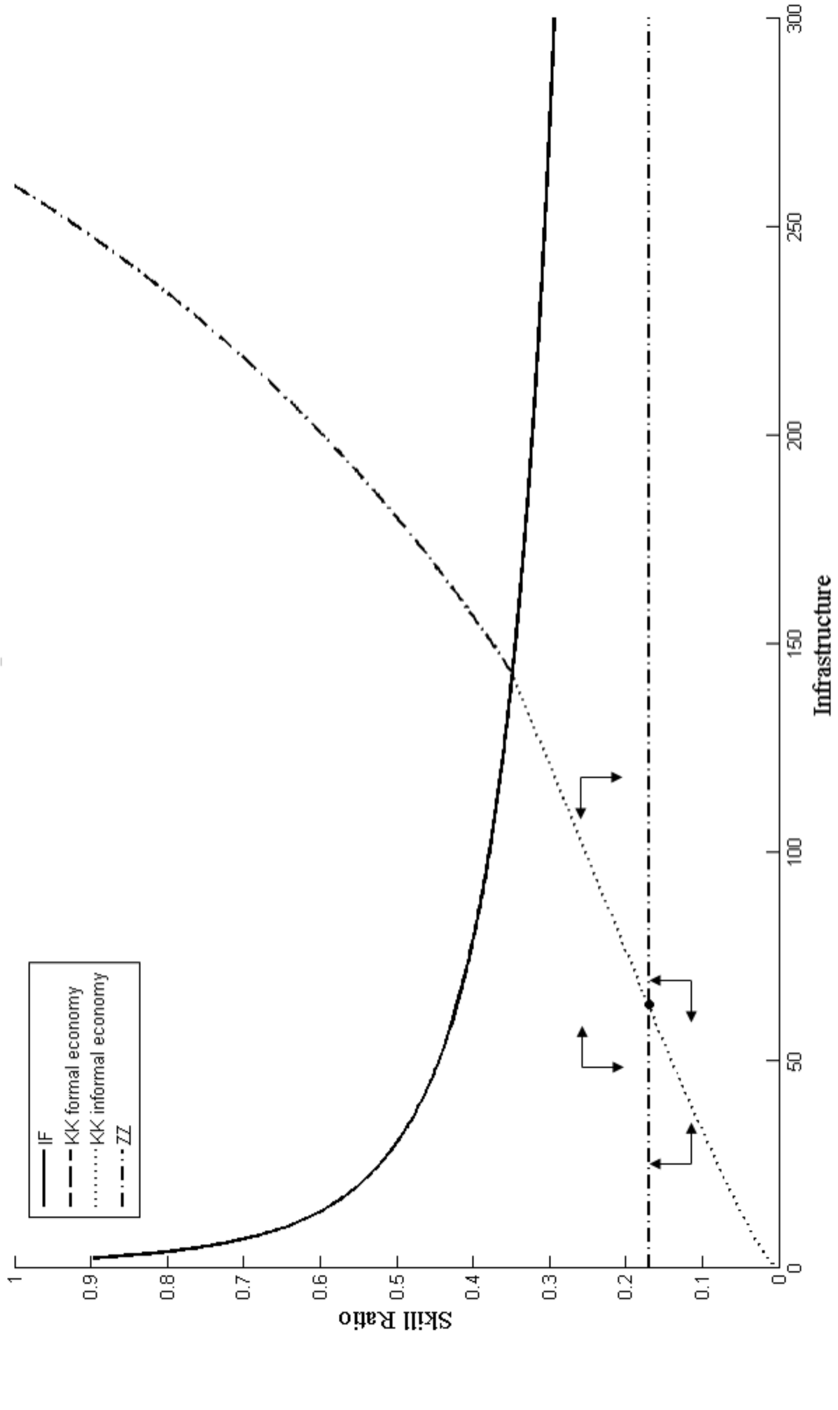
Given that $\varepsilon, \alpha, \phi$ are all larger than 0 both the trace and the determinant of J_i are larger than zero. From now on I assume that $\varepsilon < \alpha + \phi$, thus it follows that both the trace and determinant belong to the interval (0 1). Consequently both eigenvalues are positive and lower than 1 implying the asymptotically stability of the steady state, namely it is a sink. The same holds if the steady state lies in the formal region given that $\left(\frac{dk_{t+1}(k)}{dk_t}\right) = \varepsilon$.

■

The phase diagram on Figure 7 is computed using the calibrated parameters of Bolivia described in Section 2.4.1. The decreasing solid curve is the informality frontier. When the pair of skill ratio and infrastructure is above the informality frontier only formal firms produce (i.e. the economy is in the informal regime). The straight dashed line parallel to the x-axis determines the skill ratio steady state. The increasing curve determines the infrastructure loci. The dotted curve defines the loci in the informal region while the dashed-dotted determines the one which marks the formal region. They cross each other at the informality frontier. The black circle highlights the steady state; the arrows shows its stability in a neighborhood of the steady state.

[21] I previously assumed $(\varepsilon < 1)$ and $(\alpha + \phi < 1)$.
[22] This result is proved in Section 2.6.1.1 of the appendix.

Figure 7: Phase Diagram-Exogenous Brain Drain



This figure is computed using the calibrated parameters obtained for Bolivia described in Section 2.4.1. The arrows show the direction field around the steady state.

2.3.8 Fiscal Policy

In this baseline version of the model, I consider that education, fertility and emigration decisions are exogenous. Hence a change in the tax rate, τ, only affects the low-skilled individuals' decision to work formally or informally. The informality frontier, defined by Eq. (34), always move upwards when the tax rate increases. In fact, an increase of the tax rate, for any level of k_t, induces a larger outflow of low-skilled workers to the informal sector, thereby increasing the skill ratio in the formal economy. I thus have:

Proposition 7. *Under the formal regime, if there is no regime switching at time t, a rise in the tax rate τ (i.e. $\Delta\tau > 0$), increases the stock of infrastructure at time $t+1$ (i.e. $k_{t+1}(\tau+\Delta\tau) > k_{t+1}(\tau)$). Instead, under the informal regime and if there is no regime switching at time $t+1$, a rise in the tax rate increases the stock of infrastructure available at time $t+1$ (i.e. $k_{t+1}(\tau+\Delta\tau) > k_{t+1}(\tau)$) only if the tax rate at time τ satisfies the following condition:*

$$\tau < \alpha + \phi. \tag{44}$$

Proof provided in the appendix, (see Subsection 2.6.1.2).

By definition, under the formal regime neither high-skilled nor low-skilled workers can escape taxation. Consequently, an increase in the tax rate at time t, at least if there is no regime switching, increases the stock of infrastructure of the next period. Differently, under the informal regime, the same rise in the tax rate induces two opposite effects. First, a larger tax rate makes the after-tax salary less attractive in the formal sector; consequently, some low-skilled individuals decide to emigrate to the informal sector. Second, formal workers pay higher taxes. These two opposite effects cancel out each other when the tax rate is equal to the threshold defined in Eq. (44).

Under the informal regime, the immediate impact of a rise in taxation differ across individuals. The larger tax rate does not affect the low-skilled wage, as the latter is totally determined by the informal-sector technology. Instead, the after-tax wage immediately decrease for the high skilled. The larger tax rate makes their net salary smaller, and this fiscal effect is reinforced by the outflow of low-skilled workers to the informal sector. Through labor complementarity (a larger skill ratio in the formal sector $z_{f,t}$ negatively impacts the skill premium), this reduces the high-skilled wage further. The next proposition characterizes the change, between period t and period $t+1$, induced by a rise in taxation on the after-tax salary of the high-skilled.

Proposition 8. *Let consider an increase of the tax rate τ at time t (i.e. $\Delta\tau > 0$). If the economy is in the informal regime at period t and there is not regime switching at period $t+1$, a rise in the tax rate increases the salary of high-skilled workers at period $t+1$ (i.e. $w_{h,t+1}(\tau+\Delta\tau) > w_{h,t+1}(\tau)$), if*

$$\tau < \left(\frac{\varepsilon(\alpha+\phi)}{\varepsilon+\alpha+\phi}\right). \tag{45}$$

If there is a regime switching at period $t+1$ (to the formal regime, a rise in the tax rate positively affects the high-skilled wage if the condition stated in Eq. (44) is satisfied.[23]

[23] It suffices to exploit an absurdum argument to show that the RHS of Eq. (45) is always smaller than the RHS of Eq. (44).

The proof is provided in the appendix, (see Subsection 2.6.1.2).

The high-skilled wage increases at period $t+1$ if the gains inducing by the larger stock of infrastructure exceeds the losses due to both the larger tax rate and by the smaller skill premium.

If the economy at time t is under the informal regime and if there is no regime switching, the fiscal policy change does not affect the salary of the low-skilled. Conversely, if there is regime switching (to the formal regime), the salary of the low skilled must be larger.

2.3.9 Extension with endogenous brain drain

I now extend the model by endogenizing the size of the brain drain ($\overline{m}_t$).[24] Each high-skilled worker now decides whether to emigrate to a rich country (denoted by *) or to stay in the origin country. In line with the random utility model (see Delogu et al. (2014), among others), I assume that high-skilled individuals have heterogeneous preferences for the two possible locations. The utility of individual i is supplemented with random terms, $\bar{\eta}_{t,i}$ in the no-migration case or $\bar{\eta}^*_{t,i}$ in the case of emigration, which capture the heterogeneity in migration costs, in the attachment to the home country, or in the capacity to integrate abroad. This random terms are assumed to follow a type 1 extreme value distribution function,

$$F(\eta) = e^{-e\left(\frac{\eta}{\mu}-\gamma\right)} \quad \eta \,\epsilon\, \Re,$$

where μ denotes the scale parameter of the distribution, and γ is the Euler's constant.

The utility of staying at home is equal to the log of the net-of-tax wage rate, $log\,(w_{h,t})$, supplemented with the random component at home $\bar{\eta}_{t,i}$. In case of emigration to the rich country, high-skilled migrants earn a net-of-tax and net-of-migration-cost salary w^*_t, which is considered as exogenous. I assume $w^*_t > 0$ The utility of emigrating is equal to the log of the net wage abroad, $log\,(w^*_t)$, supplemented with the random term $\bar{\eta}^*_{t,i}$. Therefore, the probability that a high-skilled worker emigrates at time t is defined as:

$$P = Pr\left[ln\,(w_{h,t}) + \bar{\eta}_{t,i} < ln\,(w^*_t) + \bar{\eta}^*_{t,i}\right].$$

When the random term follows a type 1 extreme value distribution, we can use the McFadden's theorem (see McFadden (1974)) and express the probability of emigrating (equivalent here to the proportion of emigrants among high-skilled natives) as a logit expression:

$$P = \frac{e^{\frac{1}{\mu}ln(w^*_t)}}{e^{\frac{1}{\mu}ln(w^*_t)} + e^{\frac{1}{\mu}ln(w_{h,t})}}.$$

Assuming $\mu = 1$, the equation that governs the high-skilled emigration rate is given by:

$$\bar{m}_t = \frac{w^*_t}{w^*_t + (1-\tau)\,\alpha A_0 z^{\alpha+\phi-1}_{f,t} k^{\varepsilon}_t}. \tag{46}$$

With endogenous brain drain, the skill ratio cannot be treated as a pre-determined variable. The skill ratio and the stock of infrastructure per worker are now simultaneously determined, which makes

[24] I consider that low-skilled emigration rates are exogenous. As Docquier and Rapoport (2012) report, low skilled emigration rates ($\underline{m}$) are much smaller than the high-skilled ones and less responsive to push-pull factors.

the model more complicated to solve. This is because the brain drain affects the law of motion of the skill ratio and the stock of infrastructure per worker. Eq. (46) shows that the high-skilled emigration rate decreases with stock of infrastructure per worker. At the same time, the stock of infrastructure per worker depends on the size of the resident workforce, as shown by Eq. (33), which is itself affected by the high-skilled emigration rate. Hence, the prevailing stock of infrastructure per worker and the skill ratio are simultaneously determined. In addition, as in the baseline variant with exogenous brain drain, the laws of motion of our variables depends on the prevailing economic regime (formal vs. informal).

If the informal regime prevails, $z_{f,t}$ is fixed and the high-skilled emigration rate only depends on the stock of infrastructure per worker.[25] On the contrary, under the formal regime ($z_{f,t} \equiv z_t$), the high-skilled emigration rate and the the stock of infrastructure influence each other. Consequently, the law of motion of the skill ratio now depends on the prevailing economic regime as well as on the skill ratio loci depicted in the phase diagram, see Figure 8.[26] In addition, the equation defining the infrastructure loci becomes an implicit function and the one which characterizes the formal regime is a function of z_t and z_{t+1}. For illustrative purpose, the phase diagram depicted on Figure 8 is drawn under a myopic-expectation assumption $\left(z^e_{t+1} = z_t\right)$.

The intertemporal equilibrium of the economy with endogenous brain drain can be defined as following:

Definition 3. *Given an initial workforce of size N_0, an initial number of high skilled workers H_0, and an initial level of infrastructure k_0, an intertemporal equilibrium consists in a sequence of wages $\{w_{h,t}, w_{l,t}, w^*_t\}$, a sequence of skill ratio in the economy $\{z_t\}$, a sequence of skill ratio in the formal sector $\{z_{f,t}\}$, a sequence of infrastructure levels $\{k_t\}$ and a sequence of high-skilled-migration rate $\bar{m}_t$ such that depending on the economic regime (34), (i) formal and informal firms maximize profits and wages are determined by Eqs. (28), (29) and (31), (ii) wages $\{w_{h,t}, w_{l,t}\}$ and aggregate quantities $\{\overline{H}_t, \overline{L}_t\}$ are such that the labor markets clear, namely Eq. (43) holds, (iii) the skill ratio evolves according to Eq. (54), (iv) depending on (34) either Eq. (35) or $z_{f,t} = z_t$ defines the skill ratio in the formal sector, (v) the stock of infrastructure evolves according to Eq. (55), (vi) the brain drain is determined by Eq. (46), and (vii) the government budget constraint Eq. (33) is balanced.*

As the skill ratio and the stock of infrastructure per worker are jointly determined, there is a possibility of obtaining multiple equilibria. However, the next proposition proves the uniqueness of the temporary equilibrium; uniqueness is obtained because there is a unique high-skilled emigration rate compatible with Eq. (46). We have:

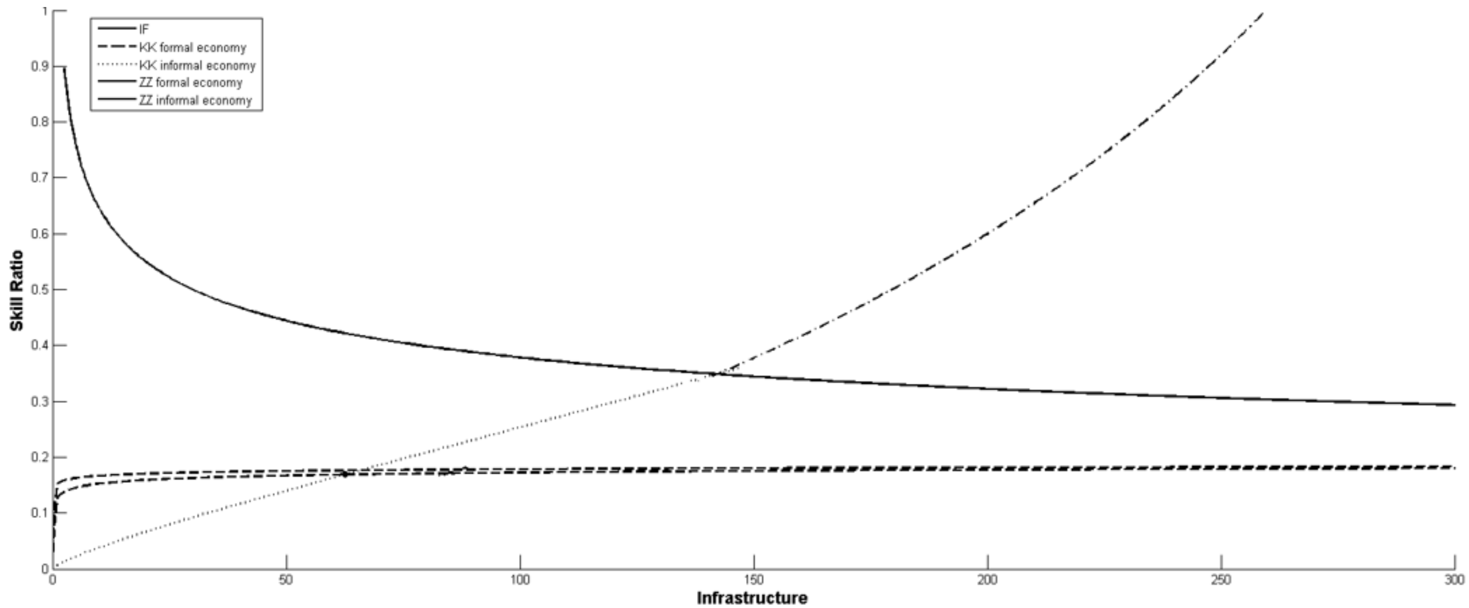
Proposition 9. *Assuming perfect foresight, there is only one equilibrium migration rate in the informal regime if condition $(\alpha + \phi < 1)$ holds. Otherwise, a high-skilled migration rate equal to 1 can be an equilibrium, while another interior equilibrium exists.*

In Subsection 2.6.1.4 of the technical appendix, I provide the proof of proposition 9. The proof is based on a fixed-point argument. I start considering the equation that determines the high-skilled emigration rate. In the informal regime, I plug the value of the skill ratio in the formal sector, given by Eq. (35), into the brain drain Eq. (46). Subsequently, I exploit the equation that governs the dynamics of

[25] This can be shown by plugging Eq. (35) into Eq. (46).

[26] The technical appendix, in Subsection 2.6.1.3 report the equations defining the dynamics of infrastructure and human capital. In the same Subsection I also report the equations defining both the infrastructure and skill ratio loci of the phase diagram.

Figure 8: Phase Diagram-Endogenous Brain Drain (myopic foresight)



This figure is computed using the calibrated parameters obtained for Bolivia described in Section 2.4.1 and exploiting a myopic expectation assumption. The black circle indicates the steady state, the intersection between infrastructure and skill ratio loci in the informal region.

infrastructure, accounting for the fact that infrastructure is now a function of the high-skilled emigration rate as well. Hence, plugging the value of infrastructure set by Eqs. (55) into (46) gives a condition in which the high-skilled-migration rate appears on both sides. An equilibrium emigration rate is a solution of this equation. Under the informal regime, as the proof in the Appendix shows, the RHS is always a decreasing function in the interval [0 1] and is always smaller than one on this interval. Consequently, this function crosses a 45 degree line only once. The same holds under the formal regime. Nevertheless, relaxing condition ($\alpha + \phi < 1$) implies that when migration rate approaches unity, the RHS becomes equal to unity as well. Hence, an emigration rate equal to one can become an equilibrium. This equilibrium arises because when the skill ratio approaches zero, the marginal productivity of high-skilled labor tends to zero. The assumptions on parameters, however, rule out this trivial possibility. Indeed, when ($\alpha + \phi < 1$), the marginal productivity of high-skilled labor tends to infinity when the high-skilled-migration rate approaches unity, thereby preventing a full brain drain to be an equilibrium.

2.4 Quantitative Assessment

The theoretical model highlights that in developing countries, infrastructure accumulation depends on the attractiveness of the informal sector. The baseline model shows that an increase in taxation has heterogeneous effects on high-skilled and low-skilled workers. I show that under the informal regime, increasing taxation does not affect the net income of the low-skilled while the dynamic impact on the high-skilled wage depends on its effect on the infrastructure accumulation and on the skill premium. The effects for high-skilled workers are amplified in the model with endogenous brain drain. Moreover, in this extended model, a developing countries may switch from informality to the formal regime by accumulating larger stocks of infrastructure and human capital. The short-run and long-run responses to a fiscal shock depends on the parameters of the model.

Hence, in this section, I quantitatively assess the impact of policy reforms affecting the tax base or the tax rate. I first describe my parametrization strategy which is common to both variants of the model. I calibrate the model on 60 developing countries at the year 2000.[27] One period lasts 25 years and I assume each country is at its steady state in the year 2000. As informality is observed in all countries, the steady state belongs, by construction, to the informal region. The parametrization strategy is designed so as to perfectly match, for each developing country, the data on the evolution of the size and structure of the labor force between 1975-2000, on the size of the formal sector, on the size of the labor force in the informal sector, and on the skill premium. The first Subsection explains my data sources and my calibration strategy. Then, the other Subsections discuss the results of my policy experiments.

2.4.1 Calibration Strategy

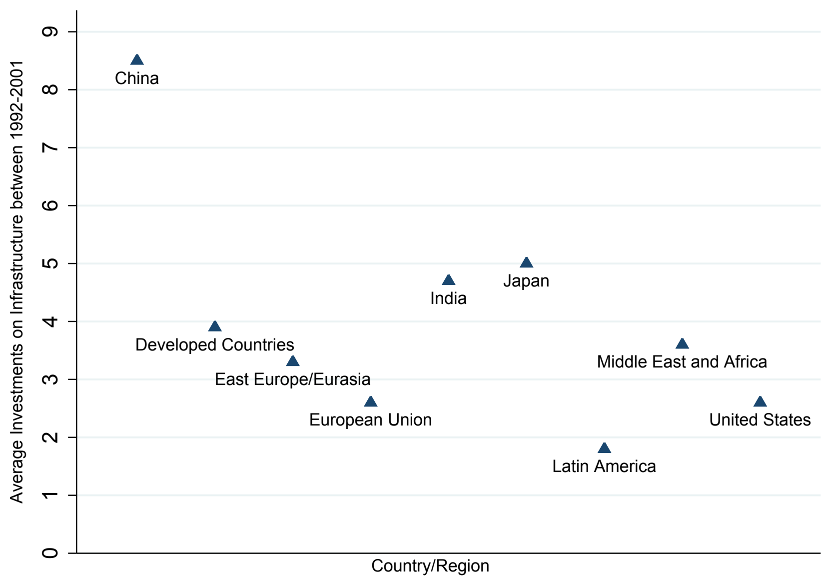
In the set of parameters, I distinguish between common (structural) elasticities and country-specific characteristics. The set of structural parameters is $(\varepsilon, \phi, n, \mu)$. A key elasticity is ε, which links the level

[27] The quantitative appendix reports the list of countries, see Subsection 2.6.3.1. The same table report the country code and the calibrated values of $\{\alpha_j, A_{0,j}, , k_{ss,j}, \gamma_j\}$.

of total factor productivity to the stock of infrastructure per worker. As IMF (2014), I use the value computed by Bom and Ligthart (2014), who find an average elasticity of output to core infrastructure of 0.17. Another important elasticity is ϕ, which captures the education externality. I follow de la Croix and Docquier (2012), who use an elasticity of 0.277. They obtain this value by regressing the level of total factor productivity on the skill ratio using a sample of 142 developing countries in the year 2000.[28] As in de la Croix and Docquier (2012), I also set the fertility differential n to 0.605 in all countries.[29] The last structural parameter is μ, the scale parameter of the distribution of migration taste shocks. As outlined in Section 2.3.9, I set it to unity. This choice implies an elasticity of the high-skilled emigration rate to the ratio of net wages equal to one.

As far as country characteristics are concerned, data on income tax rate are taken from Dobbs (2013). He provides estimates on public infrastructure investments as a percentage of GDP for the period 1992-2001. This variable is computed for some countries and for most regions of the world.[30] According to Figure 9, the country that invested the highest share of its GDP in infrastructure is China, where the average investment rate in public infrastructure was equal to 8.5% of GDP between 1992 and 2001. Much smaller levels are obtained for Africa and the Middle East, where average investments in infrastructure were equal to 3.6% of GDP.

Figure 9: Income taxes devoted to public infrastructure (1992-2001)



Data on average investments on infrastructure (as a % of GDP) for the period 1992-2001 comes from Dobbs (2013). The tax rate borne by formal sector workers matches these estimates.

[28]Following the same paper, I recall that there is still a debate about the size of the education externality. For instance, Acemoglu and Angrist (2001) find no effect of schooling on productivity, whereas Iranzo and Peri (2009b) find a value of 0.44 for the US States.

[29]They use data on on fertility rates from Kremer and Chen (1999) and then compute the differential fertility for the period 1985-1989 and for 26 developing countries. They find that the correlation between country-specific levels of the fertility differential and the human capital of women is small. On this basis, they assume that the fertility differential is independent of the level of development.

[30]If Dobbs (2013) does not provide a country estimate, I use the average level of the region to which the country belongs.

Some other country-specific parameters and endogenous variables,[31]
$\{n_{l,j}, n_{h,j}, \alpha_j, \overline{m}_j, \underline{m}_j, z_{ss,j}, z_{ss,f,j}\}$ for each country j,[32] are calibrated by combining various data sources and to match some moments. From Defoort (2008) and Docquier et al. (2009), I use data on the size and education structure of the labor force in the years 1975 and 2000. This allows me to compute the gross growth rate of the workforce, $g_{2000,j}$. Furthermore, Docquier et al. (2009) provide data on emigration rates by education level for each source country. I use them as proxies for $\overline{m}_{2000,j}$ and $\underline{m}_{2000,j}$.[33] Using $g_{2000,j}$, n, and the skill-specific emigration rates, I identify the low-skilled fertility rate, $n_{l,j}$, as the solution of Eq. (40). I also obtain $n_{h,j}$ after dividing $n_{l,j}$ by n.

From Docquier et al. (2009), I compute the skill ratio in year 2000, $z_{ss,j}$. I combine this variable with data on the size of the informal sector labor force. Such data were compiled in Schneider (2012), after exploiting OECD and World Bank data. In particular, Schneider (2012) provides estimates of the level of informal employment for 60 developing and transition countries and for the year 1998. The sample include 33 African countries (average proportion of informal workers equal to 54.2% of the labor force), 12 Asian countries (average proportion equal to 46.5%), 9 Latin American countries (average proportion equal to 46.5%), and 6 European transition economies (average proportion equal to 50.0%).[34] This allows me to identify the skill ratio in the formal sector, $z_{ss,f,t}$, one of the key variables of my model, using:

$$z_{ss,f,j} = \frac{H_{2000,j}}{L_{2000,j}\left(1 - s_j\right)}, \tag{47}$$

where s_j is the size of the informal labor force in country j as reported in Schneider (2012) for the year 1998, $H_{2000,j}$ and $L_{2000,j}$ are the stocks of high-skilled and low-skilled workers reported in Docquier et al. (2009).

Then, I calibrate α, the elasticity of official GDP to the stock of high-skilled, so as to match data on the skill premium. From Section 2.3.1, the wage ratio between high-skilled and low-skilled workers in the formal sector is equal to $WR = \frac{\alpha}{(1-\alpha)z_{f,t}}$. Hendricks (2004) provides Mincerian measures of returns per year of schooling for 54 countries around the year 2000. From Barro and Lee (2013) I can assess the difference in years of schooling between a high-skilled and a low-skilled worker.[35] In the following, $MR_{2000,j}$, means the Mincerian return in country j, while $DY_{2000,j}$ stands for the difference in years of schooling between high-skilled and low-skilled workers. Therefore, the wage ratio is given by $WR_{2000,j} = \left(1 + MR_{2000,j}\right)^{DY_{2000,j}}$. I determine α as following:

$$\alpha_j = \frac{WR_{2000,j} z_{ss,f,j}}{1 + WR_{2000,j} z_{ss,f,,j}}, \tag{48}$$

I also assume that α is time invariant. Finally, a last set of country-specific parameters and the value of

[31] The subscript ss stands for steady state.

[32] $\overline{m}_{2000,j}$ is endogenous in the second variant, in such a case the right notation requires the drop of the year from the subscript, namely $\overline{m}_{ss,j}$.

