Education subsidies in a globalized world: Endogenous policy as a source of brain drain

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We develop a model of a globalized world in which education policy is determined by national governments. Education subsidies are necessary, because of positive knowledge spillovers. Richer and poorer countries are both partly open, which allows a fraction of the high skilled population to migrate to the destination of their choice. In equilibrium, there will be a positive fraction of high skilled workers that emigrate from the poorer to the richer economy. This influences global education policies in two ways. The source country will decrease public education expenditure, because the brain drain leads to a partial loss of its investment in skilled workers. Furthermore, the possibility to emigrate will lead to higher private incentives to invest in education, which decreases the need to for public subsidies. The destination country will reduce education subsidies, because the inflow of high-skilled immigrants decreases the need for domestically educated skilled workers. Remittance payments by emigrants can help to overcome this underinvestment if social planners of both countries anticipate that some of the migrants income is sent back home. We find that nationally optimal policies lead to an aggregate education subsidy that is lower than what would be globally optimal.

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1. Introduction

One major aspect of economic policy that determines a country's innovation potential is education policy. With positive productivity spillovers of human capital, the privately optimal level of education will typically not account for positive externalities and thus be inefficiently low. The government of a closed economy will then have an incentive to subsidize education in order to internalize these spillovers. We now ask, which influence does the possibility of (skilled) migration have on such national education policy? If its benefits can only be partly captured by one country, but become freely available for another, will governments still have enough incentives to subsidize education?
It is clear that with increasing globalization, the incentives to invest in human capital, both private and public, will change. Gradstein and Justman (1995) develop the claim that, if foreign direct investment flows are determined by the relative skill differences between countries, each national government will have an inefficiently high level of public education expenditure, in order to attract foreign funds. But what if it is skilled labor instead of capital, that is internationally mobile?

In this paper, we argue that the incentives for national policymakers to invest in public education decrease as a result of skilled international migration. If national governments anticipate skilled migration flows, they will adapt their education policy accordingly. The purpose of subsidizing education is to internalize its positive externalities and to achieve a level of human capital that is optimal for a country. We argue that the country of origin will have less incentives to invest in education if it anticipates that some of its educated citizens will migrate, and thus take their human capital with them. At the same time, the destination country anticipates that they can free-ride on the human capital of skilled immigrants, and consequently lower their public education expenditure as well. We demonstrate that this behavior of national governments leads to an equilibrium, where the aggregate level of education subsidies and, consequently, human capital is lower than under globally optimal policies. We argue that remittances might be one way to solve this problem.

A big part of the brain-drain literature has argued, that one way to overcome the underinvestment in education can be to open the country for emigration to higher-wage destinations. This will increase the expected skill premium for education, and therefore lead to a higher private incentive to accumulate human capital. The brain drain literature however typically neglects the interplay between emigration and national education policy. If education is not only determined through a private decision, but partly or entirely publicly provided, then emigration will have an effect that goes beyond the private incentive effect. With skilled emigration, not all the recipients of education subsidies will choose to work at home, which decreases the positive impact of the education externality induced by the subsidy. Thus, while the possibility to work abroad will increase the incentives to privately invest in education, it decreases the incentives for public education provision. It has already been recognized that these two mechanisms are linked. Stark and Wang (2002) show that the optimal level of education for a society can both be achieved by either using education subsidies or by allowing for a certain, positive amount of

emigration. Along similar lines, Docquier et al. (2008) show that there is a trade-off between the two instruments, and that emigration can be seen as a substitute for subsidies.

We are adding to this literature, by not only focusing on the optimal policy for a poor, sending country, but also on the influence that skilled migration flows have on the policy in the high-wage destination of migrants, the host country. We propose a model of skilled migration with an exogenous migration rate in an asymmetric world, i.e. where income is considerably higher in one country. Migration then only flows from the country of origin to the host country. We first analyze how emigration affects the education policy of the sending country. For this country, emigration makes it harder to appropriate the positive education effect of a subsidy, since part of the skilled population leaves the country. At the same time, the remaining population has to pay higher taxes in order to finance the public education that the emigrants have received. As a consequence, the optimal education subsidy for the country of origin is decreasing in the skilled emigration rate. Subsequently we analyze the influence of migration on the host country's policy. With skilled immigrants contributing to the aggregate level of its human capital, immigration is decreasing the necessity for public education in the host country. Here also, the optimal subsidy is decreasing in the migration rate.
Through migration, education policy has international spillover effects on aggregate productivity. This however is neglected by the national social planners. In equilibrium, the national education policies are thus lower than what would be globally optimal. We show that this results in a level of human capital that is lower than under a globally optimal education policy. We argue that one way to partly resolve the negative effect of migration on education subsidies and to internalize their international spillovers are remittances. If social planners anticipate that some of the migrant's income will be sent back to the country of origin, this creates incentives to increase education subsidies in both countries. For the country of origin remittances lower the negative effect of skilled migration on the optimal education subsidy, because remittances are increasing in the emigrant's income, and thus in their level of education. The social planner of the host country on the other hand will care less about the income of the immigrants if they send part of it back home. The planner will then have an incentive to increase taxes in order to finance higher education subsidies for the natives.
To our knowledge, this is the first paper that explicitly explores this underprovision problem in the setting of a brain-drain model between first and third world, and assesses the impact on the policy of both countries.

The remainder of this paper is structured as follows. In section 2 we discuss the literature on human capital investment and growth to give a better understanding for the necessity of education subsidies. We then review the literature on brain-drain and labor mobility, and show how our work connects both strands. In section 3 we present a theoretical model of education subsidies and brain-drain, both from the point of view of a sending and a host country. We then investigate how remittances influence the education policies and compare the optimal national policies to the global optimum. Section 4 concludes and discusses policy implications of our findings.

2. Literature review

The literature review is structured as follows. First, we are going to present work that shows that human capital is important for growth, but that due to externalities the aggregate private investment in education will be lower than socially optimal. In the presence of spillovers, education should thus be partly subsidized.
Second, we review the brain-drain/brain-gain literature, which is concerned with the effect of skilled emigration on the poor source countries in the developing world. This literature takes investment in education as a private decision and shows that the possibility to emigrate to a high-wage destination will increase the incentive to invest in education. It thereby shows that skilled migration can serve as a substitute for public education subsidies, by providing a higher expected skill premium. In these models, migration is typically restricted by a fixed migration quota. Since wage differences between first and third world are substantial, workers are assumed to always prefer emigrating over staying, if they are allowed to leave their country. The migration choice is thus not explicitly modeled, an the probability of migration is an exogenous variable which individuals take as given when making their education decision.
Third, we present literature on public education under labor mobility. This literature is concerned with the problem that local authorities might underinvest in education, if skilled workers are mobile and can apply their skills elsewhere. Typically, these models investigate symmetric regions, which engage in a Nash game with other regions, taking the foreign education investment as given. The main reason for underinvestment in these models is free-riding and tax competition between states. Countries will lower their investment in public education, if lower taxes will make them more attractive for high-skilled immigrants. In these models, typically migration will not be restricted by quotas, but there is uncertainty about the transferability of the acquired skills. The motivation for migration depends on the wage differences and the migration costs.

2.1. Evidence for education spillovers and growth effects of education

As has already been pointed out by Lucas (1988), the spillovers of human capital on the entire economy might be large enough to explain long run differences between the income of rich and poor countries. There is ample evidence which shows that aggregate education expenditure, both private and public, has a significant influence on growth and technological innovation. However, there is also evidence that the social return of human-capital investment is higher than the private return. This implies that the equilibrium private investment in education will be lower than the socially optimal level, which justifies education subsidies.[1]
Acemoglu and Angrist (2001) find that aggregate secondary schooling has significantly positive externalities on average wages. This effect becomes smaller when aggregate schooling is instrumented by compulsory schooling laws, but stays significant.
Moretti (2004a) finds evidence that higher rates of postsecondary education create local spillovers

[1] Another justification for education subsidies can be redistributional considerations, as shown in Trostel (1996) and Bovenberg and Jacobs (2005). Other forms of externalities, besides technology spillovers, that are associated with human capital formation are presented in Hall (2006).

on wages of both low- and high-skilled workers. The author demonstrates that a change in the average rate of college graduates at a location strongly increases the average wages of high-school dropouts and high school graduates. The effect on college graduates' average wages is lower, but also significant. Since low- and high-skilled labor are complements, the stronger effect on the average wages of low-skilled workers follows economic intuition.
Along similar lines, Moretti (2004b) shows that it is not only wages that change as a result of a higher average rate of college graduates, but that these go along with increases in productivity of plants. Controlling for the human capital that each firm employs, firms in regions that have a strong increase in the average college graduate rate experience a stronger increase in productivity than firms in other regions.
The findings of these articles suggest that it should be beneficial to subsidize education in order to internalize some of the externalities.

There is indeed evidence that public education expenditure is growth enhancing. Aghion et al. (2009) show that investment in different types of education, high-brow and low-brow, have different implications for growth, depending on the initial technology level of a state. In the presence of skilled migration, regions that are close to the technological frontier should invest more in high-brow education than they would do under autarky. Low-tech states on the other hand, should invest in low-brow education, in order to minimize the brain drain to the other state. The authors present empirical evidence for their claims, using data on education expenditure for the US. While an investment in higher education increases growth significantly for states that are close to the technological frontier, the impact of investment in low-brow education on growth is non-significant. For low-tech states investment in higher education is found to decrease growth, due to the brain-drain that this investment induces. Investment in mid-level education has a significantly positive impact on growth, whereas investment in low-brow education does not considerably contribute to growth.
Their results are related to our findings: In the aggregate, public education provision has a significant impact on growth. However, under the presence of skilled migration a brain-drain makes it difficult for the low-wage locations to appropriate the returns on their investment. In our model, this is one of the reasons that we identify for an underprovision of public education in open developing countries.
In a related article, Stone et al. (2010) show how regions can capture returns to education expenditures when labor is mobile. They find that expenditures in public infrastructure and education are complements, and that isolated expenditures in either of these will have negative effects on growth. However, the complementarity between them is high enough to create spillovers, such that coordinated investments in both will have a significantly positive effect on growth. The authors thus suggest that creating a favorable environment for the educated may be one way to capture the returns to investments in human capital.

2.2. Migration as a substitute for subsidies

This part of the literature is concerned with the impact of high-skilled emigration on developing countries. In these models, migration streams flow typically in one direction and potential earnings in the destination country are considerably higher than in the source country. The possibility to emigrate for high-skilled workers is then found to increase the private incentives to invest in education, thereby reducing the necessity to subsidize education.
Mountford (1997) is mainly concerned with the effect that a brain drain has on the average skill level of a sending country. Most importantly, he models present productivity as a function of the average human capital of the previous period. There is therefore a growth externality to the private education decisions of the previous generation on the present level of output. Workers take the technology as exogenously given when making their education decision. Mountford shows that there will be at least one steady state level of technology. He argues that a higher level of human capital can be achieved if the country opens up to allow for skilled emigration. The higher expected skill premium that probabilistic migration induces increases private incentives to invest in education. If the emigration probability is not too high, a brain-drain will increase the long-term income of the remaining population, if the difference in domestic and foreign skill premiums is sufficiently high. Subsidies are not explicitly discussed, but it is clear that, since individuals do not take the influence of their own human capital on the next generation's technology into account, the no-migration level of education will be inefficiently low.

Stark and Wang (2002) show that both migration and education subsidies can be a way to attain a socially desirable education rate. In their model, the equilibrium autarky level of human capital is too low under private education provision. This is the case because individuals do not consider the positive externality of their education choice on the aggregate productivity. It is subsequently demonstrated that education subsidies can help to achieve the socially desirable human capital level. The authors proceed by showing that allowing for a certain level of skilled emigration to a high wage destination can also lead to an average post-migration human capital level, that is optimal, if the differences between foreign and domestic wages are sufficiently large. In conclusion, it is shown that migration can be an alternative to subsidies. However, the authors do not explicitly calculate the optimal subsidy as a function of the migration rate.