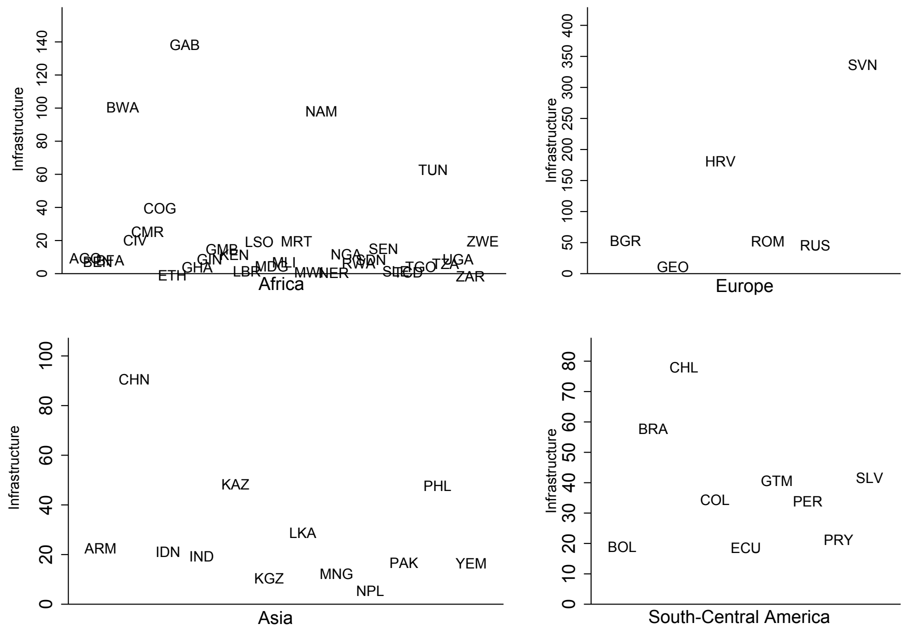
[33] They define as high-skilled workers all individuals aged 25 and over with at least one year of college education.

[34] A key assumption made on estimating the informal sector labor force is that its magnitude in cities is at least as high as in rural areas, which is clearly a conservative assumption.

[35] For some countries, data on Mincerian returns or on years of education are not available. In such cases, I proxy the wage ratio as in Delogu et al. (2014), who predicted wage ratios using a simple OLS regression, $ln\left(WR_{2000,j}\right) = 0.25 - 0.131 \ln\left(\frac{h_j}{1-h_j}\right)$ with $R^2 = 0.57$.

infrastructure per capita at the steady state are calibrated,
$\left(A_{0,,j}, q_j, \gamma_j, w_j^*, k_{ss,j}\right)$, are calibrated using the assumption that the year 2000 is a steady state (the subscript ss stands for steady state). I need to calibrate $A_{0,j}$ and γ_j, the formal and informal scale parameters, q_j the fraction of children receiving higher education in low-skilled families, and $k_{ss,j}$, the stock of infrastructure per worker. Furthermore, when brain drain is endogenous I also calibrate w_j^*, the high-skilled net wage abroad. I identify the level of these variables by numerically solving a non-linear system at the steady state. In the exogenous brain drain case $(A_{0,j}, q_j, k_{ss,j}, \gamma_{ss,j})$ are determined simultaneously, solving numerically (for each country considered) the non-linear system delineated by Eqs. (25), (35), (49), (53).[36] I use data on GDP in USD dollars for the year 2000 from World Bank (2012). For the extended model with endogenous brain drain, I add the equation which governs the brain drain, Eq. (46), and then I solve for $\left(A_{0,j}, q_j, k_{ss,j}, \gamma_j, w_j^*\right)$. The equations defining the steady state levels of the skill ratio and the stock of infrastructure change as well. I numerically solve a new system which includes Eqs. (57) and (59) instead of Eq. (49) and Eq. (53).[37] Figure 10 shows the calibrated values of the stock of infrastructure per worker for all countries considered. A table in Subsection 2.6.3.1 of the Appendix reports the list of the countries with the associated code and the calibrated value of the stock of infrastructure per worker.

Figure 10: Calibrated stock of infrastructure per worker (by continent)



This figure reports the calibrated values of infrastructure, k_{ss}. In the appendix, Section 2.6.3.1 provides the association between countries codes' and countries' names.

[36] In Section 2.6.1.1 of the Technical Appendix, I report Eqs. (49), (53) which set, respectively, the skill-ratio and infrastructure- levels at the steady state for the model with exogenous brain drain.

[37] In Section 2.6.1.3 of the Technical appendix, I report Eqs. (57) and (59). These equations define the skill ratio and infrastructure loci for the model with endogenous brain drain.

Figure 10 shows that the calibrated value of k_{ss} reaches its greatest value in Slovenia. Among Asian countries, China is the country where the index reaches its greatest value, in spite of the fact that it looks evidently too small when compared to some European and African countries.

I validate the parametrization strategy by computing correlations between the calibrated values of k_{ss} and physical measures of infrastructure. Table 4 shows that the calibrated infrastructure index exhibits strong correlations with actual measures of infrastructure.

Table 4: Correlation between k_{ss} and official proxies for infrastructure

Var (year 2000)	k_{00}
Paved roads (%)	0.49
Kwh per capita	0.69
Telephone Lines	0.74
Electricity Losses	-0.20

Data Source: World Bank (2010)

The first row shows that k_{ss} is positively correlated with the percentage of paved roads (69%). Importantly, the correlations between k_{ss} and the production of *Kwh per capita* (69%) or the number of *telephone lines* (74%) are large. Finally, the last row shows that infrastructure is negatively correlated with a measure of electric power transmission and distribution losses.

2.4.2 Simulations

I now use the calibrated model to simulate the country-specific responses to three policy reforms, which affect either the tax base or the income tax rate. I simulate the effects of these reforms on the trajectory of the stock of infrastructure per worker (k_t), of wages ($w_{h,t}$ and $w_{l,t}$), and of the high-skilled emigration rate ($\bar{m}_t$). In all cases, the shock occurs in the year 2025 and is assumed to be permanent. I study its short- and long-run effects (abusing the standard terminology, I refer to the year 2100 when describing the long-run effects), considering both variants, namely with exogenous and endogenous emigration rates.

In the first numerical experiment, labeled as *"Removing informality"*, I simulate the effect of a total ban of the informal sector. The shock consists in setting $\gamma = 0$, so that all low-skilled workers are forced to join the formal sector, then paying taxes and contributing to the funding of public infrastructure. The informal sector is usually described as a heterogeneous sector including registered firms activities hidden from the state, wage employment or self-employment in unregistered small-scale business units, and sometimes home production. A total ban of informality is neither a feasible option (as part of it involves home production) nor a desirable option (informality serves a subsistence sector for many workers) in developing countries. This experiment must only be considered as a thought experiment that illustrates the effect of the informal sector on the marginal productivity and income of workers at low level of development. Results are discussed in Subsection 2.4.2.1.

In the second numerical experiment, labeled as "*Taxing informality*", I allow the government to tax informal workers at the same rate as the formal ones. A large share of informality (including the overwhelming share that involves market transactions) is tolerated by the State in developing countries. The reasons are multiple, such as the incapacity of the State to develop or maintain social programs, its incapacity to manage unemployment, the fear of a bankruptcy of the economy, the fear of social tensions, etc. I disregard the political implications of changing the tax base, and consider this scenario as another thought experiment illustrating the role of tax evasion. Contrary to the first experiment, which induces a drastic fall in the marginal productivity of low-skilled workers (due to their massive inflow in the formal sector), this shock induces smaller effects on their marginal productivity. However, it implies that all low-skilled workers become fiscal contributors. Results are discussed in Subsection 2.4.2.2.

The third numerical experiment, labeled as *"Fiscal policy"*, considers a 1 percentage point increase in the tax rate borne by formal workers. This scenario can be considered as a feasible policy reform. It allows understanding the dynamic implications of an expansive fiscal policy for infrastructure accumulation, human capital accumulation, brain drain and development. Results are discussed in Subsection 2.4.2.3.

2.4.2.1 Removing Informality

I start simulating the effect of a total ban of informal activities (setting $\gamma = 0$) from the year 2025 onward. In this counterfactual experiment, I prevent low-skilled workers from using the informal technology in developing countries, although they have incentives of doing so.[38] As infrastructure is defined as a stock variable (see Eq. (33)), the shock has gradual implications for the economy. When brain drain is exogenous, the stock of infrastructure per worker does not change in the short-run. Instead, when emigration rates are endogenous, the inflow of low-skilled workers in the formal sector increases the marginal productivity of high-skilled workers and reduces the brain drain. The stock of infrastructure per worker is then negatively affected in the short-run. However, a sizable impact on infrastructure is obtained in the long-run, after taxes have been invested. For each country in my sample, Figure 11 shows the long-run effect of banning informality on the stock of public infrastructure per worker, measured as percentage of deviation from the initial steady state. The grey bars show the effect obtained under exogenous brain drain, while the black bars show the additional gains obtained once emigration rates are endogenous.

The change in the stock of infrastructure per worker varies across countries. These variations are explained by the initial size of the informal sector, which is itself determined by the country-specific parameters of the model. As far as the exogenous migration scenario is concerned, it is possible to identify the exact equation that governs the percentage change in public infrastructure. This equation is reported in Subsection 2.6.3.2 of the appendix; it shows that the relative change in infrastructure is a function of a set of parameters and initial conditions (z_{ss}, k_{ss} , γ, α and τ). To disentangle the sources of variation across countries, I use the model with exogenous migration and compute the correlation between the change in public infrastructure per worker and each of these five determinants. Table 5

[38] On the contrary, high-skilled workers in developed countries have no incentive to work in the subsistence sector given the large productivity gap between the two sectors.

reports these correlations. I find that the relative change in public infrastructure is negatively correlated with each determinant. Consequently, countries starting with a lower initial level of infrastructure, with a smaller tax rate, with a less productive informal sector, or with a lower value of α experience larger effects on the public-infrastructure stock.

Table 5: Removing informality: determinants of the long-run change in public infrastructure (exogenous brain drain)

Parameter/Variable	Correlation
γ	-0.38
k_{ss}	-0.30
z_{ss}	-0.58
α	-0.55
τ	–0.17

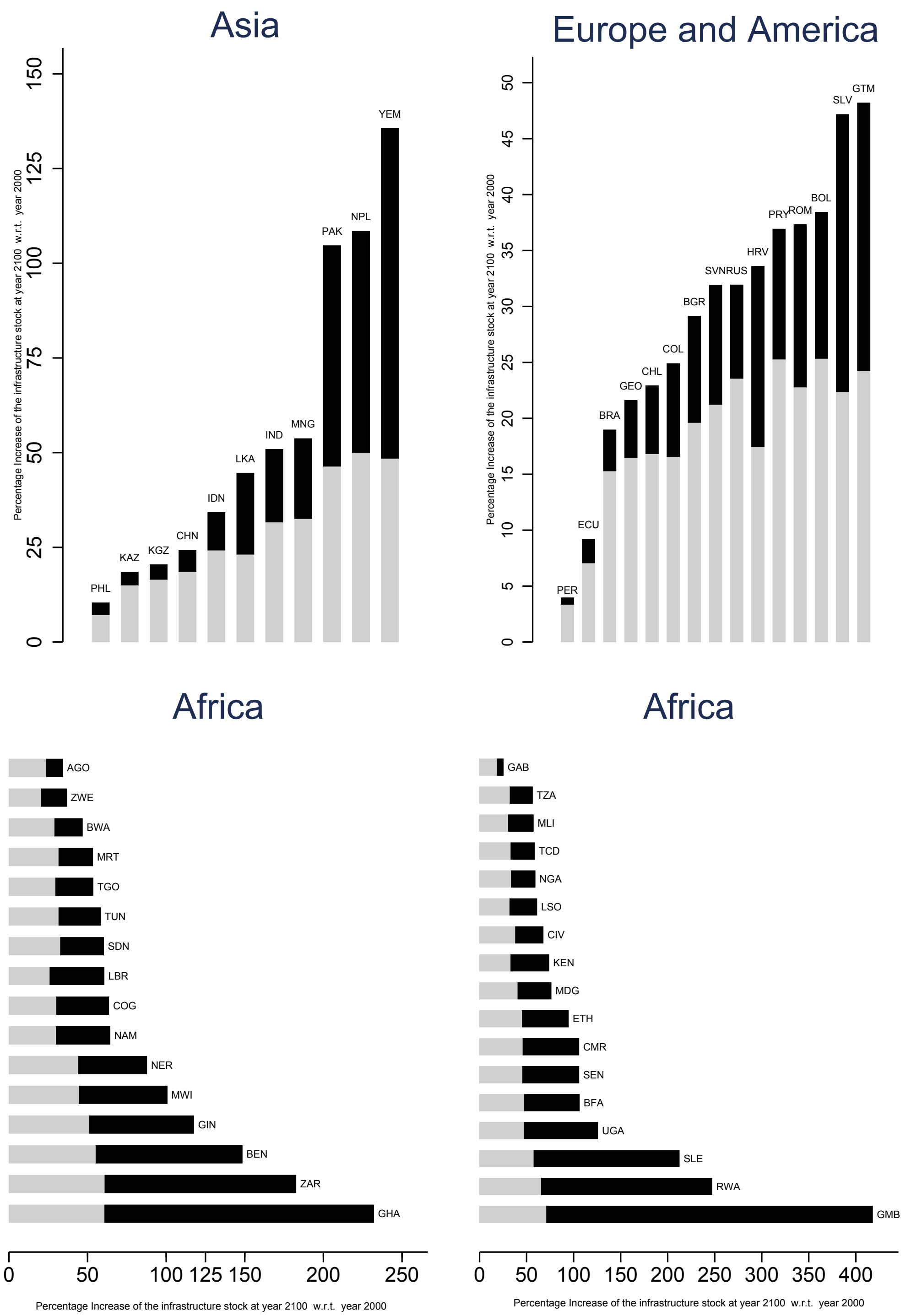
The solution is more complex under the endogenous brain drain scenario. Figure 11 clearly illustrates that larger effects on infrastructure are obtained when the brain drain responds to the shock (see black bars). In this context, I compute the correlations between the extra-gain in public infrastructure gains and the high-skilled emigration rates in year 2000. Unsurprisingly, the size of the extra-gain is highly correlated with the current brain drain rate (the correlation is equal to 0.76). Banning the informal sector suddenly reduces the number of high-skilled emigrants. This effect materializes in the short-run, right after the shock. This is due to the rise in the domestic skill premium induced by the inflow of low-skilled workers in the formal sector. In subsequent periods, the brain drain rate slightly decreases due to gradual effect of the stock of public infrastructure on total factor productivity. Hence, the variations in the brain drain are correlated with the change in the stock of public infrastructure provided in Figure 11. Figure 12 illustrates the long-run change in the brain drain for a subset of countries (I only select countries where the high-skilled emigration rate exceeds 20% in the year 2000). It demonstrates that a large portion of the current brain drain can be explained by the existence of the informal economy in developing countries. Considering the extreme example of Gambia, a complete ban of informality reduces the brain drain from 70 to 30% in the long run.

Despite large long-run effects on the stock of public infrastructure, the model with exogenous brain drain predicts a negative effect on the GDP per capita, both in the short run and in the long run. This is due to the fact that low-skilled workers, the large majority of workers in poor countries, earn less. In the model with endogenous brain drain, banning informality increases human capital and productivity; the effect on GDP per capita becomes ambiguous. For ten developing countries (Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Sierra Leone, Sri Lanka and Uganda), I predict a positive effect on GDP per capita in the long-run. In the other countries, the effect is negative: banning informality hurts low-skilled workers and benefits the highly skilled. The gains for the highly skilled are large and governed by three effects: a higher skill premium (due to the inflow of low-skilled workers in the formal sector), an uncertain effect on human capital in the formal sector (due to lower brain drain and the inflow of low-skilled workers), and a higher stock of infrastructure (due to greater tax base).

Endogenizing the brain drain has different implications for the low-skilled and high-skilled workers. When the brain drain decreases, total factor productivity is positively affected. However, the supply of human capital increases and this negatively affects the skill premium. The calibrated model shows that the latter effect dominates for the highly skilled. In the case of exogenous brain drain, the rise in high-skilled wage rates are greater, as illustrated on Figure 13, which provide the short-run and long-run changes in high-skilled wage for the set of countries where the brain drain rates are above 20% in the year 2000.

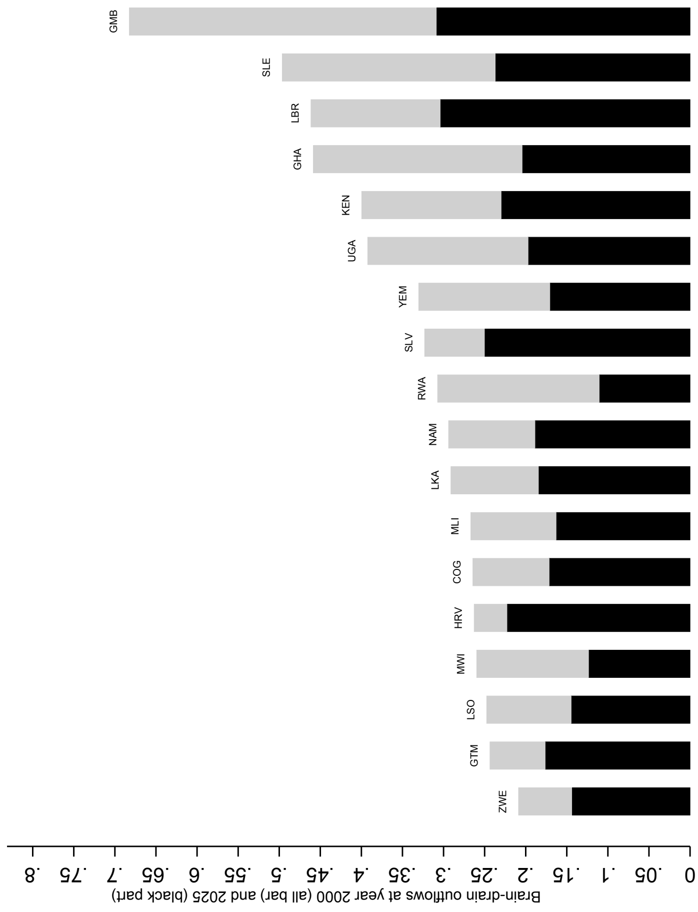
The opposite outcomes emerge for the low-skilled. Banning informality substantially decreases the low-skilled wage rate (due to the decrease in marginal productivity). The fall in income is attenuated when the brain drain is endogenous. In most countries, the effect remains negative in the long run. In three countries only (Gambia, Liberia and Kenya), the long-run wage rates gets larger after banning informality, as shown on Figure 14.

Figure 11: Removing Informality: effect on $\Delta k_{2100}/k_{ss}$
(Grey bars: exogenous brain drain; Black bars: endogenous brain drain)



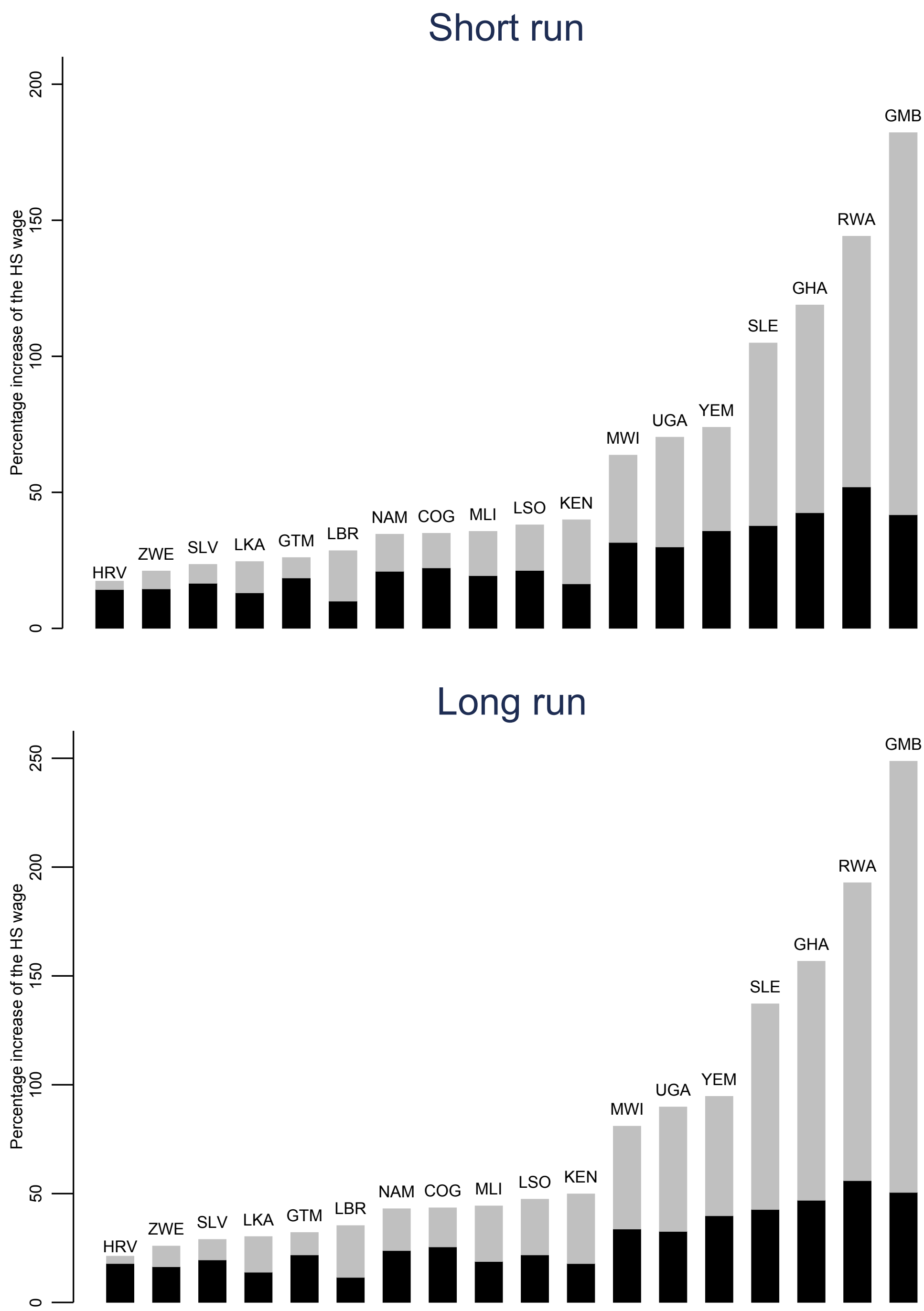
This graph shows the change in the stock of infrastructure per worker in the year 2100, as percentage of the initial steady state level. The grey bars show the effect obtained under exogenous brain drain scenario, while the black bars show the additional gains obtained once emigration rates are endogenous.

Figure 12: Removing informality: effect on $\bar{m}_{2100} - \bar{m}_{2000}$
(Grey bars: actual emig. rate in 2000; Black bars: new long-run emig. rate)



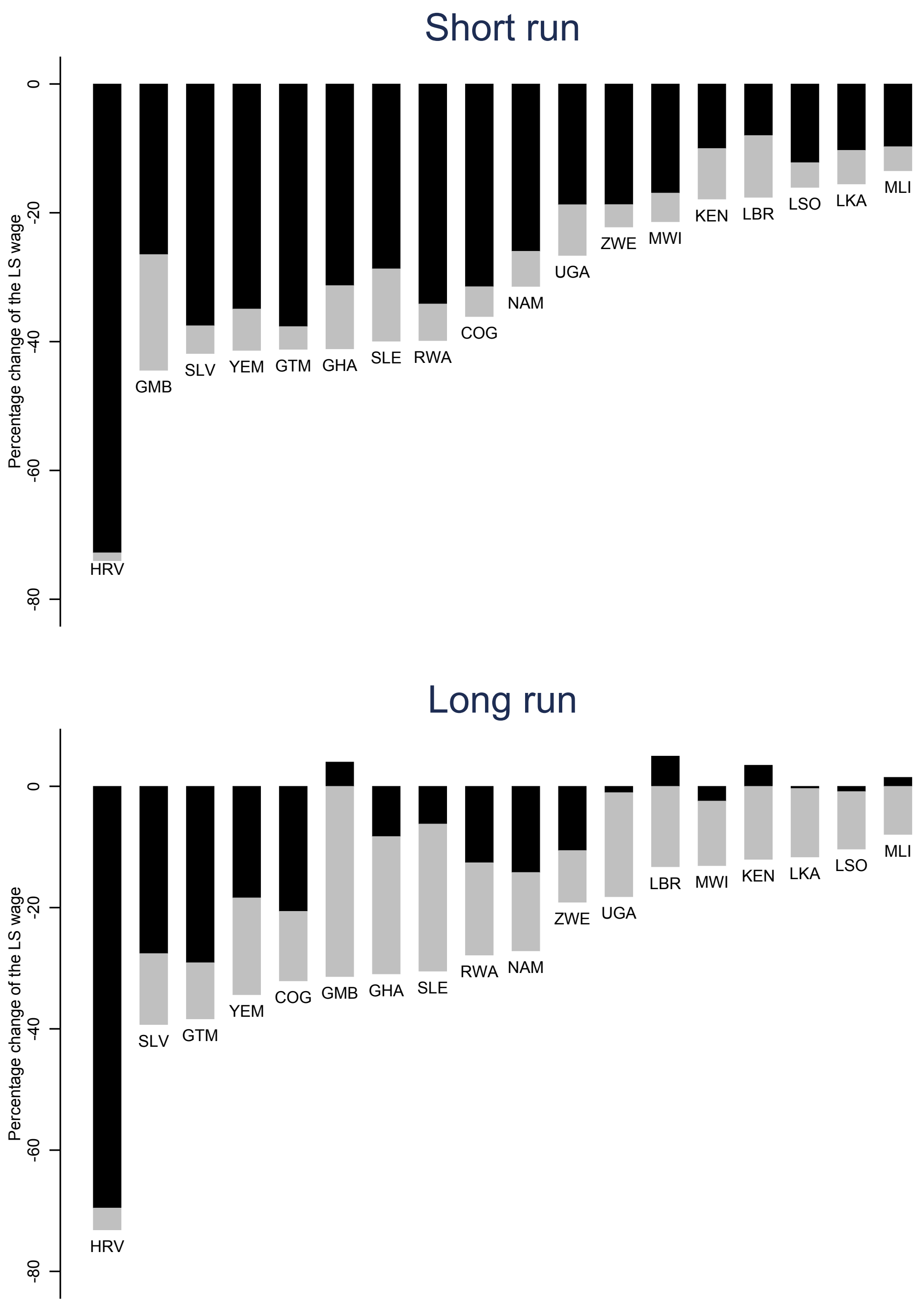
This graph compares the new brain drain rates in the year 2100 (black bars) for a subset of countries with actual emigration rates above 20% in year 2000 (grey bars).

Figure 13: Removing informality: effect on $\triangle w_{h,t}/w_{h,ss}$
(Grey bars: exogenous brain drain; Black bars: endogenous brain drain)



This graph shows the predicted short- and long-run changes in the high-skilled wage rate under both variants of the model, and for the subset of countries with high-skilled emigration rates above 20% in the year 2000. The black bars give the effect obtained with endogenous brain drain while the grey bars give the effect obtained when the brain drain rates are constant at their 2000 level.

Figure 14: Removing Informality: effect on $\triangle w_{l,t}/w_{l,ss}$
(Grey bars: exogenous brain drain; Black bars: endogenous brain drain)



This graph shows the predicted short- and long-run changes in the low-skilled wage rate under both variants of the model, and for the subset of countries with high-skilled emigration rates above 20% in the year 2000. The black bars give the effect obtained with endogenous brain drain while the grey bars give the effect obtained when the brain drain rates are constant at their 2000 level.

2.4.2.2 Taxing Informality

In this Subsection, I assume that the income generated in the informal economy can be taxed at the same rate as in the formal sector. This experiment is at odds with the definition of the informal sector I provide in Section 2.3. However, in poor countries, a large part of the informal economy consists of unregulated and exempted market transactions, and it is relevant to investigate whether making these transactions taxable could boost development.

Taxing informality implies that the informality frontier becomes independent on the tax rate, as shown in Section 2.3.4. If the labor income in the informal sector can be taxed, the size of the informal sector decreases in the short run and in the long run. The decrease is gradual and cumulative as it takes time for additional public revenues to be invested in public infrastructure. In the case of endogenous brain drain, the rise in total factor productivity discourages high-skilled workers to emigrate, and this incites even more low-skilled workers to join the formal sector. Figure 16 shows the effect of taxing informality on the level of informal employment for the model with endogenous brain drain. The black bars represent the predicted drop of informal employment at year 2100. The grey bars show the level obtained at year 2000. Each bar shows the actual size of informal employment at year 2000. In all countries, taxing informality induces a sizable decrease in informal employment. Interestingly, the calibrated model predicts a switch from the informal to the formal regime in some countries. In the exogenous brain drain scenario, the regime switching occurs only in China as early as in the year 2025.