Docquier and Rapoport (2007) argue that, if the government of the source country of migration pays education subsidies, then skilled emigration represents a net fiscal loss. The authors state that this implies that the government will have to respond by either lowering the subsidy or raising taxes for the remaining population. An explicit influence of the migration rate on the optimal subsidy is not calculated.
Docquier et al. (2008) explicitly show that migration can serve as a substitute for education subsidies, from the point of view of a poor, sending country. The authors present an overlapping generations model where education creates intergenerational spillover effects on income and the return to education. All agents are homogeneous in their abilities and can emigrate to a high-wage country at a certain probability, where their expected skill premium is substantially higher. In such a scenario, a situation without migration and public education subsidies

constitutes a first-best solution, if there are no distortion effects related to the subsidy. When migration is possible, the optimal education subsidy is shown to be decreasing in the migration rate. This result is caused by two channels. First, migration reduces the social return to education subsidies, since the beneficial education externalities cannot be captured for migrants. Second, the migration probability stimulates private investment in education, which decreases the necessity of subsidies to achieve the optimal education level. In the empirical part of the paper, the authors find a negative relationship between migration rate and subsidies. It is then concluded, that the beneficial brain-gain effect found in previous literature is likely to be overstated, since the endogeneity of education subsidies is typically not taken into account.
This article is closely related to our work. However, we go beyond the scope of Docquier et al. (2008) by extending our analysis on the impact of migration on education policy in the host and in the source country. Furthermore, we assume a model with different levels of skill and ability, which allows us to identify the effects of migration on the different groups.

Bertoli and Brücker (2011) present a model of a brain-drain from a *low* to a *high* income destination with selective immigration policies. In their model, the probability to be admitted to the high income destination depends linearly on the level of schooling of each individual. They find that, if the social planner maximizes the expected welfare of all the native citizens, even the potential emigrants, the optimal education subsidy will be decreasing in the slope parameter of the migration probability.

In summary, the findings of this part of the literature suggest that migration might be beneficial for the population of the poor source country and that the optimal education subsidy will be lower, if emigration is possible.

2.3. Local education provision and labor mobility

This part of the literature shows that labor mobility lowers incentives for regional governments to invest in publicly provided education. In these models, migration streams flow in both directions, which gives incentives to free-ride on foreign education, both because only a fraction of domestically educated workers remains at home and because immigrants provide freely available skilled-labor.
Justman and Thisse (1997) propose a model in which the amount of education is entirely determined by the authorities of each region. There are two symmetric regions between which skilled workers can migrate. The social planners will invest in education in order to maximize the profit of the local landowners, which depends on a fixed amount of land and skilled labor. After education is completed, a fraction of the skilled workers migrates from one region to the other and vice versa, such that the total fraction of skilled labor that flows out of one jurisdiction equals that of the other region. Each region thus loses part of its own skilled workforce, but receives skilled migrants. This lowers the incentive to invest in local education, since part of the investment is lost, and part of the skilled labor arrives for free. The model represents thus a Nash game between the two regions, where each region takes the other region's education investment as given. Justman and Thisse (1997) show that a higher skilled migration rate will

lead to a lower investment in education. While this main finding is similar to ours, the model is very different, since it cannot capture the incentive effect that the possibility to emigrate has on workers. Furthermore, the authors do not motivate the migration decision of the skilled workers, but just assume that a certain fraction will leave, for whatever reason.
This shortcoming is addressed in Justman and Thisse (2000), where the probability of migration depends on the wage differences between the regions and the location specific amenities. They show that if skilled labor is state provided and mobile, there will be an underprovision of education if the decision is made by the local authorities, instead of a centralized authority. This shortfall in education increases as the monetary motives for migration increase. The result is reverted if the local authorities do not care about local output but about the output of the native population. Then there will be an overprovision of education. As in Justman and Thisse (1997), education decisions are made by the authorities, which implies that the migration probability will not have a positive incentive effect on the education decision of the individuals.
In both papers, migration streams between countries are balanced in equilibrium, which distinguishes them from our work. Furthermore, both models assume that public education provision is necessary, without giving an explicit justification for this, like e.g. externalities. It is simply assumed that there is no private investment in education.

Wildasin (2000) investigates several implications of labor-market integration on the investment in human capital, both public and private, when skilled labor is sector specific and mobile. He finds that, when unskilled workers are immobile and skilled workers value mobility, because it decreases their unemployment risk, public education provision will increase inequalities. With perfect mobility of skilled labor, symmetric jurisdictions will engage in a tax competition that drives taxes on skilled labor to zero. Public education will then be entirely financed by taxes on the unskilled. With labor mobility, the equilibrium level of education subsidies is found to be lower than in the case of non-integrated labor-markets, because higher subsidies decrease welfare by increasing inequality.
Poutvaara and Kanniainen (2000) show that it may be in the interest of *low*-ability workers to subsidize the education of *high*-ability individuals, if the externalities to human-capital are strong enough. However, if skilled individuals are mobile, this result will become infeasible since the skilled will leave the country if emigration increases their potential earnings. If domestic income is higher, the result is also unfeasible because the *low*-ability workers will free-ride, anticipating high skilled immigration from abroad. In equilibrium there will be an underinvestment in education.
Poutvaara (2008) investigates the public and private provision of two types of education in a federal state composed of two separate entities. One skill is country-specific, the other is internationally applicable, but working abroad implies losing a fraction of one's workforce. Wages in both regions are stochastic. Workers who have acquired the transferable skill will migrate to a different location if they can earn more abroad. Individuals will take this into account when choosing their level of education. Each individual has a comparative advantage in one of the skills. Under a public education regime, the government decides who will be trained in which skill, depending on individuals' comparative advantages. The social planner chooses its education policy with the intention of maximizing a welfare function, composed of the weighted