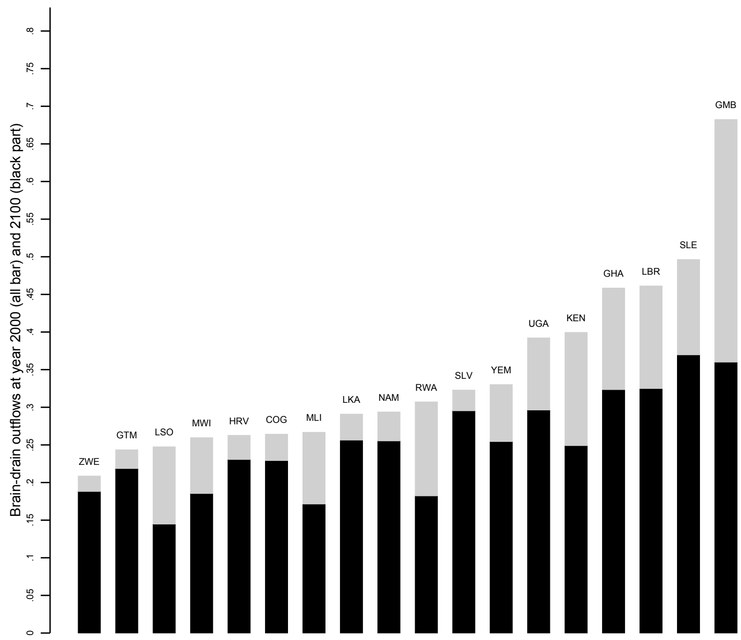
Accounting for endogenous brain drain induces greater effects. The brain drain rate decreases from the year 2025 on, although the change becomes substantial in the long run. Figure 15 compares the long-run emigration rates after taxing informality (the black bars) with the actual emigration rates observed in the year 2000 (grey bar), for the subset of countries characterized by a current brain drain rate above 20% in year 2000. In some countries (Chad, Gambia, Lesotho, Rwanda and China) the brain drain is divided by slightly less than two in the year 2100. Hence, the case for regime switching becomes stronger. In China, the regime switching still occurs in the year 2025. Seven other cases of regime switching are identified when emigration is endogenous. In Kenya and Liberia, the regime switching occurs in the year 2050. In Chad, Gambia, Gambia, Mali and Togo, it occurs in the year 2075.

How does taxing informality affect public infrastructure? As in the previous section, it is possible to identify the exact equation that governs the percentage change in public infrastructure the exogenous migration scenario. This equation is provided in Subsection 2.6.3.2 of the appendix. The relative change in the stock of infrastructure per worker is a function of $\{\gamma, k_{ss}, \tau, \alpha, z_{ss}.\}$. Table 6 gives the correlation between simulated changes in public infrastructure and their determinants. The correlations are negative and usually smaller than after banning informality, except the correlation with τ. In the case of endogenous brain drain, I cannot identify the exact equation governing the infrastructure response. However, I can numerically compute the correlation between the extra-gain in infrastructure and the current level of the brain drain. The correlation coefficient is equal to 0.34. When the shock does not induce a regime switching, the low-skilled wage rate decreases by a fraction equal to the tax rate. In the long run, positive effects on low-skilled wage rates can be obtained if the changes in infrastructure and human capital are large enough, or if there is a regime switching. This occurs in a very limited number of countries. On the contrary, the high-skilled wage rate increases both in the short run and in the long run. Figure 17 shows the long-run changes in the high-skilled wage rate for countries characterized by a current brain drain rate above 20%. With exogenous brain drain, the high-skilled wage rate increases by more than 50% in some countries. As in the previous Subsection, it increases more when the brain drain is exogenous. Overall, the effect on the low-skilled dominates in the short-run. Hence, taxing informality decreases the 2025 level of GDP per capita in all countries and under both variants of the model. On the contrary, both variants predict an increase in GDP per capita in the long run.

Table 6: Taxing informality: determinants of the long-run change in public infrastructure (exogenous brain drain)

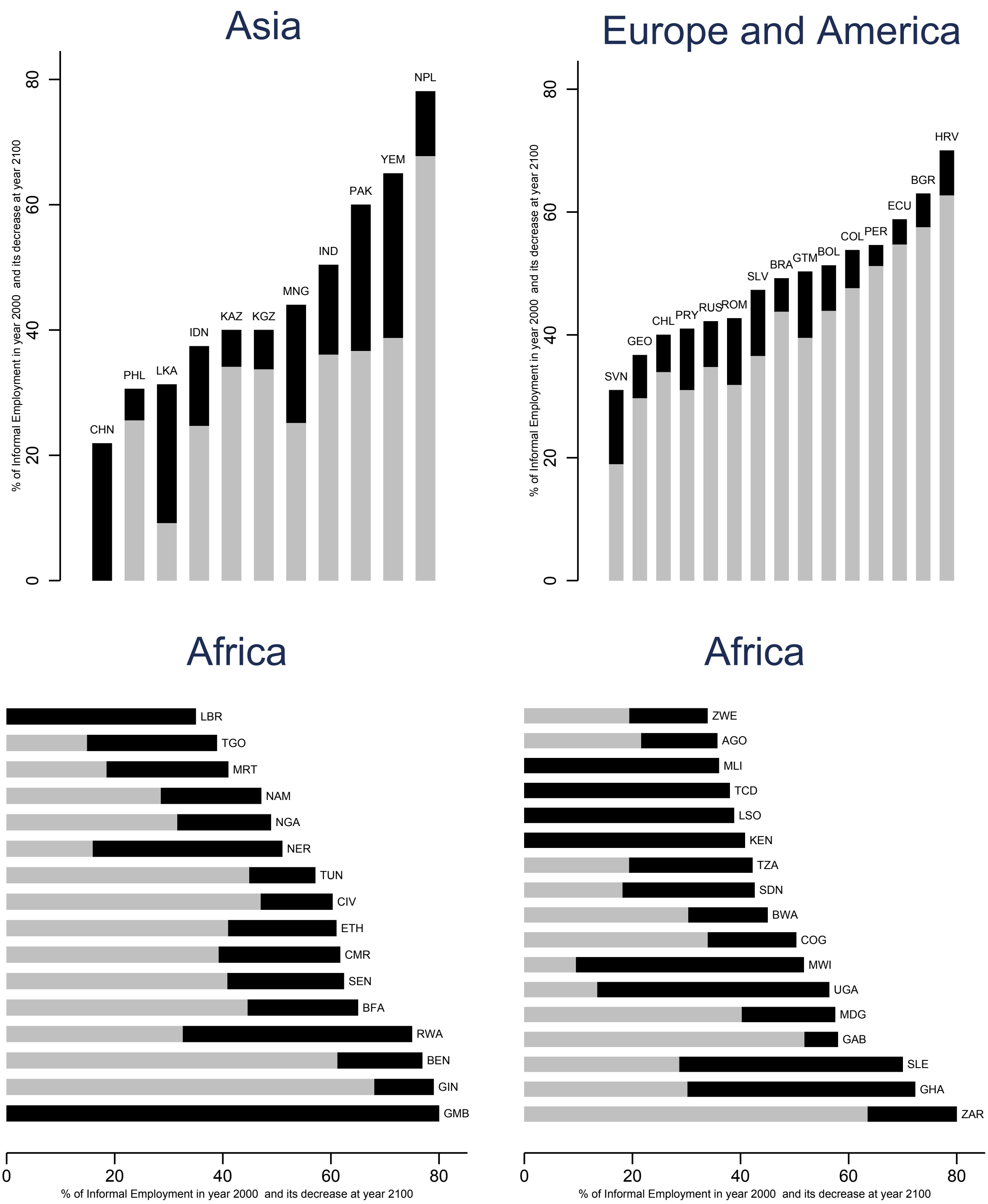
Parameter/Variable	Correlation
γ	-0.23
k_{ss}	-0.22
z_{ss}	-0.05
α	-0.12
τ	-0.31

Figure 15: Taxing Informality: effect on $\bar{m}_{2100} - \bar{m}_{2000}$
(Grey bars: long-run emig. rate; Black bars: actual emig. rate in 2000)



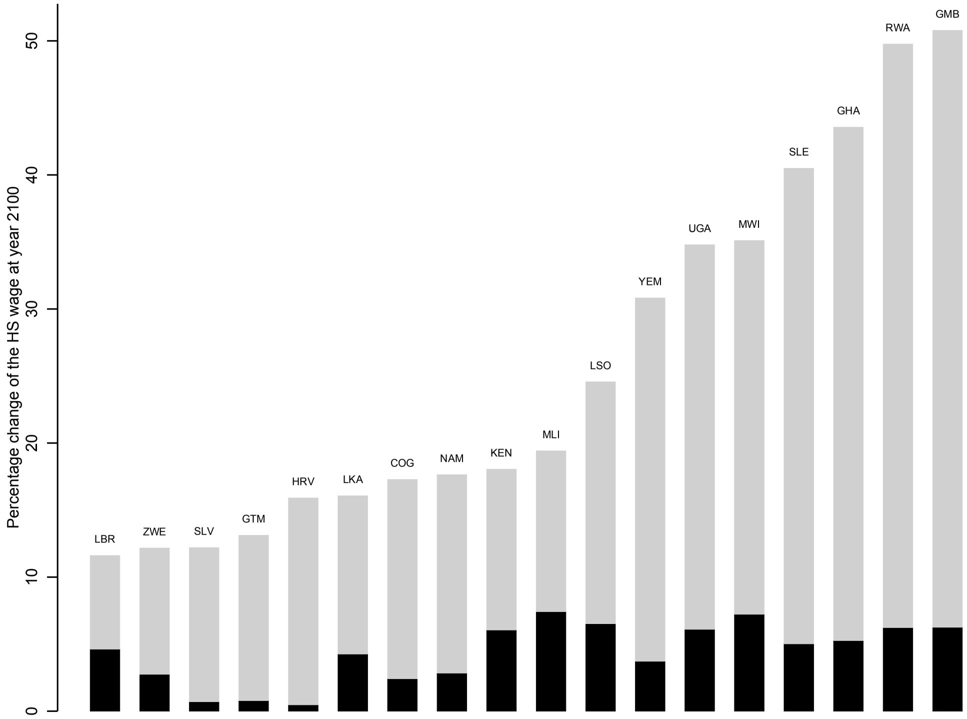
This graph compares the long-run brain drain rate obtained after taxing informality (black bars) with the observed level in the year 2000. I only consider the subset of countries with emigration rates larger than 20% in the year 2000.

Figure 16: Taxing Informality: long-run effect on informal employment
(Grey bars: long-run informal empl.; Black bars: drop of informal empl. at year 2100 w.r.t. actual 2000 levels)



This graph compares the size of the informal sector at year 2000 and year 2100 (year 2100) w.r.t. the model with endogenous brain drain. The grey parts of the bars show the predicted size of the informal sector at year 2100 while each bar reports the actual size of the informal sector at year 2000.

Figure 17: Taxing Informality: effect on $\triangle w_{h,2100}/w_{h,ss}$
(Grey bars: exogenous brain drain; Black bars: endogenous brain drain)



This graph shows the long-run effect of taxing informality on the high-skilled wage rates under both variants of the model, and for a subset of countries with emigration rates above 20% in the year 2000. The black bars show the estimated gains with endogenous brain drain while the grey bars show the additional effect obtained when the brain drain is constant.

2.4.2.3 Fiscal Policy

In this last Subsection, I simulate the effect of a one-percent increase in the formal income tax rate, assuming this shock is permanent. In the exogenous brain drain scenario, informal employment increases in the short run. The adjustment stops when the, low-skilled before-tax wage rate is one percent greater in the formal sector. Hence, the shock has not effect on the net income of low-skilled workers. This outflow of low-skilled workers pushes the high-skilled wage rate downwards. These two effects reduce the tax base and the effectiveness of the fiscal reform. Hence, GDP per capita decreases in all countries in the short run. In the endogenous brain drain case, the decrease in the high-skilled wage rate leads more high-skilled workers to leave their country. This larger brain drain reinforces the negative effect on GDP per capita.

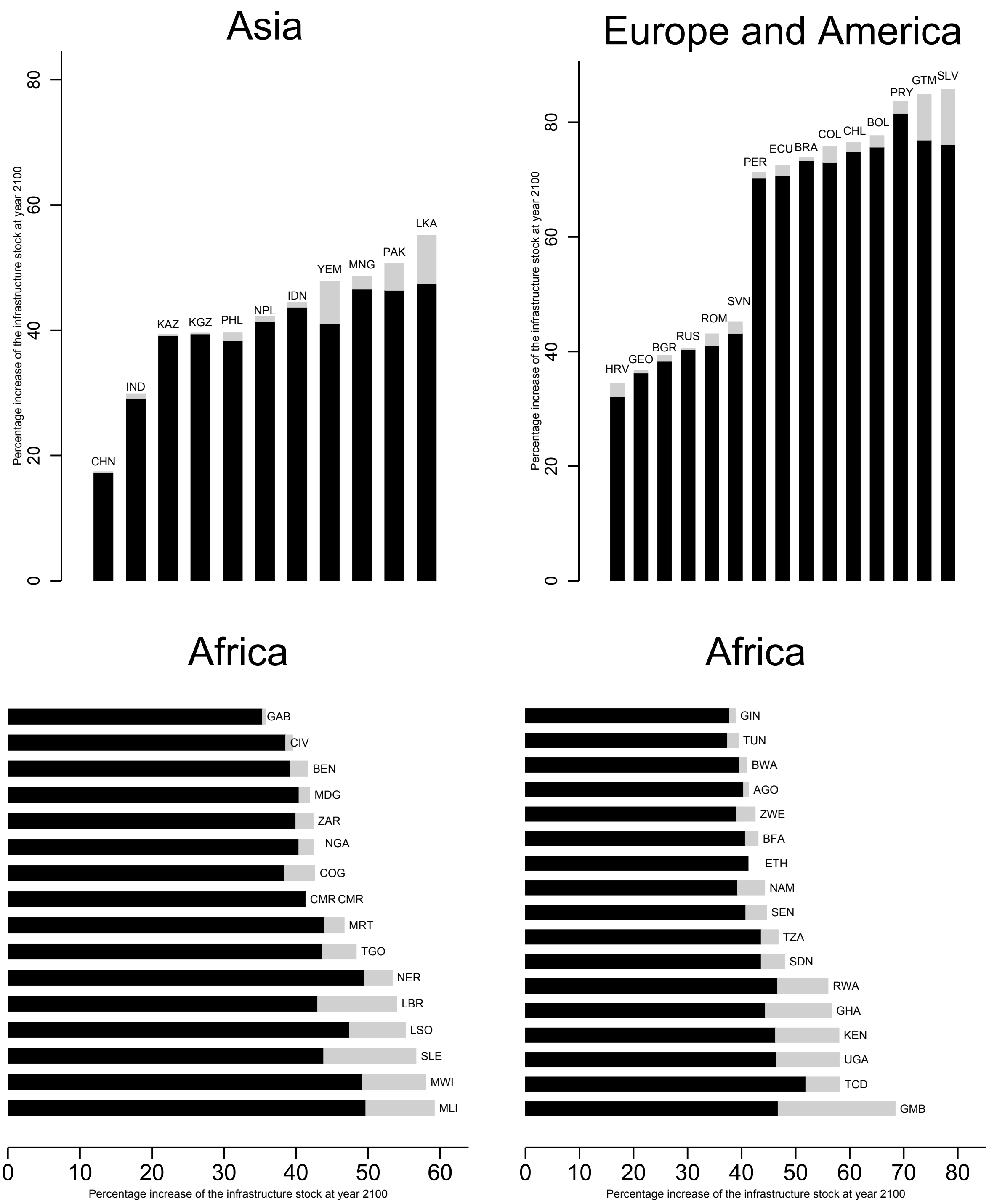
Gradually, as additional public revenues are invested in infrastructure, the change in total factor productivity increases the effectiveness of the fiscal policy. Despite the short-run adverse effects, both public infrastructure and human capital substantially increase in the long run. Figure 18 reveals that a small increase in the tax rate has large positive effects on the long-run stock of infrastructure per worker. The figure reports the relative deviation from the initial steady state in the cases of exogenous (grey bars) and endogenous (black bars) brain drain.

Long-run changes in infrastructure are always larger when brain drain is endogenous. This is because the change in infrastructure increases total factor productivity and high-skilled wage rates in the formal economy. In addition, long-run gains are substantial, ranging between 40 to 80 percent. For the exogenous brain drain model, I provide the exact equation that governs the percentage deviation in infrastructure in Subsection 2.6.3.2 of the appendix. I show that the gain is a function of α and τ only. Then, I compute the correlation between the long-run changes in infrastructure and α or τ. The correlation coefficient with α is equal to 0.23, while the correlation with τ is equal to -0.82. In the case of endogenous brain drain, I can not identify the exact relationship. However, I can numerically compute the correlation between the extra effect on infrastructure and the actual emigration rate observed in the year 2000. The correlation is equal to 0.28. Figure 19 shows that a small permanent increase in taxation reduces the long-run level of the brain drain. In line with the previous experiments, I report the results obtained for the subset of countries characterized by emigration rates above 20% in the year 2000. The black bars give the long-run brain drain levels after the fiscal reform, while the grey bars report the level observed in the year 2000. The variation in the brain drain is greater in countries where the initial brain drain is important. When brain drain decreases, the fiscal base increases and this reinforces the effectiveness of the fiscal policy.

Finally, Figure 20 depicts the long-run effect of the fiscal policy on the high-skilled wage rate. I focus on the subset of countries with brain drain rates above 20% in the year 2000. The Figure shows that a small increase in the tax rate substantially benefit the highly skilled. The relative changes in wages are in the same order of magnitude under the two variants of the model. For some countries such as Ghana, the effect is larger when brain drain is endogenous (the positive effect triggered by the human capital externality prevails), while the effect is smaller for other countries such as Mali (due to the decreasing skill premium).

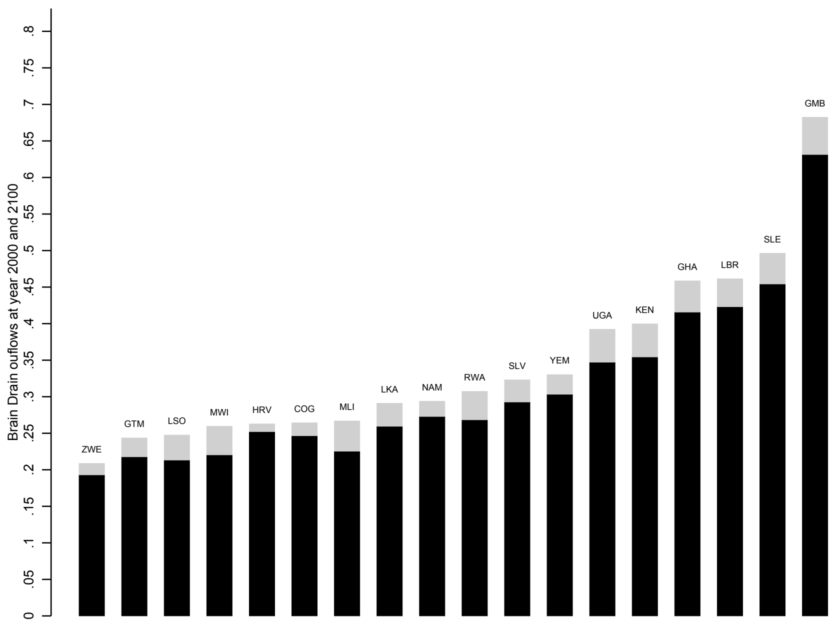
Remember that, if there is no regime switching (this is the case for a one-percent increase in the tax rate), the net income of the low-skilled is unaffected both in the short run and in the long run. Overall, the stock of infrastructure per worker is always greater than in the initial steady state, the brain drain is smaller, and high-skilled workers earn more. This leads to a long-run increase in GDP per capita for both variants of the model.

Figure 18: Fiscal policy: effect on $\Delta k_{2100}/k_{ss}$
(Grey bars: exogenous brain drain; Black bars: endogenous brain drain)



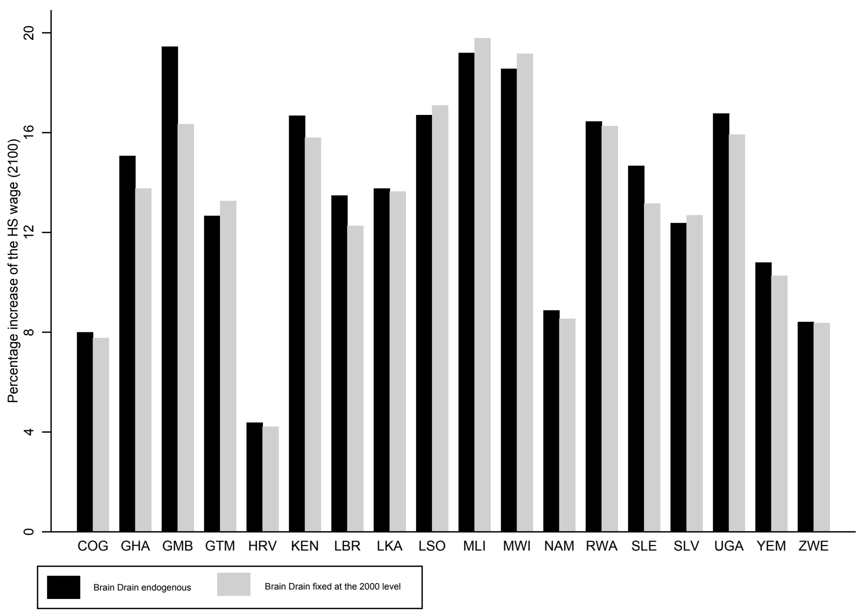
This graph shows the long-run effect a one-percent increase in taxation on the stock of infrastructure per worker, as percentage of the initial steady state. The grey bars show the effect obtained under the exogenous brain drain scenario, while the black bars show the effect obtained with endogenous emigration rates.

Figure 19: Fiscal policy: effect on $\bar{m}_{2100} - \bar{m}_{2000}$
(Grey bars: actual emig. rate in 2000; Black bars: long-run emig. rate)



This graph shows the long-run changes in the brain drain for a sub-set of countries with emigration rates above 20% in the year 2000. Grey bars show the actual brain drain levels observed in the year 2000, while black bars give the long-run brain drain rate after the fiscal reform.

Figure 20: Fiscal Policy: effect on $\Delta w_{h,2100}/w_{h,ss}$
(Grey bars: exogenous brain drain; Black bars: endogenous brain drain)



This graph shows the long-run changes in the brain drain for a sub-set of countries with emigration rates above 20% in the year 2000. Grey bars show the actual brain drain levels observed in the year 2000, while black bars give the long-run brain drain rate after the fiscal reform.

2.4.3 Robustness checks

I now consider the same counterfactual experiments as the ones discussed in the previous sections, and I conduct a sensitivity analysis using both variants of the model (i.e. exogenous vs endogenous brain drain). It allows me to assess the robustness of my results to the level of the structural parameters $\{\varepsilon, \phi, n\}$ and to the hypothesis that public infrastructure only affects the total factor productivity of formal firms. It is worth noticing that when a parameter changes, I re-calibrate the model following the same strategy as in Section 2.4.1.

Four robustness checks are conducted in this section:

- First, I reduce the elasticity of productivity to public infrastructure, ε, from 0.17 to 0.10. The latter value is the upper bound of the range reported in Calderón et al. (2015), as discussed in Section 2.2.
- Second, I reduce the elasticity of productivity to the skill ratio, ϕ from 0.277 to 0.177, in the same vein as in the previous robustness check.
- Third, I consider a greater value for the differential fertility, i.e. the ratio of the high-skilled fertility rate to the low-skilled one. I use $n = 0.705$ instead of the benchmark level 0.605.
- Fourth, I assume that the stock of public infrastructure per worker also affects the total factor productivity of informal firms. I assume that the elasticity of the informal productivity to infrastructure is equal to 0.07, which corresponds to the lower bound of the interval reported in Calderón et al. (2015), whereas the elasticity in the formal sector is kept at its benchmark level, 0.17.

For the key variables, $\{k, w_l, w_h, \bar{m}\}$, the tables below report the average-cross-country difference between robustness-check and benchmark-variations. These deviations are computed for each experiment,[39] for the short run (year 2025) and the long run (year 2100) and considering both variants of the model.

[39] I remind that the three experiments considered are: "*removing informality*", "*taxing informality*" and "*fiscal policy*".

2.4.3.1 Smaller infrastructure externality

In the simulation with $\varepsilon = 0.10$, the effectiveness of the expansive fiscal policy is smaller. Table 7 reports the average difference between the new steady-state variations and the benchmark ones. It shows that the long-run levels of infrastructure and brain drain differ from the benchmark. However, the low-skilled and high-skilled wage rates are slightly affected by the change in ε.

Table 7: Robustness check: $\varepsilon = 0.10$

Exogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	-
	Banning inf.	0.00	0.00	0.00	-
	Taxing inf.	0.00	0.00	0.00	-
2100	Fis. policy	-10.35	0.00	-0.13	-
	Banning inf.	-7.80	-3.01	-0.05	-
	Taxing inf.	-3.79	-0.04	-0.12	-
Endogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	0.00
	Banning inf.	0.00	0.02	0.00	-0.01
	Taxing inf.	0.00	0.00	0.00	0.00
2100	Fis. policy	-13.40	0.00	-0.14	6.92
	Banning inf.	-11.16	-4.45	-0.06	2.36
	Taxing inf.	-5.78	-0.52	-0.12	11.03

This table reports for the key variables of the model $\{k, w_l, w_h, \bar{m}\}$, for each numerical experiment and for both variants of the model, the average-cross-country difference between robustness-check and benchmark-variations.

*Average-cross-country difference between robustness-check and benchmark-variations.

2.4.3.2 Smaller human capital externality

In the simulation with $\phi = 0.177$, banning informality has a smaller effect on the economy. Table 8 reports the average difference between the new steady-state variations and the benchmark ones. It shows that the long-run levels of infrastructure and brain drain differ from the benchmark. Due to the complementarity between low-skilled and high-skilled workers, reducing ϕ decreases the long-run change in the low-skilled wage rate. For the same reason the contraction of brain drain rates would be stronger. However, the trajectory of the other variables are very similar to the benchmark ones.

Table 8: Robustness check: $\phi = 0.177$

Exogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	-
	Banning inf.	0.00	0.00	0.00	-
	Taxing inf.	0.00	0.00	0.00	-
2100	Fis. policy	4.69	0.00	0.05	-
	Banning inf.	18.53	6.75	0.12	-
	Taxing inf.	2.33	0.10	0.07	-
Endogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	0.45
	Banning inf.	-0.07	4.99	0.07	-6.87
	Taxing inf.	0.00	0.04	0.02	-1.43
2100	Fis. policy	6.75	0.27	0.06	-5.63
	Banning inf.	17.89	6.57	0.07	-6.45
	Taxing inf.	4.90	1.11	0.08	-6.94

This table reports for the key variables of the model $\{k, w_l, w_h, \bar{m}\}$, for each numerical experiment and for both variants of the model, the average-cross-country difference between robustness-check and benchmark-variations.

*Average-cross-country difference between robustness-check and benchmark-variations.

2.4.3.3 Greater differential fertility

In the simulation with $n = 0.705$, the number of high-skilled workers increases over time relative to the benchmark. Table 9 reports the average difference between the new steady-state variations and the benchmark ones. It shows that results are very similar to those of the benchmark.

Table 9: Robustness check: $n = 0.705$

Exogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	-
	Banning inf.	0.00	0.00	0.00	-
	Taxing inf.	0.00	0.00	0.00	-
2100	Fis. policy	0.00	0.00	0.00	-
	Banning inf.	0.00	0.00	0.00	-
	Taxing inf.	0.00	0.00	0.00	-
Endogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	0.00
	Banning inf.	0.02	-0.22	0.00	3.21
	Taxing inf.	0.00	0.00	0.00	0.00
2100	Fis. policy	0.05	0.00	0.00	-0.01
	Banning inf.	0.11	0.20	0.00	3.20
	Taxing inf.	-0.01	-0.01	0.00	0.50

This table reports for the key variables of the model $\{k, w_l, w_h, \bar{m}\}$, for each numerical experiment and for both variants of the model, the average-cross-country difference between robustness-check and benchmark-variations.