welfare of native stayers, native emigrants and foreign-born immigrants. It is found that, if a local government puts less weight on native emigrants' welfare than that of the stayers, there will be an underprovision of internationally applicable education, compared to the solution that a federal government would choose. This shortfall becomes more important as the international applicability of the transferable skill increases. Poutvaara (2008) then proceeds by showing that financing education through a graduate tax will lead to an equilibrium where each national government will invest more in the internationally applicable skill, compared to a situation with an income tax. A graduate tax allows governments to tax the individuals it has educated, even if they work abroad. This will increase their incentives to invest in internationally mobile students, because emigration will not lead to a shortfall in the tax-base.
The intuition behind the shortfall in a provision of internationally transferable skills is closely related to one of the five mechanisms that we identify in this paper. We show that public education expenditure is lower when the risk to loose some of the initial investment through migration rises. Poutvaara (2008) shows that, if there are two possible education regimes, governments will invest more in region specific skills in order to be sure that their investment stays. The scope of the paper however differs from ours. In Poutvaara (2008), regions are symmetric in their wages and productivity. There is therefore no systematic migration from one region to the other, as in our model. Furthermore, migration is unrestricted for those who acquired the internationally applicable education and they can freely choose whether to move or not. Another main difference is that the model is not concerned with the aggregate amount of education, but the composition of skills of its labor-force. In our model the government provides education subsidies in order to increase the productivity spillovers of education.

In an article that is in between the brain-drain and the labor-mobility literature, Haupt and Janeba (2009) show that a government who cares about maximizing the transfer that it pays to the unskilled part of the population, will decrease education subsidies when skilled migration becomes less costly. In their model, the government extracts taxes from the skilled and redistributes it to the unskilled. The skilled will emigrate if the tax burden becomes too high, in order to avoid exploitation. If migration costs are low, the skilled will be able to make a more credible threat to emigrate and thus stop paying taxes. Since the government invests in human capital in order to extract taxes from them, the investment becomes less attractive, if taxation becomes more constrained due to migration possibilities. Lower migration costs thus lead to less public investment in education.

Egger et al. (2012) investigate the incentives for governments to engage in fiscal competition in order to attract highly-skilled workers. In their model, the brain-drain is an endogenous outcome of education policy, where the national social planners decide to invest less in education in order to have a lower tax burden and higher skilled wages which makes them more attractive for skilled immigrants. They assume that there are no exogenously given migration quotas, but that individuals can freely choose their destination, if they have previously invested in education. Governments provide a homogeneous education regime which is financed by an income tax. Once they have acquired their education, skilled individuals will leave their home if they can attain a higher utility abroad. Individuals are heterogeneous in their perceived

migration cost. This assures that there are no equilibria where all the skilled workers leave one destination. The probability to migrate does not have an influence on the education choice of an individual.
The main results are that national governments of symmetric countries will engage in a tax race to the bottom in order to attract skilled workers. This will lead to an inefficiently low level of public education provision. It is subsequently shown that cooperation between governments will be hard to achieve and that such an equilibrium will be biased against migration. The main reason why we do not observe such a tax competition in our model, is that we assume highly asymmetric countries with substantial wage differences. This insures that migration streams will strictly flow in one direction.
In a related article Demange et al. (2014) predict that governments will lower their income taxes if skilled labor is mobile in order to attract high-skilled workers. In their model, education is financed through a mixture of fees and taxes. They focus on the influence that labor and student mobility has on the optimal financing scheme for education. They conclude that education provision will be increasingly financed by fees, rather than taxes, if migrants can choose their destination freely. This will lead to an underprovision of public education. If students as well are mobile, the result may shift back again, as countries will want to be attractive for high-skilled students as well.

Another article that focuses on student mobility is Mechtenberg and Strausz (2008). In a setting with two symmetric countries and endogenous migration decisions, it is shown that there are two forces that determine the effect of higher student mobility on education expenditure. Countries will want to attract the best students by offering high-quality education, if there is a high probability that they will stay after having completed their studies. On the other hand, they have an incentive to free-ride if the return rate of students is high. This will allow a country to enjoy the benefits of the higher-education provided by a third country without having to invest in education itself.
Lange (2009) also finds that the stay rate of foreign educated students is a key variable in the determination of the effect of increased student mobility on education expenditure. Other related research which finds that the free-riding problem which student mobility causes will decrease public education expenditures are Büttner and Schwager (2004), Gérard (2007), and Krieger and Lange (2010).

In one of the few empirical analyses of the relationship between globalization and education expenditures, Baskaran and Hessami (2010) find that an increase in globalization causes a shift from expenditure on primary education to tertiary education. This is explained by the fact that globalization tends to increase the wages for skilled labor, while it decreases the wages for unskilled workers.[2]
Other empirical papers on the impact of different forms of globalization on education spending, that find mixed results, are Avelino et al. (2005), Dreher et al. (2008), and Busemeyer (2009). Since these papers typically do not measure globalization by skilled migration rates, but rather

[2]Blanchard and Willmann (2013) show how trade liberalization will favor the high-skilled while crowding out the middle-class.

by trade liberalization, the implications of their findings might not be directly applicable to our context.

3. A theoretical model of education subsidies and migration

We now develop a model whose basic setup is similar to Stark and Wang (2002). We show how international migration and remittances can influence in education subsidies, both in sending and host countries. We focus on the case where the social planners of both the source and destination countries take the actual migration rate as given. They will thus adapt their education policy, in order to respond to changes in international migration.

3.1. Setup sending country

Consider the citizens of a poor country. We call this the sending or source country, because migrants will choose to leave this country for a high wage destination. Variables concerning the sending country are denoted by subscript 1. Each individual lives for two periods. When an individual is young, she can invest in education. When grown up, individuals work and produce output, which differs with respect to their previously acquired education. The total population L_1 is composed of N_l individuals that are of *low*-ability and N_h individuals that are of *high* ability. If they are of the *high* type, education causes them a cost of k_h per unit. For the *low* type, the costs are k_l. Clearly, the *high*-ability individuals experience lesser costs for education, therefore $k_h < k_l$. Education is subsidized with s for each consumed unit. These subsidies are financed through a lump sum tax τ, which every individual has to pay in the second period.[3] Stark and Wang (2002) assume an ad-valorem income tax. We depart from this assumption, because a lump sum tax allows us to focus on the implications of migration on education subsidies, without paying increased attention to the implications for the income distribution. This assumption of a lump sum tax to finance education can be equally found in Justman and Thisse (2000), Mechtenberg and Strausz (2008) and Lange (2009).[4]
In addition to their income from work, individuals in the sending country receive remittance payments from emigrated family members, denoted by r.[5]

[3] We assume that there is no intertemporal discounting, both for taxes and income.