*Average-cross-country difference between robustness-check and benchmark-variations.

2.4.3.4 Infrastructure externality in the informal sector

Finally, I now consider that the productivity of informal firms is also affected by the stock of public infrastructure per worker. I assume that the elasticity in the informal sector, $\underline{\varepsilon}$, is equal to 0.07. Hence, production in the informal economy (previously governed by Eq. (30)) is now given by

$$Y_{i,t} = BL_{i,t}k_t^{\underline{\varepsilon}},$$

This hypothesis changes the properties of the model. However, as Table 10 shows, the long-run effects are almost identical to those obtained in the benchmark model.

Table 10: Robustness Check: $\underline{\varepsilon} = 0.07$

Exogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	-
	Banning inf.	0.00	0.00	0.00	-
	Taxing inf.	0.00	0.00	0.00	-
2100	Fis. policy	-5.23	3.47	-0.07	-
	Banning inf.	0.00	0.00	0.00	-
	Taxing inf.	14.02	7.17	-0.04	-
Endogenous Brain Drain					
	Counterfactual	$\%\triangle k$ *	$\%\triangle w_l$ *	$\%\triangle w_h$ *	$\%\triangle \bar{m}$ *
2025	Fis. policy	0.00	0.00	0.00	0.00
	Banning inf.	0.00	0.00	0.00	0.00
	Taxing inf.	0.00	-0.01	0.00	0.00
2100	Fis. policy	-7.05	3.60	-0.07	3.62
	Banning inf.	0.00	0.00	0.00	0.00
	Taxing inf.	12.50	6.73	-0.04	4.75

This table reports for the key variables of the model $\{k, w_l, w_h, \bar{m}\}$, for each numerical experiment and for both variants of the model, the average-cross-country difference between robustness-check and benchmark-variations.

*Average-cross-country difference between robustness-check and benchmark-variations.

2.5 Conclusions

In this paper, I develop a stylized model that highlights the dynamic interdependencies between infrastructure accumulation, brain drain and the size of the informal sector. I first distinguish between two possible equilibrium regimes: the formal regime (all economic activities are formal and taxable) and the informal regime (part of the low-skilled labor force is employed in the non-taxable, informal economy). The equilibrium regime depends on initial the levels of infrastructure and human capital, as well as on country characteristics (such as the relative productivity of the informal sector, openness to migration, education policy, etc.). Assuming developing countries are in the informal regime, I study the effect of expansive fiscal policies designed to increase the level of infrastructure per worker. Depending on two simple conditions on the parameters, an increase in the taxation of formal workers boosts or deteriorates the level of infrastructure and the income of high-skilled workers.

Then, a calibration strategy is used to match country-specific observations, i.e. data on the size of the informal employment, on formal GDP, on skill premia and on emigration flows. The calibrated model is then used to simulate the effects of various policy experiments in 60 developing countries. As a first thought experiment, I first simulate the effect of a full ban of the informal sector. This forces a regime switching which is beneficial for the high-skilled, but detrimental for the low-skilled workers. The latter face tremendous wage losses in the short-run, and these losses usually persist in the long-run. My results show that informality is responsible for huge losses in public infrastructure. Once I consider endogenous brain drain I also find that informality explains larger brain drain rates, in some countries even by a factor of two. In spite of the larger infrastructure-stock the adverse effect prevail even in the long run, average income decreases in most of the countries. The second experiment consists in taxing informal and formal activities at the same rate. This reform has sizable impact on both infrastructure and brain drain without worsening too much the welfare of the low-skilled. Long-run gains may accrue to low-skilled workers if and only if the economy switches to the formal regime, something that the model predicts for a few countries only. These results confirm that a large informal sector slows down the accumulation of infrastructure and human capital accumulation, while protecting the low-skilled from extreme poverty.

The third experiment consists in increasing the tax rate in the formal sector. This policy has adverse effects in the short-run, while inducing large gains in the long-run. These short- and long-run effects are amplified when brain drain is endogenous, they are also greater where the initial level of infrastructure is low and the brain drain is large. High-skilled workers are unambiguously better off whereas low-skilled workers are unaffected, the welfare of low-skilled can change only after a regime switching, and for this policy experiment none of the countries considered switch regime.

It is worth noticing that my model disregards some ingredients. First, it disregards the possibility that developing countries finance infrastructure by taking loans on the international capital market. The reasons are twofold: developing countries have not complete access to the international capital market and, in most cases, these resources are not employed to finance infrastructure projects. Second, It does not consider the role of international aid in the financing of public infrastructure. This is because it is difficult to distinguish the part of international aid that goes directly to individuals from the part invested in infrastructure or used in corruption.[40] Finally, my model considers the tax rate as exogenous. Exploiting tools developed in the political economy literature allows endogenizing taxation. These extensions are left for further research.

[40]It is easy to guess the implications of using aid. Financing new infrastructure with aid unambiguously decreases the brain drain and the size of the informal sector. If the amount of aid does not induce a regime switching, the welfare of the low-skilled is not affected.

2.6 Appendix

Section 2.6.1 of the appendix provides equations and proofs recalled in the theoretical part of the paper. Section 2.6.3 provides tables and equations recalled in the quantitative part of this study.

2.6.1 Technical Appendix

Subsection 2.6.1.1 provides the equation which defines infrastructure and skill ratio loci for the model with exogenous brain drain. It also provides the qualitative proof of the steady state stability for the exogenous brain drain case. Subsection 2.6.1.2 provides the proofs of the proposition stated in Section 2.3.8 of the paper. Subsection 2.6.1.3 characterizes the phase diagram for the model with endogenous brain drain. Subsection 2.6.1.4 provides the complete proof of proposition 9. Finally Subsection 2.6.2 determines the optimal tax rate for the model with exogenous brain drain under the formal regime.

2.6.1.1 Characterization of the Phase Diagram. Exogenous Brain Drain.

I first determine the skill ratio steady state which also coincides with the skill ratio loci in the space (k_t, z_t). It suffices to set $(z_{t+1} = z_t)$ in Eq. (38) and then to solve for z_t:

$$z_{ss} = \frac{(1-\bar{m})\, q}{(1-q)\,(1-\underline{m}) - n\,(1-\bar{m})}. \tag{49}$$

As a second step I determine the infrastructure loci in the space (k_t, z_t). For the formal regime setting $(k_{t+1} = k_t)$ w.r.t. Eq. (41) gives:

$$k_t = \left(\frac{\tau A_0 z_t^{\phi+\alpha}}{n_h\,(1-\bar{m})\, z_t + \Theta}\right)^{\frac{1}{1-\varepsilon}} = \varphi\,(z_t)\,. \tag{50}$$

I obtain a similar equation for the informal regime applying the condition $(k_{t+1} = k_t)$ w.r.t. Eq. (42):

$$k_t = \left(\frac{\tau A_0 \left(\Psi^{\frac{\phi+\alpha-1}{\alpha+\phi}}\right) z_t}{n_h\,(1-\bar{m})\, z_t + \Theta}\right)^{\frac{\alpha+\phi}{\alpha+\phi-\varepsilon}} = \xi\,(z_t)\,. \tag{51}$$

I prove that Eq. (50) and Eq. (51) cross each other at the informality frontier setting z_t equal to the RHS of Eq. (35) in both Eqs. (50) and (51). Collecting for z_t I obtain

$$z_t^{-\frac{\phi+\alpha}{\varepsilon}}\,\Gamma^{-1} = \Psi^{-\frac{1}{\varepsilon}}\tau A_0,$$

which proves that both equations that define the infrastructure loci in the space (k_t, z_t) cross the informality frontier at the same point.

By replacing z_t with z_{ss} in Eq. (50) and Eq. (51) the steady state level of infrastructure, depending on the prevailing economic regime, is determined:

- Infrastructure Steady State, formal regime:

$$k^*_{for} = \left(\frac{\tau A_0 \left(z_{ss} \right)^{\phi+\alpha}}{n_h \left(1-\bar{m}\right) z_{ss} + \Theta} \right)^{\frac{1}{1-\varepsilon}}. \tag{52}$$

- Infrastructure Steady State, informal regime:

$$k^*_{inf} = \left(\frac{\tau A_0 \left(\Psi^{\frac{\phi+\alpha-1}{\alpha+\phi}} \right) z_{ss}}{n_h \left(1-\bar{m}\right) z^{ss} + \Theta} \right)^{\frac{\alpha+\phi}{\alpha+\phi-\varepsilon}}. \tag{53}$$

Phase Diagram Here I determine the direction of change for both z_t and k_t around the steady state. Section 2.3.7 already proved the uniqueness and the stability of the steady state. Additionally, this paragraph also determines the direction field around the steady state. I first consider Eq. (38), then

$$z_{t+1} - z_t > 0 \longleftrightarrow \frac{\left(1-\overline{m}\right)\left(nz_t + q\right)}{\left(1-q\right)\left(1-\underline{m}\right)} - z_t > 0,$$

which is equivalent to

$$z_{t+1} - z_t > 0 \longleftrightarrow z_t < \frac{\left(1-\bar{m}\right) q}{\left(1-q\right)\left(1-\underline{m}\right) - n\left(1-\bar{m}\right)} = z_{ss}.$$

The next step is to consider the infrastructure law of motion, around the steady state. I start with the informal regime

$$k_{t+1} - k_t > 0 \longleftrightarrow \frac{\tau A_0 z_{f,t}^{(\alpha+\phi-1)} k_t^{\varepsilon} z_t}{n_h \left(1-\overline{m}\right) z_t + \Theta} - k_t > 0$$

Exploiting Eq. (35), which sets $z_{f,t}$, and then solving for k_t

$$k_{t+1} - k_t > \longleftrightarrow \frac{\tau A_0 \left(\left(\frac{\gamma}{(1-\tau)(1-\alpha)} \right)^{\frac{\phi+\alpha-1}{\alpha+\phi}} \right) k_t^{\frac{\varepsilon-\alpha-\phi}{\alpha+\phi}} z_t}{n_h \left(1-\overline{m}\right) z_t + \Theta} > 1,$$

I further assume that $\varepsilon < (\alpha+\phi)$. Finally I analyze the equation in a neighborhood of the steady state

$$k_{t+1} - k_t > 0 \longleftrightarrow k_t < \left(\frac{\tau A_0 \left(\Psi^{\frac{\phi+\alpha-1}{\alpha+\phi}} \right) z_{ss}}{n_h \left(1-\bar{m}\right) z^{ss} + \Theta} \right)^{\frac{\alpha+\phi}{\alpha+\phi-\varepsilon}} = k^*_{inf}.$$

Doing the same for the formal regime I have:

$$k_{t+1} - k_t > 0 \longleftrightarrow \frac{\tau A_0 z_t^{(\alpha+\phi)} k_t^{\varepsilon}}{n_h (1-\overline{m}) z_t + n_h (1-\overline{m}) z_t + \Theta} - k_t > 0$$

Solving for k_t and recalling the assumption made on ε, namely $\varepsilon < 1$, it follows:

$$k_{t+1} - k_t \leftrightarrows k_t < \left(\frac{\tau A_0 z_{ss}^{\phi+\alpha}}{n_h (1-\bar{m}) z^{ss} + \Theta} \right)^{\frac{1}{1-\varepsilon}} = k^*_{for}$$

Consequently, the directions field suggest the steady-state stability. Further, this stability is irrespective of the prevailing economic regime.

2.6.1.2 Fiscal Policy

Proposition 7

Proof.

I start considering Eq. (41), which defines infrastructure accumulation for the formal regime. Clearly an increase in the tax rate makes larger the RHS of Eq. (41). Then, a larger tax rate will make bigger the amount of infrastructure in the next period, assuming that the economy does not switch to the informal regime. The same does not hold under the informal regime, in such a case after a tax increase some low skilled workers will find profitable to join the informal sector thus reducing the tax base. By computing the derivative of the RHS of Eq. (42) for the tax rate, τ, I obtain:

$$\frac{dk_{t+1}}{d\tau} = \frac{A_0 z_t k_t^{\frac{\varepsilon}{\alpha+\phi}}}{\Gamma} * \left(\Psi^{\frac{\phi+\alpha-1}{\alpha+\phi}} \left(1 + \frac{\tau \left(\frac{\phi+\alpha-1}{\alpha+\phi} \right)}{1-\tau} \right) \right),$$

the first term of the RHS is clearly positive. Hence I focus on the second one and after collecting for the tax rate I obtain:

$$\Psi^{\frac{\phi+\alpha-1}{\alpha+\phi}} \left(\frac{1 - \tau \left(\frac{1}{\alpha+\phi} \right)}{1-\tau} \right),$$

the first term, Ψ, is always positive whereas the second one is not negative if and only if the condition stated in Eq. (44) holds.

■

Proposition 8

Proof.

I start considering Eq. (28) for period $t+1$. In the case of no regime switching Eq. (42) determines the stock of infrastructure, after the tax increase. Computing the derivative of $w_{h,t+1}$ with respect to the tax rate, τ, I obtain:

$$\frac{\varepsilon}{\alpha+\phi} \left(\tau^{-1} \right) - \frac{(1-\phi-\alpha)\varepsilon + (\alpha+\phi)}{(\alpha+\phi)^2} (1-\tau)^{-1} > 0,$$

the disequation above reduces to Eq. (45). The second case considers a regime switching, from the informal to the formal regime. In this case, Eq. (41) determines infrastructure on the high-skilled wage equation for period $t+1$. Applying the same procedure used for the no regime switching case, I obtain the second threshold stated in proposition 8.

■

2.6.1.3 Characterization of the Phase Diagram. Endogenous Brain Drain

I start providing the equations which characterize the law of motions of both infrastructure and skill ratio. For the skill ratio law of motion I take Eq. (38) and substitute into it the exogenous high skilled migration rate, $\bar{m}$, with the one defined by Eq. (46). It follows

$$z_{t+1} = \frac{(1-\bar{m}_{t+1})(nz_t + q)}{(1-\underline{m})(1-q)}, \tag{54}$$

the equation above implies the following:

$$\text{formal regime } \bar{m}_{t+1} = f(z_t, k),$$
$$\text{informal regime } \bar{m}_{t+1} = g(k_t).$$

Consequently, the equation which determines the skill ratio law of motion depends on the economy regime. Eq. (54) also clarifies that the skill ratio is not a predetermined variable anymore.

It remains to provide the equations which determine the evolution of infrastructure depending on the prevailing regime. Plugging Eq. (46) into the infrastructure law of motions obtained for the exogenous high skilled migration rate case allows me to obtain the law of motions for the endogenous migration case.

- Infrastructure law of motion:

$$k_{t+1} = \frac{\tau A_0 z_{f,t}^{\phi+\alpha-1} k_t^{\varepsilon} z_t}{(1-\bar{m}_{t+1})(z_t n_h + n_l q) + n_l((1-\underline{m})(1-q))} \tag{55}$$

where in Eq. (55), as for the skill ratio law of motion, both $z_{f,t}$ and $\bar{m}_{t+1}$ depends on the economy regime. Applying to Eq. (54) the condition ($z_{t+1} = z_t$), and considering separately for the formal and the informal regime, I obtain:

- Skill ratio loci, Formal Region

$$k_{t+1} = \left(\frac{\Lambda}{(1-\tau)\alpha A_0 \left(q z_t^{\alpha+\phi-2} + z_t^{\alpha+\phi-1} (n - (1-q)(1-\underline{m})) \right)} \right)^{\frac{1}{\varepsilon}} = \lambda(z_t). \tag{56}$$

- Skill ratio loci, Informal Region

$$k = \left(\frac{\Lambda}{(1-\tau)\,\alpha A_0\,(B)^{\frac{\alpha+\phi-1}{\alpha+\phi}}\left(qz_t^{-1} + (n-(1-q)(1-\underline{m}))\right)} \right)^{\frac{\alpha+\phi}{\varepsilon}} = \gamma(z_t)\,, \tag{57}$$

where

$$\Lambda = w_t\,(1-x_t)\,(1-q)\,(1-\underline{m})\,.$$

The skill ratio loci can be drawn in the space (k_{t+1}, z_t). The next step consists in obtaining the infrastructure loci. Before showing the equation which define the infrastructure loci I provide, for the sake of clearness, the equation which characterize the fraction of stayers for the formal regime.

$$(1-\bar{m}_{t,f}) = \frac{(1-\tau)\,\alpha A_0 z_t^{\alpha+\phi-1} k_t^{\varepsilon}}{w_t\,(1-x_t) + (1-\tau)\,\alpha A_0 z_t^{\alpha+\phi-1} k_t^{\varepsilon}},$$

The amount of stayers is a function of both infrastructure and the skill ratio, hence it is not a predetermined variable anymore. Applying to Eq. (55) the condition $(k_{t+1} = k_t)$, separately the formal and the informal regime, I obtain:

- Infrastructure loci, Formal Region

$$n_l\,((1-\underline{m})\,(1-q))\,k_t + (1-\bar{m}_{t,f})\,k_t * (n_h z_t + n_l q) - \tau A_0 z_t^{\phi+\alpha} k_t^{\varepsilon} = 0. \tag{58}$$

- Infrastructure loci, Informal Region

$$\left(\frac{(1-\tau)\,\alpha A_0 \left(\Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}}\right) k_t}{w_t\,(1-x_t) + (1-\tau)\,\alpha A_0 \left(\Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}}\right) k_t^{\frac{\varepsilon}{\alpha+\phi}}} \right) (n_h z_t + n_l q) + \tag{59}$$

$$\left(k_t^{\frac{\alpha+\phi-\varepsilon}{\alpha+\phi}}\, n_l\,((1-\underline{m})\,(1-q)) \right) = \tau A_0 \Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}} z_t.$$

The comparison of Eq. (58) with Eq. (59) reveals that the infrastructure loci is a function of both z_t and z_{t+1} under the formal regime, while the loci for the informal regime can be drawn in the space $\{k_{t+1}, z_t\}$.

2.6.1.4 Proof of Proposition 9.

In the following proposition 9 is proved.

Proof.

I first prove the part of the statement which considers the informal regime. Take Eq. (55) for period t

$$k_t = \frac{\tau Y_{f,t-1}}{\left(\left(1-\bar{m}_{t,i}\right)\left(n_h H_{t-1} + q n_l L_{t-1}\right)\right) + n_l\left(1-\underline{m}\right)\left(1-q\right)L_{t-1}},$$

by plugging the value of k_t defined by the equation above into Eq. (46) and also assuming that the economy is under the informal regime the equation defining the brain drain level is obtained:

$$\bar{m}_{t,i} = \frac{w_t^*}{w_t^* + (1-\tau)\,\alpha A_0 \Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}} \left(k_t\right)^{\frac{\varepsilon}{\alpha+\phi}}} = f\left(\overline{m}_{t,i}\right).$$

An equilibrium high skilled migration rate should should equalize the LHS and the RHS of the equation above. Namely, I am looking for a fixed point, the one at which a 45 degree line crosses the function defined by the RHS of the above equation. The next step is to prove that the above equation has one solution and that it is unique. Let consider the limits of $f\left(\overline{m}_{t,i}\right)$ first as $\overline{m}_{t,i}$ approaches to 0 and secondly as $\overline{m}_{t,i}$ approaches to 1. I obtain

$$\underline{lim}_{\overline{m}_{t,i}\to 0}\; f\left(\bar{m}_t\right) = \frac{w_t^*}{w_t^* + (1-\tau)\,\alpha A_0 \Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}} \left(\underline{lim}_{\overline{m}_{t,i}\to 0}\; k_t\right)^{\frac{\varepsilon}{\alpha+\phi}}} =< 1.$$

The disequation above holds because the first component of the second term appearing in the denominator is always positive, namely:

$$(1-\tau)\,\alpha A_0 \Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}} > 0,$$

Proving that $\left(\underline{lim}_{\overline{m}_{t,i}\to 0}\; k_t\right)$ is equal to:

$$\underline{lim}_{\overline{m}_{t,i}\to 0}\; k_t = \frac{\tau Y_{f,t-1}}{\left(\left(n_h H_{t-1} + q n_l L_{t-1}\right)\right) + n_l\left(1-\underline{m}\right)\left(1-q\right)L_{t-1}} > 0,$$

makes evident that as the brain drain approaches to zero the RHS gets a value between (0 1). Let consider the other border case, namely as $\overline{m}_{t,i}$ approaches to 1. It holds that:

$$\underline{lim}_{\overline{m}_{t,i}\to 1}\; f\left(\bar{m}_t\right) = \frac{w_t^*}{w_t^* + (1-\tau)\,\alpha A_0 \Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}} \left(\underline{lim}_{\overline{m}_{t,i}\to 1}\; k_t\right)^{\frac{\varepsilon}{\alpha+\phi}}} =< lim_{\bar{m}_t\to 0} f\left(\bar{m}_t\right) < 1.$$

The components which determine the denominator of the equation defining infrastructure accumulation satisfy the following:

$$\left(\left(n_h H_{t-1} + q n_l L_{t-1}\right)\right) + n_l\left(1-\underline{m}\right)\left(1-q\right)L_{t-1} > n_l\left(1-\underline{m}\right)\left(1-q\right)L_{t-1},$$

Consequently:

$$\lim_{\overline{m}_{t,i\to 1}} k_t = k_t = \frac{\tau Y_{f,t-1}}{n_l\left(1-\underline{m}\right)\left(1-q\right)L_{t-1}} > \lim_{\overline{m}_{t,i\to 0}} k_t$$

Both limits are lower than 1 and the second one is lower than the first one. Having that Eq. (46) is clearly continuous I eventually prove that $f\left(\overline{m}_{t,i}\right)$ crosses at least one time the 45 degree line. Proving that $f\left(\overline{m}_{t,i}\right)$ is always decreasing in the interval [0 1] is enough for uniqueness.

$$\frac{df\left(\overline{m}_{t,i}\right)}{d\overline{m}_{t,i}} = \frac{-\frac{\varepsilon}{\alpha+\phi}w_t^*\left(1-\tau\right)\alpha A_0\Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}}\left(k_t\right)^{\frac{\varepsilon}{\alpha+\phi}}}{\left(w_t^*+\left(1-\tau\right)\alpha A_0\Psi^{\frac{\alpha+\phi-1}{\alpha+\phi}}\left(k_t\right)^{\frac{\varepsilon}{\alpha+\phi}}\right)^2} *$$

$$\frac{\left(n_h H_{-1}+q n_l L_{-1}\right)}{\left(\left(\left(1-\bar{m}_{i,t}\right)\left(n_h H_{-1}+q n_l L_{-1}\right)\right)+n_l\left(1-\underline{m}\right)\left(1-q\right)\right)}$$

The equation above is clearly negative, and this is enough to show the uniqueness of the equilibrium HS migration rate under for the informal regime. It remains to analyze the formal regime, thereby $z_{f,t}$, the skill ratio in the formal sector is now equal to the skill ratio in the whole economy, z_t.

$$z_t = \frac{\left(1-\bar{m}_{t,f}\right)\left(nz_{-1}+q\right)}{\left(1-q\right)\left(1-\underline{m}\right)}.$$

It follows that the equilibrium brain drain for the formal regime must satisfy the following equation:

$$\bar{m}_{t,f} = \frac{w_t^*}{w_t^*+\left(1-\tau\right)\alpha A_0\left(z_t\right)^{\alpha+\phi-1}\left(k_t\right)^{\varepsilon}} = f\left(\overline{m}_{t,f}\right). \tag{60}$$

As done for the informal regime case, let consider the limit of the RHS of the above equation when the high skilled emigration rate approaches to both 0 and 1. The first limit can be easily computed:

$$\lim_{\overline{m}_{t,f\to 1}} f\left(\bar{m}_t\right) = \frac{w_t^*}{w_t^*+\left(1-\tau\right)\alpha A_0\left(\lim_{\overline{m}_{t,f\to 0}} z_t\right)^{\alpha+\phi-1}\left(\lim_{\overline{m}_{t,f\to 0}} k_t\right)^{\varepsilon}} = C < 1.$$

The limit of $f\left(\overline{m}_{t,f}\right)$ as m_t approaches 1 is not as straightforward as it was for the informal regime. I determine it exploiting the assumption that $\alpha+\phi<1$. I begin determining the limit of z_t as $\overline{m}_{t,f\to 1}$approaches to 1

$$\lim_{\overline{m}_{t,f\to 1}} z_t = \left(\frac{\left(1-\bar{m}_{t,f}\right)\left(nz_{t-1}+q\right)}{\left(1-q\right)\left(1-\underline{m}\right)}\right)^{\alpha+\phi-1},$$

the limit above is an undetermined form which can be solved exploiting the following substitution

$$e^{(\alpha+\phi-1)ln\left(\frac{\left(1-m_{t,f}\right)\left(nz_{t-1}+q\right)}{(1-q)(1-\underline{m})}\right)} = +\infty.$$

The result reported above holds if and only if $\alpha + \phi < 1$. Exploiting the last result it is easy to recognize that

$$\lim_{\overline{m}_{t,f}\to 1} f(\bar{m}_t) = \frac{w_t^*}{w_t^* + \infty} = 0.$$

The function goes from a number lower than 1 to zero in the interval [0 1]. The next step is to determine the derivative of Eq. (60) with respect to $\overline{m}_{t,i}$

$$\frac{df(\overline{m}_{t,i})}{\overline{m}_{t,i}} = \frac{-(1-\tau)\alpha A_0(\alpha+\phi-1)\left(\frac{nz_{-1}+q}{(1-q)(1-\underline{m})}\right)\left(\frac{(1-m_{t,f})\frac{(nz_{-1}+q)}{}}{(1-q)(1-\underline{m})}\right)^{\alpha+\phi-2}(k_t)^{\varepsilon}}{\left(w_t^* + (1-\tau)\alpha A_0(z_t)^{\alpha+\phi-1}(k_t)^{\varepsilon}\right)^2}$$

$$\frac{-\varepsilon\left((1-\tau)\alpha A_0\left(\frac{(1-m_{t,f})nz_{-1}+q}{(1-q)(1-\underline{m})}\right)^{\alpha+\phi-1}\right)(k_t)^{\varepsilon}\frac{(n_h Ht_{-1}+qn_l L_{t-1})}{(((1-m_{t,f})(n_h Ht_{-1}+qn_l L_{t-1}))+n_l(1-\underline{m})(1-q)L_{-1})}}{\left(w_t^* + (1-\tau)\alpha A_0(z_t)^{\alpha+\phi-1}(k_t)^{\varepsilon}\right)^2}.$$

In such a case the derivative is made up by two components. The second is always negative while the first one is negative if $\alpha + \phi < 1$, otherwise the sign is ambiguous. This proofs the uniqueness when the latter condition on parameters holds.

I complete the proof showing that once the condition on $\alpha + \phi$ gets relaxed multiplicity of equilibrium may arise.

Applying the same substitution done for the case analyzed before, but assuming $\alpha + \phi > 1$ I obtain

$$e^{(\alpha+\phi-1)ln\left(\frac{(1-m_{t,j})(nz_{t-1}+q)}{(1-q)(1-\underline{m})}\right)} = 0$$

which implies

$$\lim_{\overline{m}_{t,f}\to 1} f(\bar{m}_t) = \frac{w_t^*}{w_t^*} = 1$$

Under the formal regime, if $\alpha + \phi > 1$, it follows that an high skilled migration rate equal to 1 is always a fixed point. The sign of the derivative is ambiguous, (see the first part of the proof), hence *there may* be multiplicity of solutions with at least one fixed point equal to $m_t = 1$.

■

2.6.2 Optimal tax rate in the Formal Regime

I determine the tax rate which maximize both low- and high-skilled wages in the formal regime for the model with exogenous brain drain. I define the Bellman equation as following:

$$W(k_t) = ln((w_{h,t}(k_t))H_t + (w_{h,t}(k_t))L_t) + \beta W(k_{t+1}).$$

Eq. (42) defines the law of motion of infrastructure.

I guess that the value function has the following form

$$W(k_t) = E + F(ln(k_t)).$$

Exploiting the equation above I obtain

$$k_{t+1} = \frac{A_0 z_t^{\alpha+\phi} k_t^{\varepsilon} \beta F}{\Gamma(1+\beta F)}$$

which implies a value of F equal to

$$F = \frac{\varepsilon}{1-\varepsilon\beta}$$

Exploiting the equation above and Eq. (42) I obtain that the optimal tax rate is equal to $\varepsilon\beta$, the same value obtained by Glomm and Ravikumar (1994).

2.6.3 Quantitative Appendix

I first report the complete list of the countries for which I calibrated and simulated both variants of the model. Then I also report the equations recalled in Subsections 2.4.2.1, 2.4.2.2 and 2.4.2.3 of the paper.

2.6.3.1 Countries and Calibrated values

The table below report the countries' list, the relative country codes and the calibrated values for α, A_0,γ and k.

Country Code	Country	Continent	$\alpha_{2000,j}$	$A_{ss,j}$	$\gamma_{ss,j}$	$k_{ss,j}$
AGO	Angola	Africa	0,237	3453	0,31	16
BEN	Benin	Africa	0,284	10211	0,27	14
BWA	Botswana	Africa	0,270	28665	0,38	107
BFA	Burkina Faso	Africa	0,226	5615	0,29	15
CMR	Cameroon	Africa	0,204	10225	0,34	32
TCD	Chad	Africa	0,022	2442	0,31	8
ZAR	Congo, Dem. Rep. of the	Africa	0,251	4597	0,23	5
COG	Congo, Rep. of the	Africa	0,322	11889	0,31	46
CIV	Cote d'Ivoire	Africa	0,315	11406	0,29	27
ETH	Ethiopia	Africa	0,206	2619	0,25	6
GAB	Gabon	Africa	0,563	32832	0,46	145
GMB	Gambia, The	Africa	0,085	17329	0,36	21
GHA	Ghana	Africa	0,126	5791	0,35	10
GIN	Guinea	Africa	0,360	12116	0,25	16
KEN	Kenya	Africa	0,092	5333	0,35	18
LSO	Lesotho	Africa	0,075	4427	0,37	26
LBR	Liberia	Africa	0,158	1872	0,29	8
MDG	Madagascar	Africa	0,235	4308	0,27	11
MWI	Malawi	Africa	0,051	2884	0,29	7

MLI	Mali	Africa	0,045	2891	0,32	14
MRT	Mauritania	Africa	0,137	5366	0,36	26
NAM	Namibia	Africa	0,282	20092	0,38	105
NER	Niger	Africa	0,047	3166	0,29	7
NGA	Nigeria	Africa	0,236	5508	0,30	18
RWA	Rwanda	Africa	0,086	6990	0,33	13
SEN	Senegal	Africa	0,222	8568	0,31	22
SLE	Sierra Leone	Africa	0,138	3435	0,29	8
SDN	Sudan	Africa	0,143	4081	0,32	15
TZA	Tanzania	Africa	0,143	3753	0,31	13
TGO	Togo	Africa	0,142	3205	0,30	11
TUN	Tunisia	Africa	0,383	19333	0,37	69
UGA	Uganda	Africa	0,091	5118	0,34	15
ZWE	Zimbabwe	Africa	0,291	6048	0,30	26
ARM	Armenia	Asia	0,892	2804	0,58	27
CHN	China	Asia	0,050	2667	0,63	95
IND	India	Asia	0,302	4525	0,31	24
IDN	Indonesia	Asia	0,260	5619	0,33	26
KAZ	Kazakhstan	Asia	0,520	4835	0,46	53
KGZ	Kyrgyzstan	Asia	0,493	1738	0,38	15
MNG	Mongolia	Asia	0,176	4756	0,32	17
NPL	Nepal	Asia	0,364	7018	0,24	10
PAK	Pakistan	Asia	0,181	6768	0,40	21
PHL	Philippines	Asia	0,599	5088	0,39	52
LKA	Sri Lanka	Asia	0,157	4710	0,37	33
YEM	Yemen	Asia	0,214	11623	0,32	21
BGR	Bulgaria	Europe	0,602	5585	0,84	71
HRV	Croatia	Europe	0,617	24917	0,49	199
GEO	Georgia	Europe	0,469	2513	0,45	29
ROM	Romania	Europe	0,382	7653	0,40	70
RUS	Russia	Europe	0,425	4980	0,73	64
SVN	Slovenia	Europe	0,280	19878	0,90	354
BOL	Bolivia	South-Central America	0,457	7734	0,48	23
BRA	Brazil	South-Central America	0,543	31010	0,24	61
CHL	Chile	South-Central America	0,485	20591	0,49	82
COL	Colombia	South-Central America	0,557	20723	0,27	38
ECU	Ecuador	South-Central America	0,675	8646	0,45	22
SLV	El Salvador	South-Central America	0,443	15851	0,39	45
GTM	Guatemala	South-Central America	0,419	23127	0,26	44
PRY	Paraguay	South-Central America	0,313	10921	0,40	25
PER	Peru	South-Central America	0,700	10524	0,53	38

2.6.3.2 Percentage deviation increase of the infrastructure stock- exogenous brain drain case

In this subsection I report the equations recalled in Subsections 2.4.2.1, 2.4.2.2 and 2.4.2.3. These equations determine the percentage deviation of the infrastructure for each counterfactual experiment for the model with exogenous brain drain.

Removing Informality

In this case the dynamic equation which defines the accumulation of the infrastructure stock becomes the one that characterize the formal economy, see Eq. (41). I determine the equation which defines the percentage change of the infrastructure stock by considering the difference between Eq. (41) and Eq. (42) and then taking logs. After some algebra I find:

$$\frac{k_{t+1}-k_t}{k_t} = \left(\frac{\alpha+\phi-1}{1} + \frac{1-\alpha-\phi}{\alpha+\phi}\right) log\left(z_t\right) + \left(1-\alpha-\phi\right) log\left(\gamma\right) + \left(\frac{\alpha+\phi-1}{\alpha+\phi}\right)\left(\varepsilon log\left(k_t\right) + log\left(\left(1-\tau\right)\left(1-\alpha\right)\right)\right).$$

The equation above makes evident that the difference in the predicted infrastructure levels computed exploiting the baseline model for the counterfactual experiment *"Removing Informality"* are a function of $\{z_{ss}, k_{ss}, \alpha, \gamma, \tau\}$. I remind that both $\{\varepsilon, \phi\}$ do not vary across across countries.

Taxing Informality

The taxation of the informal sector workers changes the dynamic equation that determines the infrastructure-stock. Infrastructure dynamic will be determined by:

$$k_{t+1} = \frac{\tau A_0 \left(\frac{\gamma}{1-\alpha}\right)^{\frac{\alpha+\phi-1}{\alpha+\phi}} k_t^{\frac{\varepsilon}{\alpha+\phi}} z_t}{n_h(1-\overline{m})z_t+\Theta} + \frac{\tau A_0 \gamma}{n_h(1-\overline{m})z_t+\Theta}\left(1-\frac{z_t}{z^*_{f,t}}\right)$$

where $z^*_{f,t}$ does not depend on the tax rate anymore. It follows that the percentage change in the infrastructure stock with respect its steady-state level is a function of $\{z_{ss}, k_{ss}, \alpha, \gamma, \tau\}$.

Fiscal Policy

In this case it suffices to consider the difference between Eq. (41) considered with a tax rate larger of one percentage point and the the baseline one. After taking logs I obtain:

$$\frac{k_{t+1}-k_t}{k_t} = log\left(1+\frac{0.01}{\tau}\right) + \left(\frac{\alpha+\phi-1}{\alpha+\phi}\right) log\left(\frac{1}{1-\frac{0.01}{1-\tau}}\right)$$

It follows that the percentage change in the infrastructure stocks reported in Section 2.4.2.3, for the model with exogenous brain drain, are a function only of $\{\alpha, \tau\}$. I remind that both $\{\varepsilon, \phi\}$ do not vary across across countries.

3

The role of Fees in foreign education: evidence from Italy and the UK.

This paper is a joint work with Prof. Dr. Michel Beine and Prof. Dr. Lionel Ragot

Abstract

This paper studies the determinants of international students mobility at the university level, focusing specifically on the role of tuition fees. We derive a gravity model based on a Random Utility Maximization model of location choice for international students. The last layer of the model is estimated using new data on students migration flows at the university level for Italy and the UK. The particular institutional setting of the two destination countries allows to control for the potential endogeneity of tuition fees. We obtain evidence for a clear and negative effect of tuition fees on international student mobility and confirm the positive impact of quality of education. The estimations find also support for an important role of additional destination-specific variables such as host capacity, expected return of education and cost of living in the vicinity of the university.

3.1 Introduction

Foreign higher education has become an increasingly important phenomenon nowadays. The degree of mobility of prospective student wishing to acquire their educational skills abroad has been constantly on the rise for more than 50 years. Large numbers of foreign students emigrating for the explicit sake of completing their graduate and postgraduate studies in renowned universities are today very usual in any country and city of most industrial countries. While there were 0.6 millions international students in 1975, this number amounted to 2.2 millions in 2008. In spite of the turmoil due to the financial crisis, the global quest for talented workers has pushed these numbers further up, with a 23% increase between 2009 and 2013 (OECD (2015)). Even if these global numbers obviously hide some uneven developments, the number of students emigrating abroad to complete their education has increased in all origin regions of the world. For more than 15 years, foreign students have represented the fastest growing category of international migrants.

The striking development of foreign education is an important economic phenomenon for the destination countries. For many developed countries like the United States, the UK, France and Australia, foreign education has become a real industry. Attracting students from abroad and charging significant tuition fees allow their universities to climb up the educational scale and in turn to act as important research institutions. Many cities in the main destination countries of foreign students favor the development of their university thus trying to take benefit from the various spillovers that these institutions generate for the public and private sector. For governments, attracting foreign students is also an important objective in the global race of quest for talented workers in which industrialized countries are engaged today. In fact, student migration might be seen as a concealed phenomenon of brain drain. Governments attract promising students and provide through foreign education the skills corresponding to their domestic labour market. By employing various schemes such as special transition visas, governments of destination countries allow those students to stay in the country and integrate more easily the national labour market. Understanding the determinants of the location choice for prospective students is therefore of utmost importance for conducting appropriate policies aiming at attracting talented international students.

This paper contributes to the literature devoted to the identification of the factors influencing the choice in terms of location made by students to complete their education abroad. In particular, we assess the importance of the various determinants of foreign students using data at the university level for two European countries, namely the UK and Italy for the academic year 2011/2012. Unlike in other European countries such as France, Belgium or Germany, the British and Italian universities display significant variation in the tuition fees across institutions, (European Commission (2012)). This in turn allows to study the role of the fees for foreign students in choosing one specific location, on top of the other institutional characteristics such as quality, host capacity, expected income and cost of living. We compile and use data of foreign student flows between (almost) all countries of the world as origins, and each university at destination of the two countries of destination under investigation. Our econometric investigation, derived from a traditional Random Utility Framework (RUM) adapted to student migration, pays special attention to the role of tuition fees. We empirically deal with the endogeneity of student fees with two proposed different solutions across the countries of destination.

We find support for a role of university quality, a result already found in some previous work, (Beine et al. (2014); Van Bouwel and Veugelers (2013)). We also find a clear role for the host capacity of the university as well as the expected return of education of the city where education is acquired, in line with the spirit of the migration model of foreign education (Rosenzweig (2008)). Regarding the role of tuition fees, we first stress the importance of dealing with endogeneity of these fees in isolating their impact on the location choice of foreign students. When dealing with that issue, we find a negative and significant effect of tuition fees on the choice of a specific university, a result new to the existing literature.

Our paper is related to the extensive literature on foreign education. At the theoretical level, as reminded by (Rosenzweig (2006, 2008)), there are first basically two complementary explanations of why students decide to go abroad to complete their higher education. The first model, from an human capital perspective, states that students go abroad because of a lack or even absence of education infrastructure in their home country. Foreign education in medicine provides lots of examples of this type of motivation. The second one, the migration model, suggests that students might favor foreign education because it raises the prospects of attractive jobs in the country (or the place) where education was obtained. As said before, this motivation is in line with the evidence that previous students tend to have easier access to the domestic labour market.[1] Our theoretical model, based on the RUM approach, integrate this type of arguments.

While the education and the migration models are about the decision to study abroad, a large part of the literature has been devoted to the location choice. Our paper definitely belongs to this strand. Most of the literature makes use of country level data and combines a multi-origin approach. Bessey (2012) focuses on foreign students in Germany, finding that the stock and the flow of students of the same nationality are positively correlated. Dreher and Poutvaara (2005) and Rosenzweig (2006) look at the determinants of foreign education in the United States. The former stresses the importance of networks Dreher and Poutvaara (2005) while the latter highlights the importance of the skill premia (Rosenzweig (2006)). Other studies combine various origins and destinations carrying out estimations in the context of a gravity model. Perkins and Neumayer (2014) consider many origin (151) and destination countries (105) over a couple of years and evaluate the role of geographic factors. Van Bouwel and Veugelers (2013) look at student migration between 18 European countries and assess the role of the university quality, evaluated through the number of institutions appearing in the most widely known international university rankings. They show that quality matters, but tend to find a positive impact of tuition fees. Beine et al. (2014) derive a gravity specification and focus on the 13 main destinations for foreign education. They estimate the role of determinants such as network, quality and fees in explaining the size of the bilateral flows of foreign students. They also find a role for quality and network. Regarding fees, while they fail to identify a negative impact of tuition fees, they show that the positive impact of fees that is obtained in "naive" regressions might be due to endogeneity.[2]

This paper aims at contributing to the literature devoted to the identification of the factors influencing the location decision of foreign students. One of main value added of the paper is that we conduct our analysis at the university level as the destination. So far, the contributions of the literature devoted to the international mobility of students have exclusively focused on factors observed at the country level. While this is important to understand the reasons of the uneven distribution of students across countries of destination, information at the country level conceals significant variation across universities of the same country. For instance, the average national quality of universities might not provide an accurate reflection of the attractiveness of the country as a provider of tertiary education. Foreign students might concentrate for instance in the upper tier of the universities of the country. If this is true, the fact that

[1]For instance, in the United States, the H1B visa is subject to a cap (65000 per year nowadays), with an additional 20000 quota for foreign students having graduated with an MBA or higher from a US University.

[2]Other interesting papers of the literature using dyadic flows include Abbott and Silles (2015), Jena and Reilly (2013), González et al. (2011) and Kahanec and Králiková (2011). Gravity models have also been used to explain student mobility between regions of the same country. See for instance Agasisti and Dal Bianco (2007) for Italy.

a country hosts many universities of relatively modest quality might not be an important factor, at least to explain inflows of foreign students to that country. This requires to make use of the information at the university level. The same applies to fees. Average level of fees might not mean anything for students since they might end up in rather good universities charging relatively high fees. To overcome this limitation, we study the role of these factors observed at the university level in a given country. While we ignore the first step in the decision making process (the choice of the destination country), we identify very precisely the various university-specific factors that lead students to choose between institutions in a given destination. Such an investigation is unique in the literature in that respect. The second related contribution is our focus on the role of tuition fees for the location choice of foreign students. The literature has failed to find a clearly negative impact of fees on the size of student inflows. Of course, failure to find a negative impact does not mean that these results are spurious per se. Indeed, fees include more than a pure cost component for prospective students. High fees obviously signal quality and a commitment of the institution to provide to the students all the necessary means to absorb the delivered learning. Students may also interpret higher tuition fees as a signal of the accountability of the education providers. Another possible explanation is that fees can be covered by grants. This is especially true for foreign students who can benefit from grants of different sources (government of the origin country, university of destination, association promoting bilateral contacts, ...). While this is not true for all students, the partial coverage of fees by grants might explain the insignificant impact that is sometimes observed, see Beine et al. (2014) for instance.

On the contrary, obtained positive impacts of fees or even zero impact might be spurious due to the high degree of endogeneity of fees. Fees are higher when universities succeed to attract a lot of students, which leads to reverse causality issues. Fees levels might be correlated to unobserved factors such as unobserved amenities in the destination countries (e.g. Australian universities might charge higher fees due to their nice environment) or by unobserved institutional factors at the country level (regulation of subsidized institutions). This calls for a causal identification accounting for the possible endogenous status of the observed fees in the econometric regression. We pay specific attention to that taking two specific approaches. For Italy, we use a classical instrumental variable (IV) approach. We instrument the tuition fees by the status of the university (private vs public). For this country we also provide additional regressions including in the set of the covariates a dummy variable which captures the availability of English-speaking programs. We find that the estimate of the coefficient of the dummy variable is both positive and significant, while the baseline results only slightly change. Private institutions tend to charge higher fees to cover specific costs and to offset the lower degree of public subsidies, compared to public institutions. Our exclusion restriction assumes that students have no particular preferences for private vs public institutions beyond the costs and the quality of education (for which we control for in the regression) when choosing a specific university. For the UK, such an instrument is not possible to implement since there is no clear-cut distinction between private and public institutions. Rather than the IV strategy, we make use of the fact that British institutions faced caps on the tuition fees that they could charge to natives and European students. These caps are almost all binding in the sense that all universities put tuition fees level equal to the maximum allowed by the law. Importantly, the cap did not apply for first degree student originating from EU enrolled in Scottish universities. The Scottish authorities indeed cover tuition fees for Scottish and EU students. By restricting our investigation to students coming from EU countries, we can estimate the impact of fees in a context in which endogeneity is clearly absent. The estimates of our model generate interesting findings. To the best of our knowledge this paper is the first one devoting a specific attention to the effect of fees.

Finally, we look carefully at the technical and econometric details of the empirical investigation. First, we use a micro-founded model based on the RUM approach, which facilitates the choice of the specification. While this has been advocated by many authors in the general literature devoted to economic international migration (Beine et al. (2015, 2011); Grogger and Hanson (2011)), the use of a theoretically consistent specification in the student literature has been very limited. Second, given the high prevalence of zero bilateral flows in the data set, the use of Poisson ML estimators is much favored (Santos Silva and Tenreyro (2006)) in order to provide unbiased estimates of the key variables. Furthermore, we combine Poisson estimations with the use of instrumental variable as to account the possible endogeneity of tuition fees.

The paper is structured as follows. Section 3.2 develops a small theoretical model useful to derive the estimable gravity equations. Section 3.3 is devoted to the exposition and clarification of the data that we use in the econometric estimations. Section 3.4 presents the estimable gravity equations and discusses the main econometric issues, including the treatment of the zeros for the dependent variable and the way we deal with endogeneity issues. Section 3.5 presents the results while section 3.6 concludes.

3.2 Theoretical background

This section derives a tractable students' migration equation from a simple theoretical model based on the human capital literature. Education is considered as an investment in future earnings and employment (see Becker (1975)) for rational students who seek to maximize their lifetime earnings. The quality of education may affect their expected returns to education (Card and Krueger (1992)). The prospective student migrant compares the present value of future earnings if he/she decides to study at home to the one obtained from studying abroad. If the increase in the present value of the future income is greater than the cost of migrating as well as other education costs, students will move to the University yielding the highest net present value. However studying at home does not rule out to migrate after graduation for the sake of working in another country. Similarly, studying abroad facilitates access to the local labor market, but does not preclude the possibility of returning home or migrating, after graduation, to a third country. Student's location decisions before and after education are not independent but are taken sequentially; first the educational location and then the working location. Students form (myopic) expectations about future income by observing the current skill prices, (Freeman (1971)), and the working migrations probabilities. The relevant probabilities are (i) the probability to migrate, once the studies at home are completed; (ii) the probability of getting a job in the destination country in which schooling has been obtained; (iii) the probability of return migration and (iv) the probability to migrate to a third country.

The set of destination countries is $D = \{D_1, ..., D_{n_d}\}$ with n_d the number of destination countries and the set of origin countries is $O = \{O_1, ..., O_{n_o}\}$ with n_o the number of origin countries. Countries can be both inside D as well as inside O. The set of universities in country j is $U_j = \left\{U_{j,1}, U_{j,2}, ..., U_{j,n_j}\right\}$ with n_j the total number of universities in country j, the index j identifies the destination country. Finally, i is the index for the origin country, u labels the university and k stands for a particular student.

Let the indirect utility derived from studying in University u located in country j of student k from country i ($VS^k_{i,j,u}$) be expressed as:

$$VS^k_{i,j,u} = VS\left(A_{j,u}, CE_{j,u}, CL_{j,u}, CM_{j,u}\right) = A_u - CE_u - CL_u - CM_{i,j,u} + \epsilon_{k,j,u}, \tag{61}$$

where A_u is a vector of unpriced amenities in University u, capturing also city-of destination related amenities, CE_u the cost of education (namely the fees charged by University u to students coming from country i), CL_u the cost of living in the city of University u and $CM_{i,j,u}$ the costs of migrating from country i to country j at the specifically university u. Migration costs, $CM_{i,j,u}$ are composed of two parts, fixed costs (C_i) and variable costs ($C_{i,j,u}$). The fixed part measures the costs of moving, independently of the destination country (home-specific costs) whereas the variable part depends both on country bilateral factors (such as transportation costs, assimilation costs), and on country/city of destination bilateral factor, $C_{i,u}$, (for instance transportation costs are smaller in cities that host an airport) . The variable migration costs depends on dyadic factors such as physical distance ($d_{i,j}$), origin and destination countries' cultural and linguistic proximity such as the use of a common official language ($l_{i,j}$) or the existence of colonial links ($col_{i,j}$).[3] In line with the empirical literature, see Beine et al. (2011) , we assume that migration cost are a decreasing function of the size the network at the city of destination, $M_{i,u}$.[4] Finally, $\epsilon_{k,j,u}$ is an individual-specific random component which captures the individual-specific preference to enroll at university u located in country j. The cost function is given by:

$$CM_{i,j,u} = C_i + C_{i,j,u}\left(d_{i,j},\, l_{i,j},\, col_{i,j},\, M_{i,j,u}\right). \tag{62}$$

We assume that the migration costs, except the network component, depend only on the destination country and not on the specific location within the country. We further assume that $CM_{i,i,u} = 0$.

The indirect utility working lifetime $VW^k_{i,j,u}$ of student k coming from country i and who is a graduate of University u in country j is given by:

$$\begin{aligned} VW^k_{i,j,u} &= VW\left(A_{j,u}, CL_{j,u}, P^s, P^f, P^r, W_{j,u}, \bar{W}_i, \bar{W}_j, \bar{W}, Q_{j,u}, \bar{Q}_i, \bar{Q}_j, \bar{Q}\right) \\ &= P^s W_u + P^f\left(\bar{W}_j + S\left(Q_{j,u} - \bar{Q}_j\right)\right) + P^r\left(\bar{W}_i + S\left(Q_{j,u} - \bar{Q}_i\right)\right) \\ &\quad + \left(1 - P^s - P^f - P^r\right)\left(\bar{W} + S\left(Q_{j,u} - \bar{Q}\right)\right) + A_{j,u} - CL_{j,u} \end{aligned}$$

[3] We acknowledge that some cities, for instance the ones hosting airports, are easier to reach than others. However, for the sake of tractability we keep physical distance as a country-of-destination bilateral variable.

[4] Data on the size of the network at the city of destination layer is not available for both Italy and the UK. This leads us to omit this variable from the empirical analysis conducted in Section 3.4.

and $VW_{i,i}^{k}$ is the indirect utility working lifetime of student k born in country i and getting higher education in her/his native country.

$$\begin{aligned} VW_{i,i}^{k} &= VW\left(A_{j,u}, CL_{j,u}, P^{s}, P^{f}, W_{j,u}, \bar{W}_{i}, \bar{W}, Q_{j,u}, \bar{Q}_{i}, \bar{Q}\right) \\ &= P^{s}W_{u} + P^{f}\left(\bar{W}_{i} + S\left(Q_{j,u} - \bar{Q}_{i}\right)\right) \\ &\quad + \left(1 - P^{s} - P^{f}\right)\left(\bar{W} + S\left(Q_{j,u} - \bar{Q}\right)\right) + A_{j,u} - CL_{j,u}, \end{aligned}$$

where P^{s} is the probability to stay and work in the same area where he has studied. P^{f} is the probability of staying in the same country but none in the same area (the vicinity of University u) and P^{r} the return probability after graduation. We assume that all these probabilities are not country specific.[5] W_{u} is the expected value of earnings in area u, $\bar{W}_{i}$ the expected value of earnings based on the average (in country i) skill prices and $\bar{W}$ the expected value of earnings based on the average skill prices. $S(.)$ a premium which depends on the difference between the quality of education where the higher education has been attained $(Q_{j,u})$ and the average quality of education in the working country which we denote, abusing notation, $\bar{Q}$.[6] For the sake of simplicity, we assume a linear premium function $S\left(Q_{j,u} - \bar{Q}\right) = a\left(Q_{j,u} - \bar{Q}\right)$, where a is a parameter that captures the effect of quality of education on wages.

The intertemporal lifetime indirect utility of student k native of country i studying in University u located in country j $\left(ILV_{i,j,u}^{k}\right)$ can be further decomposed into two components:

$$ILV_{i,j,u}^{k} = \int_{0}^{T_s} e^{-\rho t} VS_{i,j,u}^{k}\left(.\right) dt + \int_{T_s}^{T} e^{-\rho t} VW_{i,j,u}^{k}\left(.\right) dt \tag{63}$$

with $\int_{0}^{T_s} e^{\rho t} VS_{i,j,u}^{k}\left(.\right) dt$ representing the studying lifetime indirect utility and $\int_{T_s}^{T} e^{\rho t} VW_{i,j,u}^{k}\left(.\right) dt$ the remaining working lifetime indirect utility. $T_s = T_k^{*} - y_k$ where T_k^{*} is the end of education age of k and y_k is the individual's age. $e^{-\rho t}$ is a discount factor with ρ the rate of time preference, T stands for a fixed retirement age. Individuals have the same rate of time preference and the same indirect utility functions.[7]

We assume that individuals expectations regarding the arguments in the two indirect utility function remain at the values observed at $t = 0$. This assumption makes $ILV_{i,j,u}^{k}$ equal to:

$$ILV_{i,j,u}^{k} = \frac{1}{\rho}\left[VS_{i,j,u}^{k}\left(.\right)\left(1 - e^{-\rho\left(T^{*} - y\right)}\right) + VW_{i,j,u}^{k}\left(.\right)\left(e^{-\rho\left(T - T^{*}\right)}\right)\right]. \tag{64}$$

[5] There are two main arguments in favor of this assumption. First, agents need to form expectations about P^{s}, P^{f} and P^{r}. To that aim, they need to rely on the available information. In that respect, there is so far no information available across a whole range of origin and destination countries. As a result, agents are more likely to form expectations based on average levels. Second, stay rates of students in a limited number of OECD countries have not been found to differ significantly, ranging from 14.7% to 29.5% (see in particular OECD, 2010, Page 45, Table I.8).

[6] By definition, this premium is not taken into account when the educational area (the vicinity of University u) will also be the working area. Also, it can be negative when the difference in quality gets a negative value.

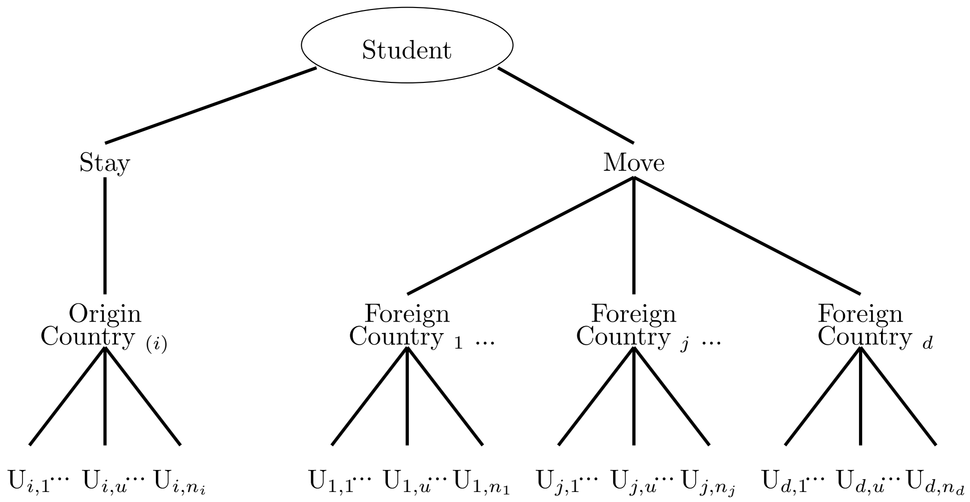
[7] In the absence of individual information in our database, we assume thereafter $\forall k\ T_k^{*} = T^{*}$ and $y_k = y$.