[4] Some of the literature has paid closer attention to the design of the education tax. García-Peñalosa and Wälde (2000) state that a graduate tax can at the same time increase efficiency of the subsidy, by increasing the aggregate education level, and reduce inequality, compared to a traditional tax-financed subsidy. Bucovetsky (2003) argues that a progressive income tax might be an efficient way to redistribute gains from migration between regions without hurting incentives to migrate. Poutvaara (2004) and Poutvaara (2008) show that a graduate tax, as opposed to an income tax, can help to overcome the underprovision of publicly financed education in the presence of mobile skilled labor. Del Rey and Racionero (2010) argue that, if deviating from public education provision, higher education should be financed through an income contingent loan with risk-pooling in order to achieve the optimal level of education.

[5] Justman and Thisse (2000) and Poutvaara (2008) assume that the social planner puts a certain weight on the welfare of expatriated natives. Remittances are one way to explain why national governments would care about the income of expats. If the social planner anticipates that part of the income that the emigrants earn abroad is transfered back, she will implicitly place a weight on the well-being of the emigrants, and act accordingly.

The expected lifetime income is composed of their earnings in the second period of their lives, and of their investment in education, minus the subsidy, that they make in the first period. The expected lifetime income of an individual of the *low* type, born in the sending country, depending on his education θ is given by

$$I(\theta)_l = \eta \ln(\bar{\theta}_1 + 1) + \alpha \ln(\theta + 1) - \tau_1 + r - (k_l - s_1)\theta \tag{1}$$

The lifetime income of the individual depends on her own education θ, but also on the average level of human capital $\bar{\theta}$, which the individual takes as given. Stark and Wang (2002) demonstrate that the fact that individuals neglect the positive externality which their education decision has on the average skill level, leads to an aggregate level of education that is lower than optimal, if there are no subsidies and no emigration possibilities.
The optimal level of education for a *low* type can be calculated to be

$$\theta_l^*(s_1) = \frac{\alpha}{k_l - s_1} - 1 \tag{2}$$

$\theta_l^*(s_1)$ has thus the following properties: $\partial\theta_l^*/\partial s_1 > 0$ and $\partial^2\theta_l^*/\partial s_1^2 > 0$.

Individuals of the *high*-ability type are assumed to be able to emigrate to a high wage destination with an exogenous probability p, whereas *low*-ability individuals do not have this opportunity.[6] We now deviate from the initial model by Stark and Wang (2002), by assuming that the income abroad is expected to be $\eta \ln(\bar{\theta}_2+1)+(1-\varphi)\beta \ln(\theta+1)-\tau_2$, where the subscript 2 denotes variables in the richer host country.
We assume that the social returns to education, η, are of the same size in both countries, but that the private returns in the high wage destination are significantly higher, $\beta > \alpha$. Since emigrants will have to adapt to the foreign culture and their new environment, part of their productivity is lost. They thus only earn $(1-\varphi)$ of the private returns to their education, where $0 < \varphi < 1$.
Furthermore, we assume that $\bar{\theta}_2 \geq \bar{\theta}$ if there is no migration. This is a reasonable assumption, because the higher return to education in the host country should assure a higher average educational attainment for a similar distribution of abilities. The difference in wages between the two countries has therefore two sources: the direct return to education is higher, which increases the incentives to invest in education. Furthermore, the higher aggregate level of education leads to a higher income for everyone, independent of their own education decision.[7]
When individuals emigrate, their families back home will expect them to send some remittances. We propose that these remittances are proportional to the lifetime income of the emigrant. She will thus send a fraction $\delta < 1$ of her lifetime income. In order to insure that the possibility to emigrate induces individuals to invest more in their education, expected remittance payments and the loss of productivity must be small enough, such that the effective wage difference is still large enough. We therefore assume that $(1-\varphi)(1-\delta)\beta > \alpha$.

[6] It is a well known finding that skilled individuals are a lot more likely to emigrate than the unskilled. See for example Docquier and Marfouk (2000).

[7] We assume that the population of each country is so large, that each individual neglects the effect that her education decision has on the average level of education.

The expected lifetime income for *high* ability individuals born in the sending country is then

$$\begin{aligned} I(\theta)_h =&(1-p)\left(\eta\ln(\bar{\theta}_1+1)+\alpha\ln(\theta+1)+r-\tau_1-(k_h-s_1)\theta\right) \\ &+p(1-\delta)\left(\eta\ln(\bar{\theta}_2+1)+(1-\varphi)\beta\ln(\theta+1)-\tau_2-(k_h-s_1)\theta\right) \end{aligned} \tag{3}$$

The optimal level of education for a *high* type individual is then calculated as

$$\theta_h^*(s_1)=\frac{\alpha+p(\beta(1-\delta)(1-\varphi)-\alpha)}{(k_h-s_1)(1-p\delta)}-1 \tag{4}$$

The properties of $\theta_h^*(s_1)$ are $\partial\theta_h^*/\partial s_1>0$, $\partial^2\theta_h^*/\partial s_1^2>0$, $\partial\theta_h^*/\partial p>0$, $\partial^2\theta_h^*/\partial p^2=0$, $\partial^2\theta_h^*/\partial s_1\partial p>0$ and $\partial\theta_h^*/\partial\delta<0$.

Obviously, since the educational attainment for *high* and *low* types is determined by the subsidy, also the post-emigration average level of education can be expressed as a function of s.

$$\bar{\theta}_1^*(s_1)=\frac{N_l\theta_l^*(s_1)+(1-p)N_h\theta_h^*(s_1)}{N_l+(1-p)N_h} \tag{5}$$

The social planner's aim is to maximize the expected lifetime income per capita of the domestic post-emigration population. Emigration affects this in three ways. First, it raises the educational investment of high skilled individuals, since they expect a higher potential return to education when migration is possible. Second, it depletes the stock of high skilled individuals. This affects both the average level of education and the taxable income, since part of the tax base leaves the country. Third, the expected remittances increase when p increases, both because of the sheer mass of emigrants, but also because these emigrants have a higher level of education if they expect that their possibility of emigration is high.

As in Stark and Wang (2002), we assume that the parameters of the model are such that a brain-gain is possible for low-enough emigration rates. This means that the average skill-rate of the source country is increasing in p at low emigration rates. The derivative of the average education level with respect to p is calculated as

$$\frac{\partial\bar{\theta}_1^*}{\partial p}=\frac{N_h}{N_l+(1-p)N_h}\Big((1-p)\big(N_l+(1-p)N_h\big)\frac{\partial\theta_h^*}{\partial p}-N_l(\theta_h^*-\theta_l^*)\Big) \tag{6}$$

This becomes negative as p approaches one. For $p=0$, it is positive if the following condition holds.

$$\frac{N_h+N_l}{N_l}(1-\delta)\frac{(1-\varphi)\beta-\alpha}{\alpha}>1-\frac{k_h-s_1}{k_l-s_1} \tag{7}$$

This will be fulfilled for a high enough difference between foreign and domestic private returns to education, $(1-\phi)\beta-\alpha$ and for a remittances that are not excessive. For $(1-\varphi)(1-\delta)\beta\geq 2\alpha$ a brain gain exists at $p=0$ for any values of k_h, k_l and for any values of N_l.[8] For the remainder of the paper, we will assume this effective wage gap is indeed sufficiently large to assure that a brain gain is possible for low emigration rates.

[8] This is analogous to the assumption in Stark and Wang (2002) that $\beta\geq 2\alpha$.

The post-emigration per capita lifetime income of the source country can be calculated as

$$\begin{aligned}
&\bar{W}_1(s_1) = \\
&\frac{1}{N_l + (1-p)N_h} * \\
&[N_l \left(\eta \ln(\bar{\theta}_1^*(s_1) + 1) + \alpha \ln(\theta_l^*(s_1) + 1) + r - \tau_1 - (k_l - s_1)\theta_l^*(s_1)\right) \\
&+ (1-p)N_h \left(\eta \ln(\bar{\theta}_1^*(s_1) + 1) + \alpha \ln(\theta_h^*(s_1) + 1) + r - \tau_1 - (k_h - s_1)\theta_h^*(s_1)\right)]
\end{aligned} \tag{8}$$

To insure equilibrium, the social planner has to set the lump sum tax τ_1 such that the intertemporal budget constraint is fulfilled with equality. Individuals are taxed once they work. High skilled emigrants receive an education subsidy when they are young, but do not pay taxes once they are grown up, because they will earn their income abroad. This increases the tax burden for all remaining individuals.

$$\begin{aligned}
\tau_1(N_l + (1-p)N_h) =& s_1(N_l\theta_l^*(s_1) + N_h\theta_h^*(s_1)) \\
\tau_1 =& s_1 \frac{(L_1 - N_h)\theta_l^*(s_1) + N_h\theta_h^*(s_1)}{L_1 - pN_h}
\end{aligned} \tag{9}$$

In the last line we used $L_1 = N_l + N_h$.

The second constraint is, that the sum of remittances that the inhabitants of the sending country receive have to equal the sum of the share of the lifetime income that the emigrants send back home.

$$\begin{aligned}
&(N_l + (1-p)N_h)r = \\
&pN_h\delta\big((\eta \ln(\bar{\theta}_2^*(s_1) + 1) + (1-\varphi)\beta \ln(\theta_h^*(s_1) + 1) - \tau_2 - (k_h - s_1)\theta_h^*(s_1)\big)
\end{aligned} \tag{10}$$

Setting equations (9) and (10) into (8) and rewriting, we get the following equation for expected per capita lifetime income.

$$\begin{aligned}
&\bar{W}_1(s_1) = \\
&\frac{1}{L_1 - pN_h} * \\
&[(L_1 - N_h) \left(\eta \ln(\bar{\theta}_1^*(s_1) + 1) + \alpha \ln(\theta_l^*(s_1) + 1) - k_l\theta_l^*(s_1)\right) \\
&+ (1-p)N_h \left(\eta \ln(\bar{\theta}_1^*(s_1) + 1) + \alpha \ln(\theta_h^*(s_1) + 1) - k_h\theta_h^*(s_1)\right) \\
&- pN_h s_1 \theta_h^*(s_1) \\
&+ pN_h\delta\big((\eta \ln(\bar{\theta}_2^*(s_1) + 1) + (1-\varphi)\beta \ln(\theta_h^*(s_1) + 1) - \tau_2 - (k_h - s_1)\theta_h^*(s_1)\big)]
\end{aligned} \tag{11}$$

We see from this that the remaining members of the source country have to pay for the education subsidies received by the high-skilled emigrants. However, this is partly or entirely offset by the remittances that the emigrants transfer back home. Whether or not the direct effect on

the budget is positive or negative depends crucially on the fraction of their income that the emigrants send back. The effect of remittances on the optimal education policy will be discussed in a separate section of this paper.
We now first proceed with the setup for the host country.