Therefore, the intertemporal lifetime indirect utility is a function of:

$$ILV_{i,j,u}^{k} = ILV\left(\rho, A_{j,u}, CE_{j,u}, CL_{j,u}, W_{j,u}, \bar{W}_j, Q_{j,u}, \bar{Q}_j, C_i, d_{i,j}, l_{i,j}, col_{i,j}, M_{i,j,u}\right). \quad (65)$$

A convenient way to represent the student's University (location) choice is given by a tree diagram, see Figure 21. There are 3 levels in this tree structure. In the upper-level, the student decides whether to study at home (h=*Stay*) or abroad (h=*Move*). If the choice of this upper-level is to move abroad, there is a subset of destination countries (*Foreign country 1* to *Foreign country d*) from which the student must choose its location (middle-level of the tree). This choice is trivial for the Stay branch, the origin country is the only choice. At the lower-level, the student chooses the university in which he would like to study. This lower-level consists of all the alternatives of this decision tree, denoted $u = \{U_{i,1}, \cdots, U_{d,n_d}\}$.

Figure 21: Tree diagram for student's University choice



This figure summarizes the three international-students' location choices. First they decide if to migrate or not. Conditionally to the migration choice, the student decides on which country to migrate. Finally, conditionally to the country of destination previously chosen, the student chooses on which university to enroll.

The lower-level indirect utility depends on characteristics that vary across university area. The corresponding factors are $X = \{A_{j,u}, CE_{j,u}, CL_{j,u}, W_{j,u}, Q_{j,u}, M_{i,j,u}\}$. The middle-level indirect utility depends on factors that differ across countries: $Y = \left\{\bar{W}_j, \bar{Q}_j, d_{i,j}, l_{i,j}, col_{i,j}\right\}$. The upper-level indirect utility depends on factor that vary with the choice of migrating ($h = m$) or staying ($h = s$), $Z = \{C_i, F_i\}$ (where C_i denotes the fixed part of the migration costs and F_i is a vectors of origin-specific fixed effects).

Following the random utility approach to discrete choice problems, (McFadden (1984)), the conditional probability, at the lower-level, that student k from country i chooses University u in foreign country j is defined by:

$$P_{i,u|j,h} = Prob\left[\left(ILV_{i,j,u}^{k} + \epsilon_{k,j,u}\right) > \left(ILV_{i,j,v}^{k} + \epsilon_{k,j,v}\right)\right], \qquad u \neq v \quad (66)$$

with $\epsilon_{k,u}$ being an iid extreme-value distributed random term.

At the middle-level, the conditional probability that student k coming from country i decides to study in University u^* located in foreign country j can be written as:

$$P_{i,j|h} = Prob\left[\left(ILV^k_{i,j,u^*} + \epsilon_{k,j}\right) > \left(ILV^k_{i,l,u^*} + \epsilon_{k,l,u}\right)\right], \qquad j \neq l \tag{67}$$

where u^* is the University that maximizes indirect utility in the lower-level.

At the upper-level, the unconditional (marginal) probability that student k decides to study in a foreign country j^* rather than in home country i can be written as:

$$P_{i,h} = Prob\left[\left(ILV^k_{i,j^*,u^*} + \epsilon_{k,j^*}\right) > \left(ILV^k_{i,i,u^*} + \epsilon_{k,i}\right)\right] \qquad i \neq j^*, \tag{68}$$

where u^* is the University that maximizes indirect utility in the lower-level and j^* is the foreign country that maximizes utility in the middle-level. Finally, the probability ($P_{i,j,u}$) that student k from country i decides to study in University u in foreign country j is defined as the product of these three probabilities:

$$P_{i,j,u} = P_{i,u|j,h} P_{i,j,|h} P_{i,h}. \tag{69}$$

Assuming that the random terms follow an iid extreme-value distribution, this three-stage discrete choice model can be estimated using a nested logit, (Train (2003)). We can notice that this structure is more precisely a partially degenerate nested logit, with degeneracy in the *Stay branch*, in which the origin country is the only choice. While *Move branch* distinguishes between all non origin countries. Using the non-normalized nested logit (NNNL) model (see Hunt (2000)), the probabilities are the following.

$$P_{i,u|j,h} = \frac{e^{\beta' X}}{e^{I^u(j,h)}}, \tag{70}$$

$$P_{i,j|h} = \frac{e^{\left(\alpha' Y + (1-\lambda^u) I^u(j,h)\right)}}{e^{I^j(h)}} \tag{71}$$

and

$$P_{i,h} = \frac{e^{\left(\gamma'_h Z_h + \left(1-\lambda^j\right) I^j(h)\right)}}{e^{(\gamma' Z_s + (1-\lambda^j) I^j(s))} + e^{(\gamma' Z_m + (1-\lambda^j) I^j(m))}}, \tag{72}$$

where β, α and γ denote parameters vectors and the inclusive values I^u and I^j are defined by

$$I^u(j,h) = ln\left(\sum_{u^* \in U}\left(e^{\beta' X_{i,u^*,j}}\right)\right), \tag{73}$$

$$I^j(h) = ln\left(\sum_{j^* \in D} e^{\left(\alpha' Y_{i,j^*} + (1-\lambda^u) I^u(j^*,h)\right)}\right). \tag{74}$$

The conditional probability for the degenerate branch (Stay branch), $P_{i,h|s}$, is trivially equal to 1.

The inclusive value coefficient λ^u measures the correlation among the random terms due to universities similarity within a country j, with $\lambda^u = 0$ denoting no correlation and $\lambda^u = 1$ indicating nearly identical unobserved attributes. Similarly, the inclusive value coefficient λ^j is a measure of correlation among unobserved countries related attributes.

The nested multinomial logit model defined by Eqs. (69)-(74) connects the levels of the tree outlined in Figure 21 with each other in the sense that the attributes of the lower branch alternatives influence the choice among any choice set of upper branches. In a sequential choice model, the levels of the hierarchy are unrelated.

Estimation of this nested multinomial logit model can be done by FIML (Full Information Maximum Likelihood) or by a sequential procedure.

The full estimation of the model defined by Eqs. (70-72) is in practice cumbersome for two main reasons. The first reason is technical: the nested logit estimation is computationally very demanding and has not been done in the literature using grouped data. As a result, the sequential procedure might be favored. Sequential estimation leads to consistent estimates but less efficient than FIML estimation.

The sequential estimation procedure is made of the 5 following steps:[8]

1. Estimate the parameters β by applying maximum likelihood estimation to the conditional choice model $P_{i,u|j,h}$. See Eq. (70).

2. Use the previous estimates to compute the inclusive values $I^u(j,h)$ for each (j,h) from Eq. (73).

3. Using $I^u(j,h)$ as a separate independent variable, estimate the parameters α and λ^u via maximum likelihood from the conditional choice model $P_{i,j|h}$. See Eq. (71).

4. Use the previous estimates to compute the inclusive values $I^j(s)$ and $I^j(m)$ from Eq. (74).

5. Using $I^j(h)$ as a separate variable and estimate the parameters γ and λ^j via maximum likelihood from the unconditional (marginal) choice model $P_{i,h}$. See Eq. (72).

The second reason for not estimating the full model concerns data availability. The full estimation of the model defined by Eqs. (70-72) requires the availability of data at all levels, i.e. at the origin level as well as at the two destination-specific levels including country-specific and university-specific information. Furthermore, this means that a large subset of the main destination countries of the international students should be included. The value added of this paper is that we have very complete information at the university level. Nevertheless, we have only 2 countries of destination for which such a data is available, preventing the estimation of the middle-level part. Therefore, our estimation can be seen as the first step of the sequential procedure outlined above and provide interesting information of the specific location, conditionally upon the two other choices depicted by decision tree of Figure 21.

3.3 Data and Descriptive Statistics

This section presents the data that we use to estimate Eq. (70). The section details the sources, the development of some indicators, such as the one capturing university quality, and provides descriptive

[8] Even if the estimation procedure is sequential we have shown that the nested logit model is not sequential but recursive.

statistics for each of them. Table 28 in Appendix (see Section 3.7) provides a brief summary of the data used in the econometric analysis.

3.3.1 International students flows

Our empirical analysis takes advantage of data of flows of international students from all countries of the world to Italy and UK for the academic year 2011/2012. Following Beine et al. (2014), the international students we consider are the ones who migrated exclusively for the sake of education. Those who spent either one or more semesters abroad into institutional programs, such as the ERASMUS students, do not comply with our definition of international students and are therefore excluded from the data. Two reasons lead us to exclude these students from the analysis. First, bilateral agreements constraint the student's choice in terms of location. Second, in some curricula, it may be compulsory to attend a period of study abroad.

Data on foreign students in the UK comes from the Higher Education Statistical Agency (HESA), which provides data on international students flows for 163 United Kingdom universities.[9] The statistical office of the Italian ministry of education (MIUR) provides similar information for 79 Italian higher education providers.

Table 12 reports some descriptive statistics on the number of foreign students for the two countries. United Kingdom hosts more than the 10% of the foreign students at the world level, (OECD (2015)), and represents the second most popular destination after the US. Consequently, international students represent a consistent share of students enrolled in UK higher institutions, which amounts to 13.55% of all students. The foreign students origin from 210 different countries.[10] Italy is a less popular destination for international students, who represent 3.65% of the total students' population. These students originate from 168 different countries. Figure 22 shows the distribution of the share of foreign students across universities for Italy and UK separately. Most Italian universities have a share of foreign students below the 10% with respect to their total students' population.

Table 12: Descriptive Statistics of foreign student flows (2011/2012)

	Italy	UK
Number of universities (a)	79	163
Origin countries (b)	168	210
Number of observations (axb)	13272	34230
% of zeroes**	68.64%	60.16%
Total number of students (Host capacity)* (c)	1710701	2518640
Number of foreign students* (d)	62512	341389
Foreign student in % of total students* (d/c)	3.65%	13.55%

*Numbers are computed aggregating all origin countries.
**The flow of students coming from country i and studying in university u is nil.

[9] Specifically, data is available for institutions located in England, Northern Ireland, Scotland and Wales.
[10] In the empirical part, we pay attention of not loosing the information relative to the empty corridors. The total number of observation is then equal to the number of universities multiplied by the number of origin countries.

Figure 22 shows the distribution of the share of foreign students across universities for Italy and the UK separately. It confirms that the share of foreigners is on average much larger in UK universities, with a large proportion of institutions in which foreign students represent more than 20% of the whole student population. The two UK institutions with the largest proportion of foreigners are *LSE* and *London Business School,* where the share of foreigner among students is even larger than 60%. While for Italy the average share is lower, there are still a significant number of universities for which the share is above 5%. This illustrates the importance of the phenomenon of foreign education.

Figure 22: Share of foreign students, by university

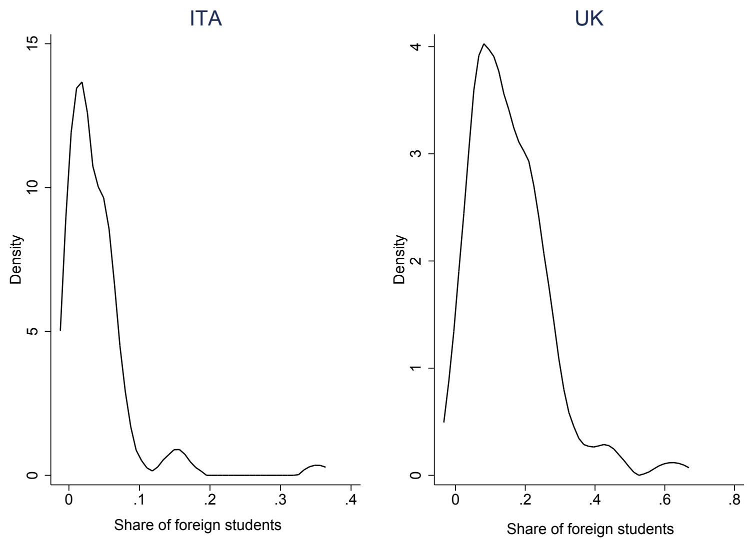


Figure 22 reports, separately for Italy and the UK, the distribution of the share of foreign students by university.

To gauge how diverse is the foreign students' population in our data, we refer to the Herfindhal index as a measure of concentration. We do that in the two dimensions: (i) across origins for each institution and (ii) across institutions for each origin country.[11] We compute this measure for both countries of destination.

Figure 23 reports the distribution of the Herfindahl index across universities. The index is small for most of the institutions, suggesting that they host foreign students coming from a wide range of origin countries. On the other hand, Figure 24 reports the distribution of the Herfindahl, but across origin countries. Specifically, for each origin country, we compute the Herfindhal index as to have an hint of how international students of the same country are split across Italian and UK universities. The figure suggests that, on average, students coming from a specific country do not tend to concentrate in a single university. Both figures illustrate that the dyadic dimension of the data is important to capture the patterns of emigration of students to both destination countries.

[11] The Herfindahl index is simply equal to the squared sum of the shares, $H_i = \sum^{J} s_{ij}^2$. In our case s_{ij} is the share of foreign students coming from country j enrolled in institution i with respect to the overall number of foreign students enrolled in institution i. We remind that the measure is comprised between $\frac{1}{n}$ (perfect diversification in terms of origins, with n being the number of origins) and 1 when the incoming population originates from a single country. Some papers measured diversity using the diversity index which is simply equal to 1 minus the Herfindahl index.

Figure 23: Herfindahl index, by university

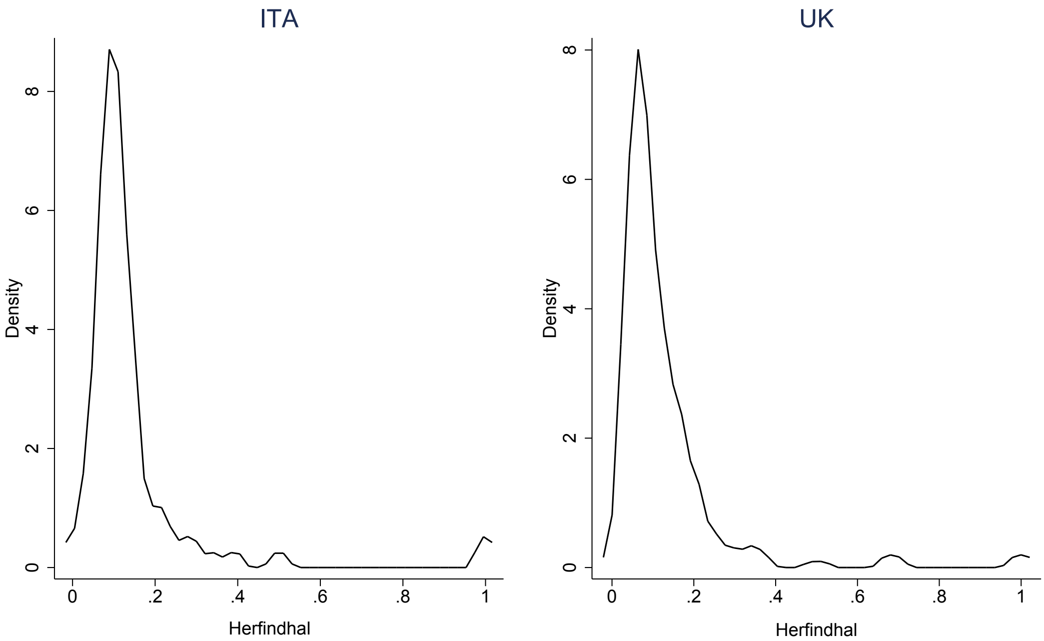


Figure 23 reports, separately for Italy and the UK, the distribution of the Herfindahl index, by University of destination.

Figure 24: Herfindahl index, by country

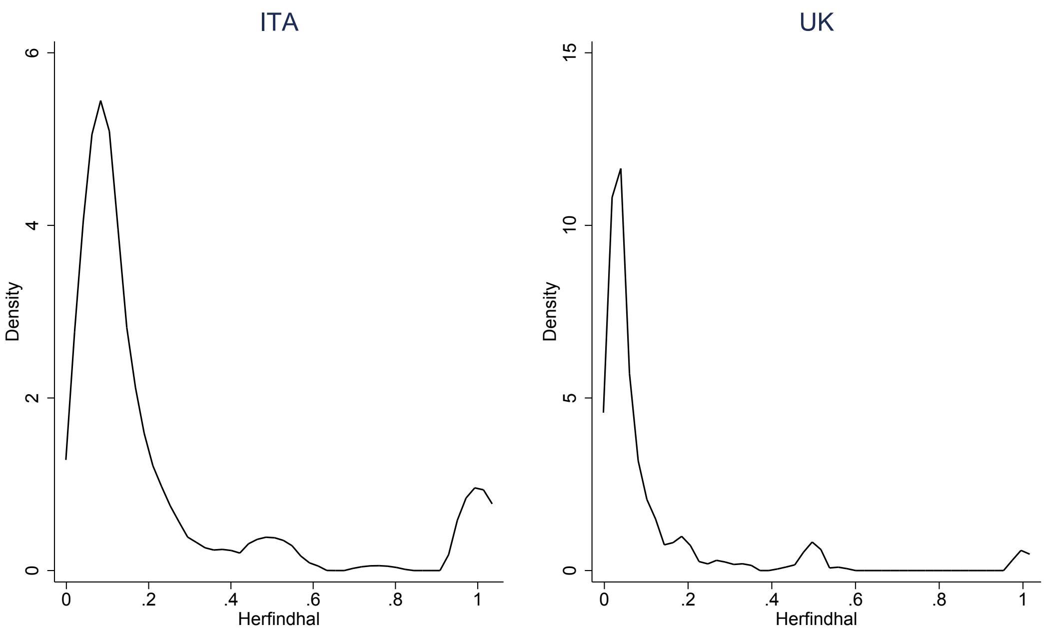


Figure 24 reports, separately for Italy and the UK, the distribution of the Herfindahl index, by country of origin.

Additionally, to gauge how diverse is the foreign students' population in these two countries, we also refer to four multigroup segregation measures. Since we are more interested by the location choice of students than the universities' recruitment policies, we compute these indexes on diversity across institutions for each origin country, rather than diversity across origins for each institution.

The four multigroup segregation measures of Table 13 are presented and evaluated in Reardon and Firebaugh (2002). The first two measures, *Dissimilarity Index* and *Gini index*, view segregation as a disproportion in the proportions of each origin country across universities. This also refers to the measurement of inequality. The higher the index, the greater the segregation. Both measures indicate that the two countries display a significant variation of foreign students by origin across institutions. The comparison between the two destinations suggests that foreign students in Italy tend to experience a higher level of segregation than foreign students in UK.[12] Figure 25 provides the distribution of the dissimilarity index for each origin country birthplace of international students. This evenness index varies between 0 (similar distribution of each origin country and the total student population distribution) and 1 (maximum segregation). It could be interpreted as the share of the students from each origin that would have to move (to another university) to match the dispersion of the total students population. The large share of origin groups with a high dissimilarity index (between 0.9 and 1), in both countries, is due to the large number of origin countries with very few individuals.

Entropy is another way to measure segregation. It is given by the last two indices, i.e. the Information theory criterion and the relative diversity. In contrast with the previous indicators, segregation is decreasing function of the index value. Again, these two other indices suggest that there is a significant degree of segregation in the two countries and, as before, that Italy faces a higher level of segregation compared to the one prevailing in the UK.

[12]The multigroup dissimilarity index is a weighted average of origin indices.

Figure 25: Dissimilarity indices

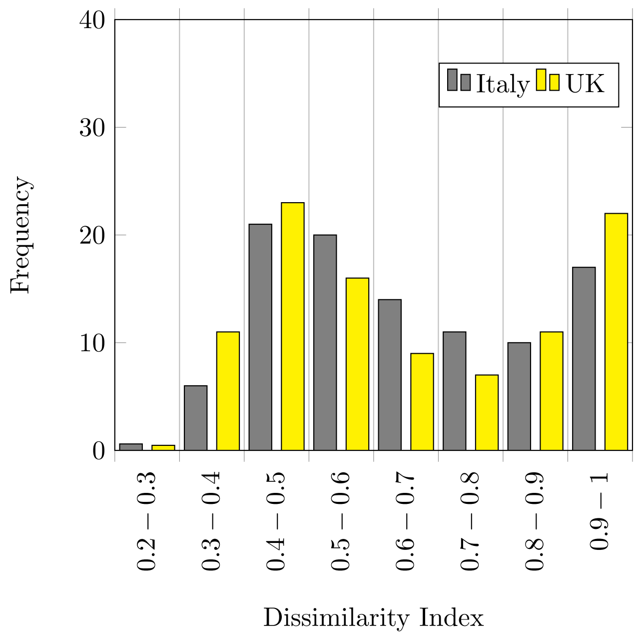


Table 13: Four Multigroup Segregation Measures

	Italy	UK
Dissimilarity (Sakoda (1981))	0,383	0,333
Gini (Reardon and Firebaugh (2002))	0,511	0,451
Information Theory (Theil (1972))	0,289	0,963
Relative Diversity (Carlson (1992))	2,284	6,119

The reference is the original citation for multigroup form

3.3.2 Covariates

3.3.2.1 Cost of living

Data on cost of living comes from the *Numbeo* website. This website provides, for each city considered various indexes of the cost of living. We use the "Consumer Price plus Rent index" for the year 2011.[13] *Numbeo* computes the index relying either on user input data or on data manually collected from authoritative sources such as websites of supermarkets, governmental institutions or other surveys. *Numbeoo* applies different techniques to filter out noisy data.

The 163 UK universities are located in 87 different locations. This website provides us information for 39 cities out of 87. For the remaining locations, we compute the closest city in terms of geodesic distance to the ones for which the data is available and we input the respective cost of living index of that city. The same approach was used for the Italian dataset. Figure 26 provides the distribution of the indicator for both countries. Table 14 reports the moments and the quantiles of the distribution. Both suggest that the cost of living considerably varies across cities in both destination countries.

Table 14: Cost of living

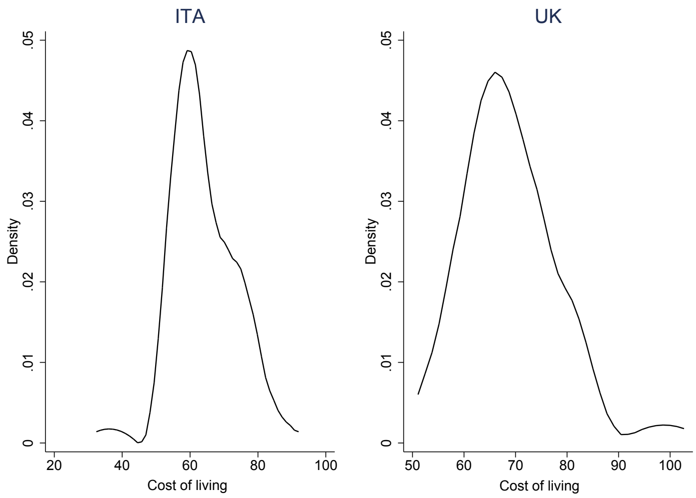
	Italy	UK
Mean	64.09	69.00
Median	62.06	67.91
Standard deviation	9.13	8.82
Min	36.17	54.94
1st Quintile	57.21	62.69
2nd Quintile	59.99	66.29
3rd Quintile	64.12	69.61
4th Quintile	73.37	76.41
Max	88.20	98.83

Index, base 100 for New-York city

Data on cost of living comes from the *Numbeoo* website.

[13] Specifically, the indexes are relative to New York city for which the index is normalized to 100.

Figure 26: Cost of living, by city



Data on cost of living comes from the *Numbeoo* website. The left panel shows the estimated distribution for the considered Italian cities while the right panel does the same for the UK cities.

3.3.2.2 Expected income

We proxy expected income at destination either using the GDP per capita of the city of destination or, when the data is not available, the one relative to the district in which the city is located. We compute this measure using both GDP and population data provided by EUROSTAT.[14] Figure 27 and Table 15 suggest that the income distribution across locations, for both countries, is quite heterogeneous across cities.

Table 15: Expected returns of education at destination

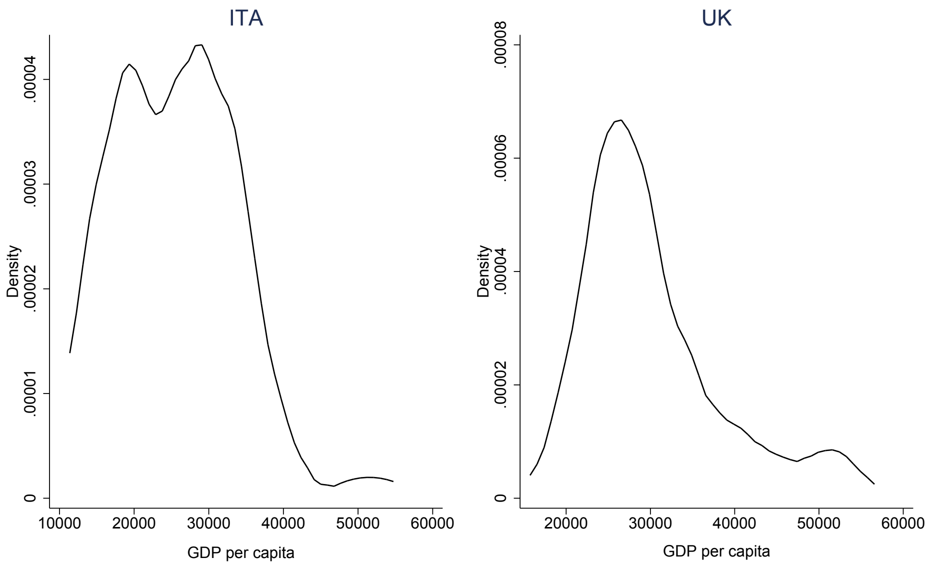
	Italy	UK
Mean	25.54	30.16
Median	24.55	27.53
Standard deviation	7.85	8.21
Min	14.61	18.09
1st Quintile	17.56	24.14
2nd Quintile	23.41	26.61
3rd Quintile	28.49	28.95
4th Quintile	31.36	35.70
Max	51.51	54.21

GDP per capita (in thousands of Euro)

Data on GDP (in thousands of Euro) per capita comes from EUROSTAT.

[14]We use the data provided at the Nuts 3 level of the EUROSTAT dataset.

Figure 27: Expected returns of education at destination



Data on cost of living comes from the *Eurostat, at the Nuts 3* level. The left panel shows the estimated distribution for the Italian cities/districts which hosts at least one university. The right panel does the same for the UK.

3.3.2.3 Tuitions fees

Italy and United Kingdom are some of the few European countries in which tuition fees varies across institutions. European Commission (2012) reports key information on tuition fees charged by European universities during the academic year 2011-2012.

For the UK, tuition fees charged to European students were subject to a cap, equal to £3375, for institutions based in England, Wales and Northern Ireland.[15] This level is set by the central government. Importantly, the institutional setting was different in Scotland. The government covered the first degree tuition fees for both Scottish and EU students. Students coming from the rest of the UK were subject to a fee equal to £1800. In contrast, universities were allowed to set tuition fees without any cap for non European students in all UK institutions.

The Tuition Reddin Survey provides only information on first cycle tuition fees charged by UK universities, differentiating between the ones charged to European students and to non European ones. Data is available for 115 institutions out of the 163 that make up the baseline dataset. Table 16 compares the restricted sample with the baseline one.

[15] As of September 2012 this level was increased in England to a new level set between £6000 and a maximum of £9000. See European Commission (2012) for more details.

Table 16: United Kingdom : benchmark and restricted sample (2011/2012)

	All institutions (163)		Restricted sample (115)	
	All students	First Degree	All Students	First Degree
Host capacity	2518640		2066290	
Foreign students	341389	All=185208 E U= 63237	309406	All = 171696 EU = 56692
% of zeroes	60.1%	All = 68.1% EU = 38%	52.1%	All = 61.6% EU = 16.72%

Table 16 compares the sub-sample of UK universities for which data on tuition fees is available with the full sample.