3.2. Setup destination country

We now develop a model that will allow us to analyze the effect of high-skilled immigration on the education policy of a high wage country. Contrary to the sending country, the host country, or destination country as we also call it, will unambiguously benefit from increased openness, as long as the effective productivity of the high skilled immigrants θ_h^* lies above the average education of the host country under autarky $\bar{\theta}_2^*$. The subscript 2 denotes variables of the host or destination country.
The production technology in the high wage country is slightly different from the poorer country, with private returns to education β instead of α. Natives of the host country will not emigrate. Consequently, the inhabitants do not receive any remittance payments. The lifetime income for a native of the destination country can thus be calculated as

$$I_2(\theta) = \eta(\bar{\theta}_2 + 1) + \beta \ln(\theta + 1) - \tau_2 - (k_2 - s_2)\theta \tag{12}$$

We implicitly make the assumption, that the spillover effect η of education on the technology of the host country is the same as for the sending country. The private return to education on the other hand is considerably larger than in the sending country, $\beta > \alpha$. As in the sending country, education is partly subsidized with s_2. The subsidy is financed through a lump sum tax τ_2 that individuals have to pay in the second period. To simplify our analysis, we assume that all individuals that are born in the destination country are of the same ability, and their perceived costs of education are k_2 per unit.[9] Any individual born in the host country will choose education in order to maximize her lifetime income.
We then find that the optimal level of education for an individual that is born in the host country is

$$\theta_2^*(s_2) = \frac{\beta}{k_2 - s_2} - 1 \tag{13}$$

We impose that β and k_2 are such that $\theta_h^* > \theta_2^* > \theta_l^* \quad p \in (0, 1)$.

As stated in the previous section, immigrants have to be skilled in order to be admitted. However, there is some productivity loss as a result of adapting to a new environment. In addition to the private loss of productivity φ that we already discussed, the education of foreign workers will also contribute less to the positive spillovers than native workers. The spillover

[9] This simplification allows us to concentrate on the implications of immigration on education policy, without having to discuss the distributional consequences. However, as shown by Benhabib (1996), the impact of immigration on the income of natives differs considerably when natives have heterogeneous levels of skill (or capital-labor ratios), and the equilibrium immigration policy will then be determined by the skill-level of the median voter, compared to the skill-level of the immigrants. If the skill of the immigrants is complementary to that of natives, they will benefit from immigration. The resulting immigration policy of a country is such that it benefits the median voter. We would expect that allowing for two skill types in the host country would then imply that low-skilled natives benefit from skilled immigration, while high-skilled natives will not. However, since this is not the question of our paper, we choose to abstract from these distributional concerns.

effect of foreign worker's education on total productivity is reduced by γ. The effective average level of education in the destination country can then be calculated as

$$\bar{\theta}_2^*(s_2, s_1) = \frac{L_2\theta_2^*(s_2) + pN_h(1-\gamma)\theta_h^*(s_1)}{L_2 + pN_h} \tag{14}$$

This is increasing in p as long as $(1-\gamma)\theta_h^* > \theta_2^*$. The education level of high skilled immigrants does not depend on the host country's education policy, because they acquire their skills in the sending country, and receive the sending country's subsidy.[10] As stated in the section above, we assume that $\bar{\theta}_2^* \geq \bar{\theta}_1^*$ for all $p \in (0,1)$.

The social planner of the host country anticipates that immigrants will send a fraction δ of their income as remittances to their families abroad, and thus spend less in the host country. As a consequence, she chooses the education subsidy that maximizes the per capita post-immigration, post-remittance lifetime income of the country's population.

$$\begin{aligned}
&\bar{W}_2(s_2) = \\
&\frac{1}{L_2 + pN_h} * \\
&[L_2\left(\eta(\bar{\theta}_2^*(s_2)+1) + \beta\ln(\theta_2^*(s_2)+1) - \tau_2 - (k_2 - s_2)\theta_2^*(s_2)\right) \\
&+ pN_h(1-\delta)\left(\eta(\bar{\theta}_2^*(s_2)+1) + (1-\varphi)\beta\ln(\theta_h^*(s_1)+1) - \tau_2 - (k_h - s_1)\theta_h^*(s_1)\right)]
\end{aligned} \tag{15}$$

The fact that the social planner takes the remittances of the immigrants into account has the effect of putting a lower weight on their lifetime income than on that of the native population. The social planner of the host country cannot influence the education decision of the high skilled immigrants, because to him, s_1 is an exogenous variable. We will therefore change the notation of immigrant education level from the host county' s point of view to $\theta_h^*(s_1) = \theta_h^*(\bar{s_1}) = \theta_h^*$. The lump sum tax is set in order to fulfill the intertemporal budget constraint.

$$\tau_2(L_2 + pN_h) = s_2 L_2 \theta_2^*(s_2) \tag{16}$$

This simplifies the per capita lifetime income to

$$\begin{aligned}
\bar{W}_2(s_2) = &\frac{1}{L_2 + pN_h}[L_2\left(\eta\ln(\bar{\theta}_2^*(s_2)+1) + \beta\ln(\theta_2^*(s_2)+1) - k_2\theta_2^*(s_2)\right) \\
&+ pN_h(1-\delta)\left(\eta\ln(\bar{\theta}_2^*(s_2)+1) + (1-\varphi)\beta\ln(\theta_h^*+1) - (k_h - s_1)\theta_h^*\right) \\
&+ pN_h\delta s_2\theta_2^*(s_2)\frac{L_2}{L_2 + pN_h}]
\end{aligned} \tag{17}$$

Since only part of the income of the immigrants remains in the economy of the destination country, the social planner cares less about the loss that the tax imposes on the immigrants' lifetime

[10] It could be argued that the education policy of the host country has an indirect effect on the education in the sending country, because it improves technology in the destination country and thereby the expected return to migration. However, we chose to model the spillover such that it creates a non-skill dependent income effect, and will therefore not influence the education decision of potential immigrants.

income. The subsidy creates a redistribution of income form the immigrants to the natives: Only the natives receive the subsidy, but it is financed through a tax on both groups. Since the social planners cares implicitly more about the income of the natives under the presence of remittances, this explains the positive last term in equation (17).