In order to account for the endogeneity of tuition fees, the empirical analysis for the UK mainly focuses only on first cycle international students. Our estimation strategy exploits the particular institutional setting of the UK, Sub-Section 3.4.3 provides a detailed analysis on this aspect. Table 17 reports the distribution of fees in the UK and Italy while Figure 28 shows the distribution for the UK differentiating between European and non-European international students. European students enrolled in Scottish universities had access to higher education for free, while in the remaining UK institutions they were charged an amount equal to £3375.[16]

Table 17: Tuition fees

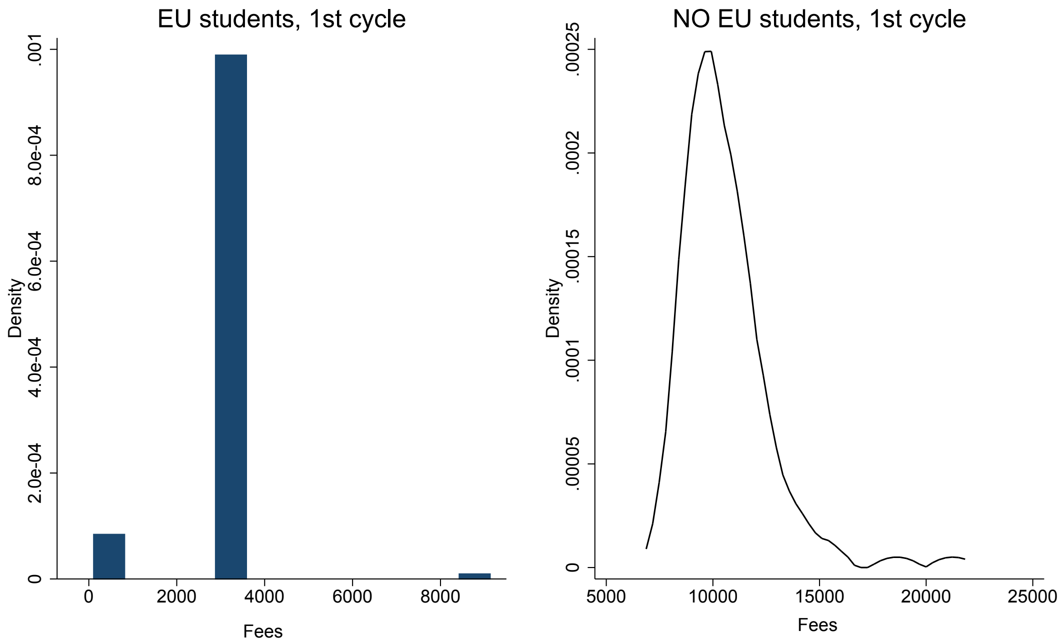
	Italy (€)	UK*(£)
Mean	1.41	10.57
Median	0.94	10.14
Standard deviation	1.57	2.03
Min	0.05	7.45
1st Quintile	0.63	9.10
2nd Quintile	0.84	9.80
3rd Quintile	1.00	10.67
4th Quintile	1.16	11.70
Max	8.26	21.25

* For non-EU students

Table 17 provides basic descriptive statistics on average tuition fees across Italian universities and on tuition fees charged to non-European students by UK universities.

[16]The only important exception is the University of Buckingham which is considered as the only private higher education in the UK (Baskerville (2013)). This institution charged EU students an amount close to 9000 €.

Figure 28: Tuition fees, UK



The left panel shows the distribution of fees charged to European students by UK universities during the academic year 2011/2012. The right panel reports a similar distribution for non-European students.

Figure 29: Average tuition fees, Italy

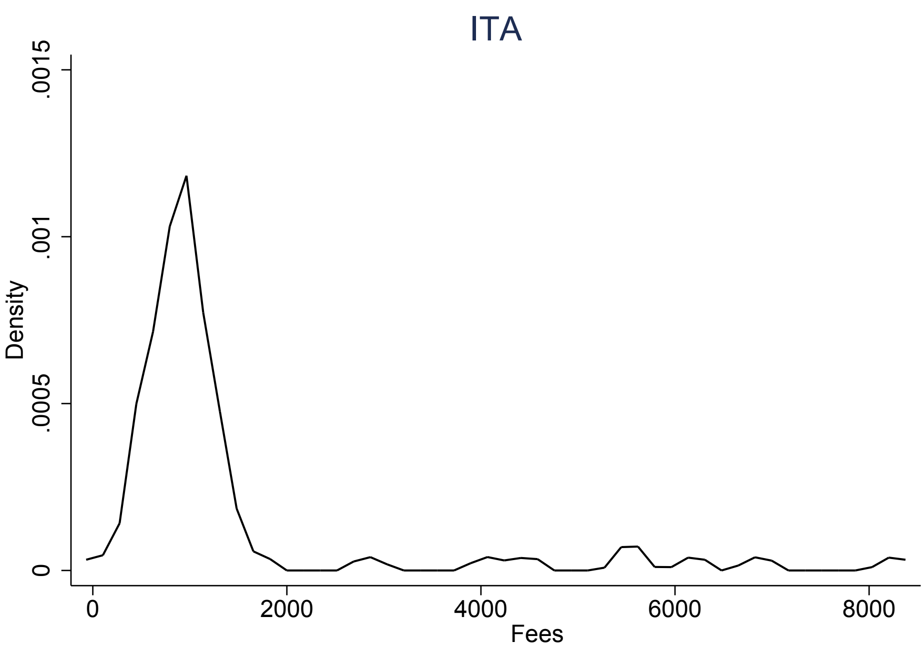


Figure 29 shows the distribution of average tuition fees charged by Italian universities during the academic year 2011/2012.

Figure 29 shows the estimated distribution of tuition fees across Italian universities. These institutions differ by their legal status, as they classified either as private or public institutions. In contrast with most Continental European countries, tuition fees charged by Italian public universities are not uniformly determined by the central government. According to the Italian law (Decree of the President of the Republic of 25.07.1997, №306), the total amount of fees raised cannot overcome the 20% of the funding received by each public university from the Italian Ministry of Education. Conversely, for Italian private institutions, the aforementioned limit does not apply, and they do charge higher fees. Tuition fees in Italian public universities depend on many determinants, in particular on the student family income and on the year of enrollment. Furthermore, Italian institutions do not charge higher tuition fees to non European students.[17]

Our primary source of data on (average) tuition fees in Italy is based on a survey conducted by the economic newspaper "*Il Sole 24 Ore*".[18] Data was missing for few public Italian universities. In that case, we use an average computed at the regional level by an Italian association of consumer (*FederConsumatori*). Data relative to private institutions is available for 9 out of the 17 institutions that make up the baseline dataset. Only private institutions charged average fees above the level of 2000 €.

3.3.2.4 University quality

In line with Beine et al. (2014) and Perkins and Neumayer (2014) we proxy university quality exploiting the Top 500 Shanghai ranking, referring to the one relative to year 2011 (ARWU).[19] This ranking determines the best 500 universities in the world. Although the index is widely known among international students and firms, its use is subject to discussion. The index should basically be interpreted as a measure of how international students perceived quality of education.

For any university appearing in the ranking we know both its position and the relative score (with respect the best one) that the university obtained. By exploiting this information we compute two quality indexes. The first one is obtained by a simple rescaling of the ARWU ranking. Specifically, if the university does not appear in the ARWU list, our index takes a value equal to 1, whereas if the university shows up its position determines the index being then equal to $(500 + 2) - ranking$.[20] The implicit assumption is that the index increases in a monotonic way with the ranking.

The ranking indicator has nevertheless some limitations. It assumes that quality is reflected in a linear way by the position in the ranking. In other terms, it disregards the fact that the score on which the ranking is based might be quite similar between a set of universities.[21] In order to account for the

[17] Only other five European countries treat equally non European students: Czech Republic, Hungary, Iceland, Liechtenstein and Norway, (European Commission (2012)).

[18] We include first degree and master degree students.

[19] The ARWU considers every university that has any Nobel Laureates, Fields Medalists, highly cited publications or papers published in Nature or Science. 1000 universities are considered and the best 500 are included in the ranking. For a full explanation on the index development the interest reader is referred to http://www.shanghairanking.com/ARWU-Methodology-2011.html.. Perkins and Neumayer (2014) proxied quality also using the World University Ranking (WUR). On the contrary of the ARWU the WUR among the criteria used considers also the number of international students. This leads us to refer only to the ARWU to avoid endogeneity issues.

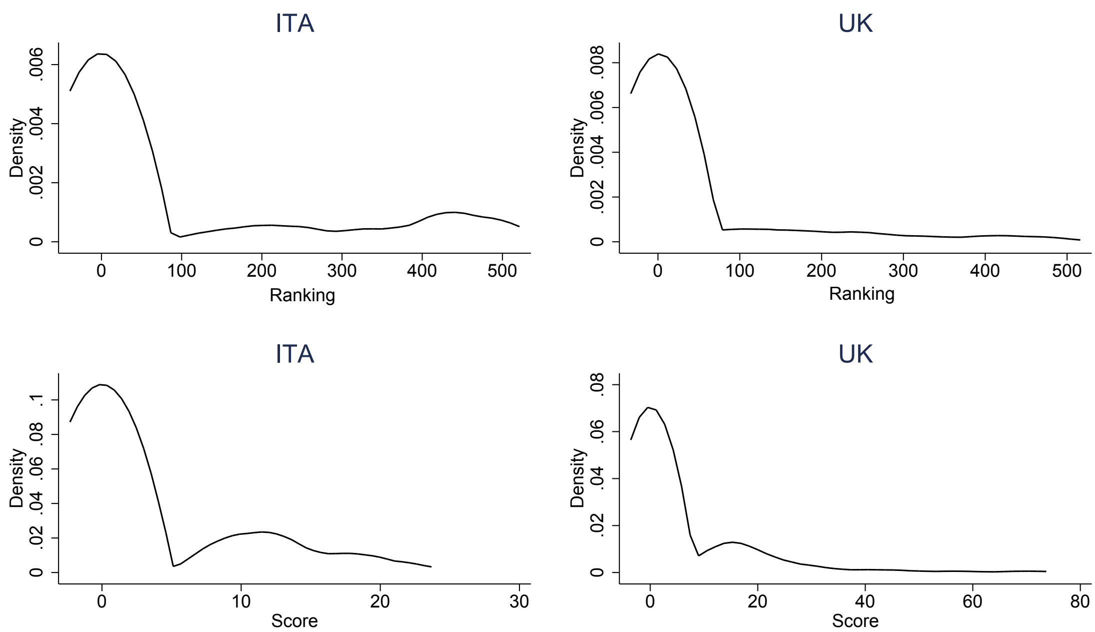
[20] In the empirical analysis we consider the log of the index. This lead us to sum 2 to 500 to keep the correspondence between the index and the its log transformation.

[21] For instance, while the first university (Harvard) has a global score of 100, universities ranked between position 2 and 5 have scores between 72.6 and 70.0. Universities comprised between top 50 and top 500 have scores between 31.7 and 24.2,

specific empirical distribution of the score, we also use the score of the Shanghai ranking instead of the position. Our quality measure takes a value equal to *score* if the university appears in the top 500 ranking. Otherwise, the index is simply equal to 0.[22] 31 universities from the UK and 20 Italian high education institutions were included in the 2011 top 500 ARWU ranking.

Figure 30 reports the two indicators of quality for each country. The graphs in the upper side of the figure show the distributions of the Ranking separately for Italian and UK universities. The other two graphs show the distribution of the *score* index. Figure 30 makes evident that UK universities appearing in the ranking have on average a better position, and consequently a better score, than Italian ones.

Figure 30: Indicators of university quality



The two upper-side graph reports the distribution of the ranking index, on the left for Italy and on the right for the UK. The two panel below reports similar graph for the Score index. Data on quality refer to the ARWU (Shanghai Ranking) for year 2011.

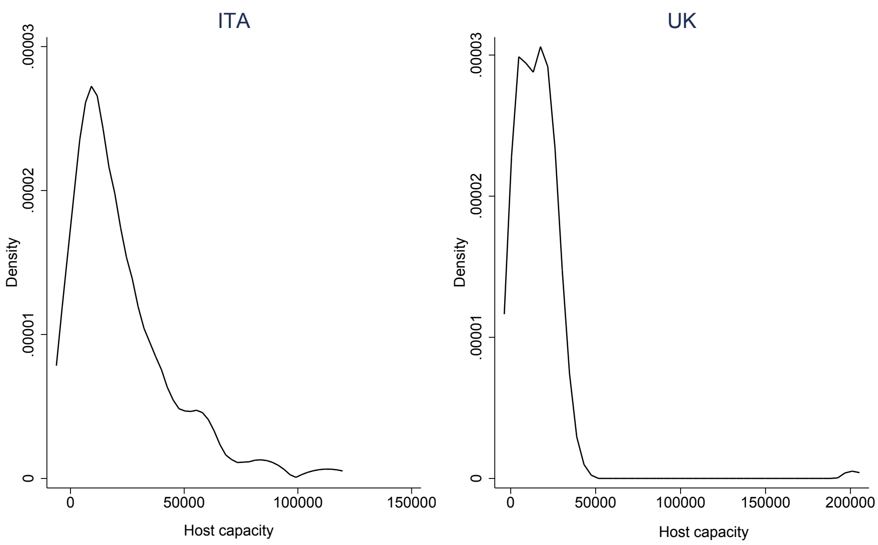
suggesting that the distribution is significantly skewed to the right.

[22] In the empirical analysis we regress for $log\,(score + 1)$.

3.3.2.5 Host capacity

Host capacity is captured by the total number of students enrolled at the university of destination during the academic year considered. Even if the median is the same for both countries (see Table 18), distributions (see Figure 31) highlight significant differences. United Kingdom has smaller size universities than Italy (with an average of 14575 students enrolled the 21932 for Italy) and a relatively smaller standard deviation. In Italy the number of universities with more than 40000 students is high and close to the number of Universities with less than 5000 students, while such huge host capacity is very rare in the UK.

Figure 31: Host capacity: distribution across universities



The left panel shows the distribution of the total amount of students enrolled in Italian university while the right panel reports the same distribution but for. UK universities.

Table 18: Host capacity

	Italy	UK
Mean	21932	14575
Median	14807	14860
Standard deviation	21721	5619
Min	405	290
1st Quintile	5789	3252
2nd Quintile	10735	10698
3rd Quintile	17672	17400
4th Quintile	33961	23480
Max	113040	40680

Total number of students

3.4 Econometric specification

3.4.1 Benchmark specification

Our econometric specification is based on Eq. (70), that provides the determinants of choosing a specific university, conditionally upon studying abroad in a specific destination country. Strictly speaking, this estimation entails the estimation of a multinomial logit, which requires the choice of a benchmark university or a “numeraire”. In other terms, the estimation should capture the determinants of choosing a specific university compared to a university of reference. Our specification does not include the choice of a numeraire and therefore slightly diverges from Eq. (70). It takes the following form:

$$\begin{gathered} ln\left(N_{i,u}\right) = \alpha + \alpha_i + \beta_1 * ln\left(fees_u\right) + \beta_2 * ln\left(livingcost_u\right) + \beta_3 * ln\left(quality_u\right) + \\ \beta_4 * ln\left(hostcapacity_u\right) + \beta_5 * ln\left(expreturn_u\right) + \epsilon_{iu} \end{gathered} \tag{75}$$

where $N_{i,u}$ denotes the number of students coming from country i and studying in university u. As said before this is applied to two countries separately, namely Italy and the UK, and to one specific academic year, 2011/2012. The data are therefore dyadic and time-invariant in nature. $fees_u$, $livingcost_u$, $quality_u$, $hostcapacity_u$ and $expreturn_u$ denote respectively the amount of annual tuition fee charged by university u, the costs of living in city where university u is located, the quality of university u, the host capacity of university u as well as the job prospects in the region where university u is located. α_i is a set of fixed effects controlling for all factors that are specific to the country of origin of the foreign students. Given that we focus on a specific country in separate regressions, α_i also controls for bilateral factors between the origin country and this destination country, such as geodesic distance, colonial links, linguistic proximity and so on. ϵ_{iu} is an error term which is supposed to be independently and identically distributed.

Before we proceed to the estimation, we discuss here a couple of issues that are relevant to the estimation of Eq. (75). We make clear that Eq. (75) corresponds to the last stage of the migration process of foreign students. Previous stages concern (i) the decision to invest in education or not (ii) the decision to study abroad or domestically and (iii) the choice of the country of destination. This paper focuses only on the last stage. Another possibility would have been to integrate in the same analysis several countries of destination, i.e. to pool universities of different countries. Beyond limitations in data availability, this is not desirable for several reasons. The main reason is that pooling universities of different countries would lead to a clear rejection of the IIA hypothesis which is implicit in the estimation of Eq. (75). The rejection of the IIA hypothesis would occur by the fact that the choice structure involves two countries that might be considered as nests in the decision process. Given that is very likely that the degree of substitution between two universities changes with respect to the country of destination, we eventually prefer to estimate the model separately for each country of destination. This issue is also related to the well known problem of multilateral resistance of migration (Bertoli and Fernández-Huertas Moraga (2013); Beine et al. (2015)). In other terms, pooling several countries and integrating the choice of the destination country would entail the estimation of a nested logit model with two potential nests. This is obviously beyond the scope of this paper and is left for future investigation.

3.4.2 Econometric method

Another issue is the prevalence of a high share of zero values for the bilateral migration flows. In our sample, for the year 2011 under investigation, we have 61.6% of zero values for the bilateral flow of first degree foreign students for the UK. The corresponding proportion for Italy is 68.84%. The presence of a high proportion of zero values is well-known to generate biases in the key estimates using traditional panel fixed effect estimates (Santos Silva and Tenreyro (2006). The use of $log\,(1+y)$ as the dependent where y is the bilateral flow (the so-called scaled OLS estimator) allows to solve the selection problem due to the drop of the zero observations. Nevertheless, the scaled OLS estimation technique would give inconsistent estimates in the presence of heteroskedasticity. Santos Silva and Tenreyro (2006) shows that Poisson regressions are robust to different pattern of heteroskedasticity. We follow this route in the subsequent estimation and use the Poisson estimates as the benchmark ones. However, our tables will report the Scaled OLS estimates of model (75) for robustness checks.

3.4.3 Dealing with endogeneity concerns

In the model of Section 3.2, tuition fees are exogenous and universities set their level independently on the number of students enrolled or other characteristics. In reality, the exogenous nature of fees in specification (75) is questionable on several grounds. First, fees might depend on the attractiveness of the university: successful universities attracting a large number of (foreign) students can easily raise the tuition fees compared to other universities. This leads to a reverse causality issue between student flows and fees. While the bilateral nature of $N_{i,j,u}$ mitigates this aspect, it is important to deal with the potential endogeneity of fees. On top of that, fees might be correlated to some unobserved characteristics of the university such as the quality of amenities on the campus or of the hosting city. This also leads to the endogeneity of tuition fees and calls for a specific treatment. This paper tackles the endogeneity of fees differently for each country of destination, by taking advantage of the two different institutional contexts.

For Italy, we deal with the endogeneity of fees using a traditional IV approach. Basically, we use the public *vs* private status of the university as an instrument of tuition fees, following a similar solution adopted in Beine et al. (2014) at the country level. In particular, we create and use a dummy variable capturing whether the university is private or not. The underlying assumption is that private universities have a higher control on tuition fees. These institutions tend to increase fees not only because of the costs but also in the reason of the fact that they receive less subsidies from the public sector. Furthermore, private institutions are not constrained by the regulation in terms of cap that applies to public universities. We should expect a positive correlation between the private status and the level of tuition fees. In terms of exclusion restriction, the underlying assumption is that foreign students should have not particular preferences for private or public universities on top of quality, host capacity, cost of living and income of the destination area. This seems to be a reasonable assumption and is confirmed by the examples of many successful public universities in the US such as Berkeley or Michigan state university.

For the UK, unfortunately, the traditional IV solution is not possible. Indeed, the status of the university is not as clear-cut as in the Italian case.[23] Some alternative instrument such as the share of the budget subsidized by the central government turned out to be a weak instrument, and generate inconsistent results.[24]

Instead of a traditional IV, we deal with endogeneity taking advantage of the institutional context of universities in the UK. During the academic year 2011/2012 UK universities were in fact subject to caps on the amount of fees that they could charge to native and European first cycle students. These caps did not apply to students originating from outside the EU. On top of that, there is some regional variation of the caps applied to universities. Scottish universities were subject to lower caps compared to those applied to other institutions in the UK. Moreover, the cap set by the Scottish government applied only for the non Scottish UK students. The Scottish government covered first degree tuition fees to both natives and European students, thus allowing them to get first cycle education in Scottish universities for free (European Commission (2012)). In contrast the other UK universities set tuition fees charged to EU students equal to the £3375 cap.[25] It follows that by restricting the sample to European countries as origins, we estimate model (75) in a context in which fees are clearly exogenous. Furthermore, the comparison of the results obtained with the full sample of origin countries or countries originating outside the EU allows to gauge, in a simple way, the degree of endogeneity of fees in using specification (75).

3.5 Results

We present the results separately for the two countries under investigation. For each set of estimates, we present results obtained using Scaled OLS and Poisson. On top of these benchmark results, for Italy, we present also results based on the combination of these techniques with the use of instrumental variable.

3.5.1 Italy

The inclusion of origin country fixed effects allows us to control for the role of usual push factors (for instance, GDP at origin) as well as the influence of bilateral determinants (colonial links, proximity, languages). The estimates reported in Table 19 are in line with a traditional view of the role of fees and of quality. In particular, both types of estimation techniques deliver a negative and significant role for fees on the university choice of foreign student, in line with the view that fees are part of the cost function. Estimates vary little with respect to the two quality indexes. Nevertheless, a couple of comments are in order. First, while fees appear to have a negative role, failure to account for their possible endogeneity leads us to take these results with caution. Second, while the benchmark results suggest an important and intuitive role for fees, quality of the university, host capacity and expected income in the area, we fail to find any evidence of a role for the cost of living. Since all estimates are potentially biased by the presence of endogenous fees, it is also important to check whether this result survives after an explicit treatment of endogeneity through IV estimates. Table 20 reports these results.

[23] According to Baskerville (2013) the only UK private institution is the university of Buckingham. All the others are defined as independent legal entities.

[24] Results are available upon request.

[25] The only exception is the already mentioned University of Buckingham.

Table 19: Italy: Benchmark estimates of determinants

Variables	Scaled OLS	Poisson	Scaled OLS	Poisson
Fees	-0.082***	-0.174**	-0.085***	-0.167**
	(0.01)	(0.06)	(0.01)	(0.06)
Cost of living	0.046	-0.625	-0.011	-0.741
	(0.06)	(0.41)	(0.06)	(0.41)
Quality (ranking)	0.080***	0.143***	-	-
	(0.01)	(0.02)		
Quality (score)	-	-	0.114***	0.234***
			(0.01)	(0.04)
Host capacity	0.156***	0.552***	0.162***	0.560***
	(0.01)	(0.06)	(0.01)	(0.06)
Income	0.625***	1.585***	0.656***	1.612***
	(0.03)	(0.16)	(0.03)	(0.16)
Origin FE	yes	yes	yes	yes
R^2	0.569	-	0.568	-
Pseudo R^2	-	0.743	-	0.744
Nber Obs	11928	11928	11928	11928

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 20: Italy: Instrumental variable estimates of determinants

Variables	Scaled IV	Poisson IV	Scaled IV	Poisson IV
Fees	-0.246***	-0.580***	-0.248***	-0.543***
	(0.02)	(0.12)	(0.02)	(0.12)
Cost of living	-0.132*	-1.419**	-0.191**	-1.410**
	(0.06)	(0.47)	(0.06)	(0.45)
Quality=ranking	0.081***	0.153***	-	-
	(0.01)	(0.02)		
Quality=score	-	-	0.119***	0.250***
			(0.01)	(0.06)
Host capacity	0.128***	0.483***	0.133***	0.501***
	(0.01)	(0.06)	(0.01)	(0.06)
Income	0.878***	2.211***	0.908***	2.166***
	(0.04)	(0.25)	(0.04)	(0.24)
Origin FE	yes	yes	yes	yes
R^2	0.562	-	0.560	-
F first stage	5014.4	-	5057.6	-
Robust Score	131.4	-	142.9	-
Robust Regression	132.7	-	134.1	-
Nber Obs	11928	11928	11928	11928

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Instrument: dummy variable indicating private vs public institution.

The estimates of Table 20 provide interesting insights. First, the use of instrumental variable estimation leads to a significant correction in the estimate of the influence of tuition fees. Endogeneity of fees might be due to either reverse causality (i.e. attractive universities are more keen to charge higher fees) or some positive correlation of fees with unobserved factors of attractiveness (e.g. universities with better amenities tend to charge higher fees). In both cases, this results in a positive correlation between fees and the error term of model (75), resulting in an upward biased estimate of the impact of tuition fees. A comparison of Tables 19 and 20 shows that the use of instrumentation corrects the bias in the expected direction, with a more negative impact of fees on the university choice. This holds for both estimation techniques.

Second, the IV results lead a significant change in all the estimates of the determinants of university's choice except quality. The correction of the impact of fees could suggest that the non-IV Poisson estimate tends to overestimate the true impact, or in other terms underestimate the impact in absolute terms. Such a bias is consistent with a positive correlation between fees and unobserved amenities. It is also consistent with a phenomenon of reverse causality (attractive universities are more expensive). The IV estimates of Eq. (75) provide support for a role of all possible determinants of the model suggesting that the choice of a particular university results from a complex assessment of benefits and costs as outlined in the theoretical RUM framework of Section 3.2. Interestingly, the estimates for Italy suggests that foreign students explicitly take into account the cost of living and the expected income at the city of destination. The estimated elasticity suggests that a 10% increase in the tuition fees tends to decrease the average bilateral flow to that university by about 5%.

We acknowledge that the exclusion restriction of our instrumental variable might be object of discussion. Even if we control for city- and university- determinants it could be that some foreign students explicitly consider the status of the university when taking their enrollment choice. For instance, it could be that foreign students believe that private universities are better organized and thus providing better services in terms of students' advices, personal tutoring and so on. It could be also the case that students believe that private universities are more accountable to students for the quality of teaching. The higher attractiveness of private institutions seems to be the prevailing dominant view. Nevertheless, this view is predominant but not the only one. On the contrary, it may be expected that degrees delivered by public universities are recognized in an easier way by private firms and public institutions; this suggests that the private status deters rather than to attract students. In these cases, there might be a positive or negative correlation between our status variable and the error term of Eq. (75) which may eventually invalidate the exclusion restriction of our IV procedure.

To cope with such concern, we exploit econometric procedures introduced by Conley et al. (2012). By doing so, we are able to account for possible deviations from the exclusion restriction. The idea is to consider the parameter capturing the restriction (the coefficient of the instrumental variable in the structural equation) as a random parameter drawn from a given distribution. The procedures, (see Conley et al. (2012) for details), allow for possible means different from zero i.e. for asymmetric deviation from the exclusion restriction. We consider two methods. The first one, coined "*Union of Confidence Interva*l" (UCI) provides an alternative IV estimation assuming that the exclusion parameter belong to a prior defined support. The other one, called "*Local to Zero Approximation*", assumes that the exclusion restriction parameter follows a normal distribution with given mean and standard deviation.

In Table 21 we report the results for the UCI procedure.[26] In this Table we report the estimates of the elasticity of foreign students to tuition fees obtained by considering different supports for the range of possible values taken by the parameter capturing the deviation from the exclusion restriction.[27]

The higher the range of possible values less precise would be the estimate of the coefficient. Symmetric ranges around zero corresponds to an agnostic view about the possible departure from the exclusion restriction. On the contrary, a positive interval (resp. negative) range corresponds to the view that foreign students value more (resp. less) private universities.

Table 21: Italy - Estimated impact of tuition fees accounting for plausible endogenous instrument

Interval Range				
min dev	max dev	Estimate of β_1	std. dev	t-ratio
Symmetric intervals				
-0.1	0.1	-0.248***	0.057	-4.36
-0.2	0.2	-0.248***	0.096	-2.59
-0.3	0.3	-0.248*	0.134	1.85
Asymmetric intervals				
-0.3	0	-0.134*	0.076	-1.77
-0.2	0	-0.172***	0.057	-3.03
0	0.2	-0.324***	0.057	-5.67
0	0.3	-0.362***	0.076	-4.73

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{*}p < 0.01$

This Table provides additional estimates of β_1, the tuition-fees coefficient, by estimating Eq. (75) employing the Union of Confidence Intervals method described in Conley et al. (2012). Tuition fees are still instrumented using the status, private vs public, of the university. Columns 1 and 2 report the minimum and maximum values of the parameter capturing the deviation from the exclusion restriction. Column 3 provides the mean estimate of the tuition-fees elasticity, β_1. Column 4 reports the respective standard deviation.

Table 21 provides evidence that the obtained negative and significant elasticity of tuition fees obtained by employing the traditional IV estimation is also robust to deviations from the exclusion restriction. The significance level drops below the 5% only for values of the parameter larger than 0.3 in absolute terms. This means that even if the mere private status of the university deters or attracts on average less than 0.3% of foreign students coming from each origin country, our IV estimates still find support for a negative effect of tuition fees. When the parameter gets a value larger than 0.3, our estimates become less significant, albeit still negative and significant for a 10% confidence interval. The bottom panel of Table 21 also reports results obtained with asymmetric interval of values of the deviation parameter. Interestingly our estimations show that if foreign students are *more attracted* by private Italian universities the impact of tuition fees becomes even *more negative*.

3.5.1.1 English-Speaking Programs

International students may opt to enroll in Italian universities but attending courses taught in English. Among the other factors considered, choosing to enroll in an university offering an English-speaking

[26] The results obtained employing the *Local to Zero Estimation* are available upon request.

[27] Estimates of the other coefficients (cost-of living, Income, Quality and host capacity) are not reported but are available upon requests. Importantly, they are in general unaffected and close to the benchmark estimations of Table 20.

program could be one the key determinants taken into account by international students. Above all, such programs allow students to develop additional skills by using the current business/academic *lingua franca*. This should increase their probability to find a job after graduation either in Italy or elsewhere.[28] In This section we extend the model of Eq. (75) by including in the set of covariates a dummy variable with the aim to account for the availability of English-speaking programs. The baseline model, Eq. (75), could be mispecified, in fact one could argue that average fees are positively correlated with the availability of English-Speaking programs. The same reasoning could apply also to the quality indicators, thus making our previous estimates potentially biased for another reason. [29]

$$ln\left(N_{iu}\right) = \alpha + \alpha_i + \beta_1 * ln\left(fees_u\right) + \beta_2 * ln\left(livingcost_u\right) + \beta_3 * ln\left(quality_u\right) + \beta_4 * ln\left(hostcapacity_u\right) + \beta_5 * ln\left(expreturn_u\right) + +\beta_5 * \left(EngDummy\right) + \epsilon_{iu} \quad (76)$$

Specifically, the dummy variable, labeled *EngDummy*, takes a value equal to 1 if the university u provided at least one bachelor or master program in English for the academic year 2011/2012 and 0 otherwise. From the website of the Italian association of Dean, "*Fondazione Crui*",[30] we borrow this information. According to this data source 39 Italian universities were providing at least a program taught in English during the academic year 2011/2012. Table 22 report the results obtained estimating model (76).

Table 22: Italy: Accounting for the availability of English-speaking programs

Variables	Scaled OLS	Poisson	Scaled OLS	Poisson
Fees	-0.085***	-0.200**	-0.089***	-0.201**
	(0.01)	(0.06)	(0.01)	(0.06)
Cost of living	0.014	-0.743	-0.011	-0.865 *
	(0.06)	(0.42)	(0.06)	(0.41)
Quality (ranking)	0.079***	0.126***	-	-
	(0.01)	(0.02)	-	-
Quality (score)	-	-	0.114***	0.225***
	-	-	(0.01)	(0.04)
Host capacity	0.148***	0.527***	0.152***	0.513***
	(0.01)	(0.06)	(0.01)	(0.06)
Income	0.622***	1.583***	0.652***	1.603***
	(0.03)	(0.16)	(0.03)	(0.16)
EngDummy	0.049***	0.345***	0.057***	0.382***
	(0.01)	(0.09)	(0.01)	(0.09)
Origin FE	yes	yes	yes	yes
R^2	0.570	-	0.568	-
Pseudo R^2	-	0.746	-	0.747
Nber Obs	11928	11928	11928	11928

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This robustness check gives additional reliability to our previous estimates. Although the added estimated coefficient of *EngDummy* is both positive and significant, as we expect, the coefficient of fees,

[28] Interestingly, Kahanec and Králiková (2011), find that the availability of English-speaking programs act as a pull factor.
[29] Even though, if such a bias exists our previous estimate on fees should be *upward* biased.
[30] This data is freely available in PDF format at: https://www.crui.it/images/documenti/2012/courses_english.pdf.

in all cases, is larger in absolute value and, more importantly, always highly significant. The sign and the significance of all other variables obtain supplementary confirmation as well. Again for the sake of robustness, we also estimate model (76) accounting for the possible endogeneity of fees, employing the IV strategy described in Section 3.5.1. Table 23 report our findings. Essentially, the coefficient on fees gets larger in absolute value and remains negative and highly significant. Interestingly, as it was the case with the estimates reported by Table 20, the Cost of living coefficient becomes both negative and highly significant.

Table 23: Italy: IV estimates accounting for the availability of English-speaking programs

Variables	Scaled IV	Poisson IV	Scaled IV	Poisson IV
Fees	-0.261***	-0.666***	-0.263***	-0.626***
	(0.02)	(0.12)	(0.02)	(0.12)
Cost of living	-0.188**	-1.806***	-0.252***	-1.756***
	(0.06)	(0.52)	(0.06)	(0.49)
Quality=ranking	0.080***	0.137***	-	-
	(0.01)	(0.02)	-	-
Quality=score	-	-	0.118***	0.242***
	-	-	(0.01)	(0.04)
Host capacity	0.114***	0.446***	0.117***	0.437***
	(0.01)	(0.06)	(0.01)	(0.06)
Income	0.888***	2.365***	0.916***	2.282***
	(0.04)	(0.28)	(0.04)	(0.27)
EngDummy	0.072***	0.364***	0.080***	0.412***
	(0.01)	(0.09)	(0.01)	(0.09)
Origin FE	yes	yes	yes	yes
R^2	0.561	-	0.560	-
F first stage	5537	5560	-	-
Robust Score	145	146.3	-	-
Robust Regression	148	149.6	-	-
Nber Obs	11928	11928	11928	11928

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Instrument: dummy variable indicating private vs public institution.

3.5.2 United Kingdom

In contrast with Italy, universities in the UK cannot be distinguished between public or private institutions. This prevents the use of the instrument capturing the public *vs* private status of the university. We deal with the issue of the endogeneity of fees taking benefit of the institutional context, namely exploiting the regional variation in the first-cycle tuition fees caps. We run regressions based on model (75) for various sub-samples in terms of origin countries. We first restrict the analysis to first-cycle students, i.e. those that are subject to caps on fees. For the reasons exposed above, restricting the sample to EU countries as origins should solve the endogenous nature of tuition fees. In contrast, if using all countries or the non-EU origins should lead to results subject to the endogeneity bias. A comparison between the results based on different samples allows to shed some light on the magnitude of the bias associated to the endogeneity of tuition fees. Based on this strategy, Tables 24 and 25 present the results of the estimation of model (75) for the three sub-samples of origin countries and for the two estimation techniques. Table 24 presents the result with the indicator of quality based on the ranking, while Table 25 reports the findings obtained with the score indicator.

Table 24: UK: Determinants of student migration, first-cycle students- Quality=ranking

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
Fees	-0.064***	-0.086***	0.114***	-0.078***	-0.084***	0.432*
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.21)
Cost of living	0.560***	1.956***	0.339***	0.993***	1.220***	0.809**
	(0.04)	(0.19)	(0.04)	(0.20)	(0.32)	(0.25)
Quality (ranking)	0.037***	0.077***	0.024***	0.073***	0.032*	0.070***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.02)
Host capacity	0.290***	0.742***	0.233***	0.892 ***	0.862***	0.933***
	(0.01)	(0.03)	(0.01)	(0.05)	(0.06)	(0.07)
Income	0.104***	-0.057	0.102***	-0.015	0.027	-0.096
	(0.02)	(0.10)	(0.02)	(0.12)	(0.15)	(0.16)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.661	0.581	0.621	-	-	-
Pseudo R^2	-	-	-	0.706	0.464	0.737
Nber Obs	24360	2900	21460	21228	2900	18328

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The estimation results of Tables 24 and 25 yield basically two lessons. First, using EU countries as origin only, we find some support in favor of a negative impact of tuition fees. This finding therefore confirms the negative impact found in the case of Italy. The estimated elasticity is much lower in terms of magnitude than for Italy. This might be due to the fact that we focus on bachelor students that are less mobile than master students.

Second, the results for the sample of non-EU regions suggest that failure to deal with the endogeneity of tuition fees lead to significant biases in the estimation of their impact. Focusing on the Poisson regressions, the results obtained for the non-EU countries exhibit a positive and a barely significant effect of tuition fees. While fees can have in practice additional dimensions that the pure cost component outlined in the theoretical framework of Section 3.2 (such as a signal of quality or a mitigation of the cost through coverage by education grants), such a strong and positive impact would be nevertheless difficult to rationalize. While we do not account for the existence of education grants, our estimations account for the variation in the quality of universities, which rules out the signaling effect of fees. Our results for the different samples suggest rather that the positive impact obtained in previous work is in great part driven by endogeneity issues.

Table 25: UK: Determinants of student migration, first-cycle students- Quality = score

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
Fees	-0.064***	-0.087***	0.110***	-0.079 ***	-0.084***	0.395
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.22)
Cost of living	0.555***	1.947***	0.336***	0.974***	1.219***	0.787***
	(0.04)	(0.19)	(0.04)	(0.20)	(0.32)	(0.25)
Quality (score)	0.059***	0.127***	0.038***	0.116***	0.056**	0.111***
	(0.00)	(0.01)	(0.00)	(0.02)	(0.02)	(0.02)
Host capacity	0.289***	0.739***	0.233***	0.888 ***	0.857***	0.930***
	(0.01)	(0.03)	(0.01)	(0.05)	(0.06)	(0.07)
Income	0.103***	-0.061	0.102***	-0.017	0.021	-0.089
	(0.02)	(0.10)	(0.02)	(0.12)	(0.15)	(0.16)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.661	0.581	0.621	-	-	-
Pseudo R^2	-	-	-	0.722	0.465	0.736
Nber Obs	24360	2900	21460	24360	2900	18328

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Tables 24 and 25 also exhibit counterintuitive results for both the cost of living and income. These implausible coefficients may be due to multicollinearity problems; once we compute the correlation coefficient between cost of living and income we obtain a value equal to 0.78. This high correlation coefficient leads us to compute the *variance inflation factor* (VIF). We obtain an average VIF equal to 1.88, for cost of living and income we obtain VIF equal to 2.55 and 2.51 respectively. Consequently we do not find evidence of multicollinearity issues.[31] The fact that the income coefficient is not significant could be due that our baseline sample contains only first cycle students. The prospects of finding a good job are much more obvious for master students compared to bachelor students. First cycle in higher education primarily aims at providing a good training to favour the access to graduate studies rather than to provide a degree directly used to find a good job.

The elasticity of quality is also found to be lower than for Italy. It might be the case that first cycle react less to quality of the university as bachelor programs are quite similar across universities and that the differences across bachelors are not that great. To check this conjecture we run similar regressions using

[31] One may argue that also fees and quality are highly correlated. For the subset of only European student this is clearly not an issue, given that fees are exogenously set by the central government. Also, the already reported values of the VIF coefficient suggest that there is no multicollinearity issue due to the correlation between quality and fees.

master students' flows instead of first-cycle students.[32] Tables 26 and 27 report the result obtained. Once we use only master student flows, the coefficient on income becomes both positive and highly significant.[33] Interestingly the quality coefficients turn being both positive and highly significant for both estimation techniques. Consequently, the failure of Tables 24 and 25 to find such an evidence could be driven by the fact that first-degree students are more likely to change location after graduation, for instance to take benefit of job opportunities or to pursue their education elsewhere.

Nevertheless, even for master students, the coefficient relative to the cost of living remains positive.[34] It may be the case that in the UK, our measure of cost of living is highly related with unobserved amenities at destination, generating endogeneity of this variable. To take care of that issue, we carry out some IV estimation, instrumenting the cost of living. The results are reported in Appendix, see Section 3.7.1.2. The results suggest that the positive coefficient obtained in Tables 24-27 might be, once again, affected by endogeneity issues.

Table 26: Uk: Master Students - Quality = ranking

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
Fees	-0.022***	-0.025***	0.068*	-0.028	-0.003	0.131
	(0.01)	(0.01)	(0.03)	(0.02)	(0.02)	(0.24)
Cost of living	0.535***	1.526***	0.379***	1.246***	1.220*	1.171***
	(0.04)	(0.15)	(0.04)	(0.28)	(0.51)	(0.33)
Quality	0.051***	0.111***	0.039***	0.116***	0.123***	0.108***
Ranking	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.02)
Host capacity	0.276***	0.557***	0.239***	0.958 ***	0.829***	0.987***
	(0.01)	(0.02)	(0.01)	(0.06)	(0.08)	(0.07)
Income	0.175***	0.418***	0.134***	0.114	0.958***	-0.046
	(0.02)	(0.08)	(0.02)	(0.15)	(0.23)	(0.17)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.619	0.590	0.616	-	-	-
Pseudo R^2	-	-	-	0.748	0.564	0.769
Nber Obs	24360	2900	21460	24360	2900	18328

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[32]Fees for master students are unregulated in UK, hence the reader should not rely on the coefficients on fees there obtained.

[33]Tables 31 and 32 in the Appendix (Section 3.7.1.2) report estimation results using the whole flows of international students to UK (first degree and master students).

[34]In the Appendix (see Section 3.7.2) we report results obtained by employing IV for the cost of living. We fail to find conclusive results.

Table 27: Uk: Master Students - Quality = score

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
Fees	-0.023***	-0.026***	0.063*	-0.030	-0.005	0.128
	(0.01)	(0.01)	(0.03)	(0.02)	(0.02)	(0.25)
Cost of living	0.528***	1.513***	0.374***	1.190***	1.179*	1.114***
	(0.04)	(0.15)	(0.04)	(0.28)	(0.51)	(0.33)
Quality	0.081***	0.179***	0.061***	0.174***	0.190***	0.159***
Score	(0.00)	(0.01)	(0.00)	(0.02)	(0.03)	(0.03)
Host capacity	0.275***	0.554***	0.239***	0.957 ***	0.822***	0.989***
	(0.01)	(0.02)	(0.01)	(0.06)	(0.08)	(0.07)
Income	0.175***	0.413***	0.134***	0.127	0.962***	-0.031
	(0.02)	(0.08)	(0.02)	(0.15)	(0.23)	(0.17)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.619	0.591	0.616	-	-	-
Pseudo R^2	-	-	-	0.746	0.564	0.767
Nber Obs	24360	2900	21460	24360	2900	18328

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.6 Conclusions

This paper revisits the issue of the determinants of student migration. In contrast with the existing literature that has focused so far on country-specific factors, we look at the determinants at the university level. This allows to address specifically the role of important factors such as the tuition fees or the quality of the university. The impact of those factors is difficult to grasp in country-level studies due to the high heterogeneity between institutions in many countries. While the analysis considers a set of university specific factors, we give a special attention to the role of tuition fees on the propensity of foreign students to choose a specific university. The existing literature has obtained so far mixed results concerning the impact of tuition fees.

We build our empirical investigation on a nested logit model capturing the decision to choose a specific university abroad. We focus on the last decision nest, i.e. the choice of a specific university for a student conditional on going abroad and conditional on choosing a specific destination country. Our model allows to identify the main factors such as the tuition fees, the quality of university, the host capacity, the expected return on education at destination and the cost of living. We estimate the role of those factors making use of data at the university level for two countries, namely the UK and Italy. One of the important issues at the econometric level is the endogeneity of fees. We propose two different solutions for the two countries. For Italy, we use a classical IV approach based on the status of the universities. In this case, we check the validity of our exclusion restriction by employing the procedures defined by Conley et al. (2012). For the UK, we make use of the regional variation in the caps that the authorities impose on the fees for native students and European ones.

Our analysis generate interesting and new findings. First, we find evidence of a negative role of the tuition fees set by a university on the flow of students choosing to study in this university. Surprisingly, this negative and significant role is new in the literature. We stress the importance of dealing with the endogeneity of tuition fees. Tuition fees are likely to be endogenous due to reverse causality or correlation with unobservable factors of attractiveness at the university level. Failure to account for endogeneity results in a positive and significant result. While such a positive impact is not to be ruled out at a theoretical level, it is nevertheless difficult to rationalize in practice. While tuition fees are found to play some influence on the location of foreign students, our analysis also emphasizes and confirms the role of other important factors. We find support in favor of a role of the university quality. Also, the expected return of education after graduation, which is proxied by the income per head of the region of location of the university is also found to be important. This last result is in line with the implications of the migration model of foreign education.

Appendix

3.7 Summary of the data

Table 3.7 summarizes our variables and the related data sources.

Table 28: Data sources and definitions

Variable	Definition	Source	Remarks
International Students ($N_{i,u}$)	Number of foreign students coming from country i and enrolled in university u	UK: HESA. Italy: MIUR	UK: 210 origins; Italy: 163 origins
Fees$_u$	Average fees charged by university u	UK: Tuition Reddin Survey and refers to first cycle students. Italy: Newspaper *il Sole24 ore.*	For the UK data on fees charged to first cycle students is available for 115 institution
Quality$_u$ (ranking)	Quality of university u based on Top 500 ranking	Top 500 Shanghai Ranking ARWU	Indicator= $ln\left((500+2) - ranking\right)$
Quality$_u$ (score)	Quality of university u based on Top 500 score	Top 500 Shanghai Ranking ARWU	Indicator= $ln\left(score+1\right)$
Host Capacity u	Total number of students enrolled at university u	UK: HESA. Italy: MIUR	
Cost of living u	Cost of Living in city/district j, where institution u is located	Numbeoo dataset.	This value is relative to New York City. The index includes cost of rent, food and other amenities. Cost of living of the closest city when data is unavailable for location j
Expected return u	GDP per capita in the district where university u is located	GDP at NUTS 3 level, Eurostat	GDP refers to the city of destination or, when this data is missing, to the district of destination

3.7.1 Additional Estimation results

3.7.1.1 Scaled Regressions

In this Section, we check the validity of our analysis defining and empirically testing an extension of model (75). For each origin country, i, we determine the university, u^*, that hosted during the academic year 2011/2012 the largest number of international students. We label the largest bilateral flow between origin country i and universities $(ui)^*$. It may be also the case that some universities share the largest bilateral student inflow from a given country i, this happens quite often for bilateral flows originating from small countries. Then, for each bilateral flow, we determine the share with respect to the largest student inflow $(ui)^*$. These numbers will become our dependent variables. In the same vein for each one of the covariates (Fees, Cost of living, Income and Quality) we compute scaled values with respect to the ones of the university characterized by the largest flow, namely $(ui)^*$. When the largest flow characterizing a given sending country, i, is shared among several universities, for each covariate we scale for the average values among these universities. The model that we consider writes as following:

$$Share\left(ln\left(\frac{N_{ui}}{N_{(ui)^*}}\right)\right) = \alpha + \alpha_i + \beta_1 * ln\left(\frac{fees_{ui}}{fees_{(ui)^*}}\right) + \beta_2 * ln\left(\frac{livingcost_{ui}}{livingcost_{(ui)^*}}\right) + \beta_3 * ln\left(\frac{quality_{ui}}{quality_{(ui)^*}}\right) + \beta_4 * ln\left(\frac{hostcapacity_{ui}}{hostcapacity_{(ui)^*}}\right) + \beta_5 * ln\left(\frac{expreturn_{ui}}{expreturn_{(ui)^*}}\right) + \epsilon_{iu} \tag{77}$$

Our results gets additional confirmation from these new estimations. Columns 2 and 3 of Table 29 report the baseline estimates of model (77) for Italy. Instead, Columns 4 and 5 contain the results obtained applying the IV strategy described in Section 3.5.1. As a quality indicator we considered the Score.[35]

Table 29: Italy, Scaled Estimations

	Benchmark Estimates		IV	
Variables	Scaled OLS	Poisson	Scaled OLS	Poisson
$\text{Fees}_{(ui)*}$	-0.025***	-0.106*	-0.066***	-0.167**
	(0.00)	(0.04)	(0.01)	(0.06)
Cost of $\text{living}_{(ui)*}$	-0.013	0.181	-0.058 ***	-0.741
	(0.02)	(0.24)	(0.02)	(0.41)
$\text{Quality}_{(ui)*}$	0.035***	0.140***	0.037***	0.140***
Score	(0.00)	(0.02)	(0.00)	(0.02)
Host $\text{capacity}_{(ui)*}$	0.046***	0.560***	0.038***	0.527***
	(0.00)	(0.04)	(0.00)	(0.04)
$\text{Income}_{(ui)*}$	0.200***	1.517***	0.264***	1.812***
	(0.01)	(0.10)	(0.01)	(0.13)
Origin FE	yes	yes	yes	yes
R^2	0.393	-	0.385	-
Pseudo R^2	-	0.174	-	-
Nber Obs	11857	11857	11928	11928

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[35] Estimations with the *Ranking* as a proxy of university quality are available upon request.

Table 29 provides additional evidence for a negative impact of fees on international students inflows. Also, the estimates of the other covariates almost perfectly mirror the results obtained considering the baseline model (75). For UK we employ model (77) for the subset of first degree of students. Those are the ones, as Section 3.5.2 explains, for which we are sure about the exogeneity of tuition-fees, when we consider as values of the dependent only international first-degree students coming from EU countries. Table 30 report the result obtained. As in Tables 24 and 25 we obtain a positive estimate for the coefficient on fees only when we consider the subset of non European countries; those for which we suppose that the tuition-fees estimate is biased due to endogeneity issues.

Table 30: UK: Scaled regressions, first-cycle students

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
$\text{Fees}_{(ui)*}$	-0.065***	-0.087***	0.129***	-0.081***	-0.092***	0.197
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.11)
$\text{Cost of living}_{(ui)*}$	0.637***	1.947***	0.392***	1.069***	1.778***	0.844***
	(0.05)	(0.19)	(0.05)	(0.12)	(0.21)	(0.15)
$\text{Quality}_{(ui)*}$	0.068***	0.127***	0.045***	0.061***	0.105***	0.027*
Score	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
$\text{Host capacity}_{(ui)*}$	0.335***	0.739***	0.275***	0.837 ***	0.818***	0.857***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.04)	(0.04)
$\text{Income}_{(ui)*}$	0.120***	-0.061	0.123***	0.301***	0.004	0.355***
	(0.03)	(0.10)	(0.03)	(0.07)	(0.11)	(0.16)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.611	0.451	0.642			
Pseudo R^2	-	-	-	0.096	0.088	0.091
Nber Obs	20996	2900	18096	20996	2900	18096

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Employing model (77) for UK we find additional evidence for a negative impact of tuition-fees on international students inflows. For the estimate concerning Cost of living and income apply the same consideration made in Section 3.5.2.

3.7.1.2 First and Master degree students combined (UK).

The two tables below report the coefficients estimated using the whole flows of international students to UK, i.e flows merging first cycle and master students.

Table 31: UK: All students (first and master degree, Quality = ranking)

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
Fees	-0.059***	-0.080***	0.134***	-0.063***	-0.063***	0.284
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.20)
Cost of living	0.726***	2.199***	0.489***	1.108***	1.270***	0.988***
	(0.05)	(0.18)	(0.05)	(0.20)	(0.36)	(0.25)
Quality	0.056***	0.107***	0.041***	0.093***	0.060***	0.089***
Ranking	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Host capacity	0.382***	0.826***	0.326***	0.919 ***	0.847***	0.959***
	(0.01)	(0.03)	(0.01)	(0.05)	(0.05)	(0.06)
Income	0.171***	0.093	0.157***	0.044	0.269	-0.070
	(0.02)	(0.10)	(0.03)	(0.11)	(0.16)	(0.14)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.694	0.629	0.667	-	-	-
Pseudo R^2	-	-	-	0.757	0.521	0.784
Nber Obs	24360	2900	21460	21228	2900	18328

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 32: All students (first and master degree, Quality = score)

	SCALED OLS			Poisson		
Variables	all	EU	No EU	all	EU	No EU
Fees	-0.060***	-0.081***	0.131***	-0.065 ***	-0.064***	0.264
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.20)
Cost of living	0.718***	2.187***	0.483***	1.073***	1.261***	0.950***
	(0.05)	(0.18)	(0.05)	(0.20)	(0.36)	(0.25)
Quality	0.087***	0.172***	0.063***	0.143***	0.098***	0.135***
Score	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.02)
Host capacity	0.382***	0.823***	0.327***	0.916 ***	0.842***	0.959***
	(0.01)	(0.03)	(0.01)	(0.05)	(0.05)	(0.06)
Income	0.170***	0.088	0.158***	0.0048	0.264	-0.060
	(0.02)	(0.10)	(0.02)	(0.11)	(0.16)	(0.14)
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.694	0.629	0.667	-	-	-
Pseudo R^2	-	-	-	0.756	0.522	0.783
Nber Obs	24360	2900	21460	24360	2900	18328

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.7.2 An IV approach to cost of living

Unlike the results obtained for Italy, all our estimations relative to the UK find a positive impact of the cost of living on the choice of a specific education location. We suspect that this might be driven by the fact that costs of living are positively associated to some unobserved factors of attractiveness at the city level, such as urban amenities. This in turn induces a positive correlation of cost of living with the error term of Eq. (75), biasing upwards the estimated coefficient. This calls for some instrumentation of this variable.

The instrument that we propose for the cost of living is based on the distance from the most touristic cities of the UK. In fact, attractive cities in terms of tourism tend to be more expensive but do not necessarily attract more foreign students. Based on that idea, we first identify the 20 most visited cities in the UK.[36] Then, for each city, we compute the log of (1+ the distance) with respect to the closest of these 20 most visited UK cities. As expected, the data confirms that this measure is negatively associated to the cost of living.[37] The table below reports the result obtained for the sub-sample of EU origin countries for both estimation techniques with our instrumented cost of living variable.

Table 33: UK: Instrumental variable estimates of determinants (EU sub-sample)

Variables	Scaled IV	Poisson IV	Scaled IV	Poisson IV
Fees	-0.040	-0.013	-0.042	-0.013
	(0.02)	(0.3)	(0.02)	(0.03)
Cost of living	-1.741	-2.983*	-1.699	-3.016*
	(0.70)	(1.41)	(1.69)	(1.42)
Quality (ranking)	0.077***	0.019	-	-
	(0.01)	(0.02)		
Quality (score)	-	-	0.127***	0.04
			(0.01)	(0.02)
Host capacity	0.691***	0.702***	0.687***	0.691***
	(0.03)	(0.07)	(0.03)	(0.07)
Income	1.504*	1.829***	1.478*	1.832***
	(0.73)	(0.55)	(0.72)	(0.55)
Origin FE	yes	yes	yes	yes
R^2	0.505	-	0.508	-
F first stage	39.8	-	39.6	-
Robust Score	7.33**	-	7.06**	-
Robust Regression	7.99**	-	7.03**	-
Nber Obs	2900	2900	2900	2900

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Instrument cost of living: minimal distance to top 20 most visited UK cities.

Focusing on the IV Poisson estimation results, we find that (part of) the explanation of the previously obtained positive impact of the cost of living could be driven by endogeneity issues. Instrumenting the

[36]The 20 most visited cities by tourists are: London, Edinburgh, Manchester, Birmingham, Glasgow, Liverpool, Bristol, Oxford, Cambridge, Cardiff, Brighton, Newcastle-upon-Tyne, Leeds, York, Inverness, Bath, Nottingham, Reading, Aberdeen, Chester. This information comes from the following website ouk.about.com/od/getawaysandshorthops/ss/top20.htm, according to data provided by the UK office of national statistics.

[37]The correlation coefficient is found being equal to -0.15.

cost of living with the minimal distance, we find a barely negative significant coefficient. Unfortunately results obtained for quality and fees are at odds with our baseline results, thus calling for a further quest of a better instrument or, alternatively, another covariate able to capture the impact of amenities at destination.

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