3.3. Education policy of the source country without remittances

In order to be able to clearly distinguish the different channels through which emigration influences the education policy in the sending country, we will now first look at a scenario, where the expected remittances are zero. Since there is no formal commitment by the emigrants to send money back home, this might be a realistic starting point for our analysis. Throughout this section we thus set

$$r = \delta = 0 \tag{18}$$

We now analyze how a government that wants to maximize the lifetime income of its post-emigration domestic population will adapt its education policy to an increase in the skilled emigration rate. We take the derivative of equation (11) with respect to s_1 and set it equal to zero to receive the social planner's first order condition.

$$\begin{aligned}\frac{d\bar{W}_1(s_1^*)}{ds_1}|_{\delta=0} =&(L_1 - N_h)\Big(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial\bar{\theta}_1^*}{\partial s_1} + \big(\frac{\alpha}{\theta_l^*(s_1^*)+1} - k_l\big)\frac{\partial\theta_l^*}{\partial s_1}\Big)\\ &+(1-p)N_h\Big(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial\bar{\theta}_1^*}{\partial s_1} + \big(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial\theta_h^*}{\partial s_1}\Big)\\ &-pN_h\left(s_1^*\frac{\partial\theta_h^*}{\partial s_1} + \theta_h^*(s_1^*)\right) \stackrel{!}{=} 0\\ &\equiv g_1(s_1^*, p)|_{\delta=0}\end{aligned} \tag{19}$$

Proposition 1. *When the social planner of the source country sets the education policy in order to maximize expected lifetime income of the local post-emigration population and if there are no remittances, the optimal education subsidy, s_1^*, is strictly decreasing in the skilled emigration rate p, for p small enough in order to insure $\frac{\partial\bar{\theta}_1^*}{\partial p} > 0$.*

Proof. We refrain from solving explicitly for s_1^* as a function of p, but will instead use the implicit function theorem to obtain an expression for $\frac{ds_1^*}{dp}$. Since

$$\frac{\partial s_1^*}{\partial p}(p) = -\frac{\frac{\partial g_1}{\partial p}(p, s_1^*(p))}{\frac{\partial g_1}{\partial s_1}(p, s_1^*(p))} \tag{20}$$

we need to determine the partial derivatives of g_1 with respect to p and s_1. $\partial g_1/\partial s_1 < 0$ is a necessary condition for s_1^* to be a local maximum.[11]

$$\frac{\partial g_1(s_1^*)}{\partial s_1}|_{\delta=0} < 0 \tag{21}$$

[11] This will be the case if the social planner's objective function is concave in the education subsidy. We verify this in the Appendix.

It is thus sufficient to show that $\partial g_1/\partial p < 0$.
In order to get to know the effect of migration on the optimal subsidy, we now take the derivative with respect to p.

$$\begin{aligned}
&\frac{\partial g_1}{\partial p}(s_1^*(p),p)|_{\delta=0} = \\
&(L_1 - pN_h)\left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial^2\bar{\theta}_1^*}{\partial s_1 \partial p} - \frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\frac{\partial\bar{\theta}_1^*}{\partial s_1}\frac{\partial\bar{\theta}_1^*}{\partial p}\right) \\
&-N_h\left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial\bar{\theta}_1^*}{\partial s_1} + \left(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\right)\frac{\partial\theta_h^*}{\partial s_1} + s_1^*\frac{\partial\theta_h^*}{\partial s_1} + \theta_h^*(s_1^*)\right) \\
&+(1-p)N_h\left(\frac{\partial^2\theta_h^*}{\partial s_1\partial p}\left(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\right) - \frac{\alpha}{(\theta_h^*(s_1^*))^2}\frac{\partial\theta_h^*}{\partial s_1}\frac{\partial\theta_h^*}{\partial p}\right) \\
&-pN_h\left(s_1^*\frac{\partial^2\theta_h^*}{\partial s_1\partial p} + \frac{\partial\theta_h^*}{\partial p}\right)
\end{aligned} \tag{22}$$

where we used the fact that $\frac{\partial\theta_l^*}{\partial p} = 0$ to simplify. Rewriting the above expression, using the FOC and some other operations[12], we get that

$$\begin{aligned}
&\frac{\partial g_1}{\partial p}(s_1^*(p),p)|_{\delta=0} = \\
&-(L_1 - pN_h)\left(\frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\frac{\partial\bar{\theta}_1^*}{\partial s_1}\frac{\partial\bar{\theta}_1^*}{\partial p}\right) \\
&-N_h\Big(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\Big(\frac{\partial\theta_h^*}{\partial s_1} - (1-p)\frac{\partial^2\theta_h^*}{\partial s_1\partial p}\Big) + \theta_h^*(s_1^*)\Big) \\
&-(1-p)N_h\Big((s_1^* + \frac{(k_h - s_1^*)p(\beta-\alpha)}{\alpha + p(\beta-\alpha)})\frac{\partial^2\theta_h^*}{\partial s_1\partial p} + \frac{\alpha}{(\theta_h^*(s_1^*))^2}\frac{\partial\theta_h^*}{\partial s_1^*}\frac{\partial\theta_h^*}{\partial p}\Big) \\
&-pN_h s_1^*\frac{\partial^2\theta_h^*}{\partial s_1\partial p}
\end{aligned} \tag{23}$$

For p such that $\partial\bar{\theta}_1^*/\partial p > 0$ we can then state that[13]

$$\frac{\partial g_1(s_1^*)}{\partial p}|_{\delta=0} < 0 \tag{24}$$

Together with equation (21) this implies that

$$\frac{\partial s_1^*}{\partial p}|_{\delta=0} < 0 \tag{25}$$

□

The higher the emigration rate of skilled workers, the lower the optimal education subsidy. This is intuitive. If all educated individuals remained in their birthplace, the increase in the

[12] See Appendix
[13] See Appendix for proof

aggregate education induced by the subsidy would be captured entirely by the country. With emigration however, there are five channels that lower the benefits of the subsidy.

First, the effect that the subsidy has on the average skill level is directly influenced by skilled emigration. We call this the *appropriation* effect. The subsidy increases the optimal private level of human capital, both for skilled and unskilled individuals, and through this, the average skill level. However, part of this effect is lost due to migration, because a fraction of the skilled will leave the country, taking with them their human capital. This effect is partly offset, because with a higher migration probability, the incentive effect of the subsidy is magnified for the *high* ability individuals, $\partial^2\theta_h^*/\partial s_1 \partial p > 0$. Overall however, migration makes it more difficult to *appropriate* the positive effects of a subsidy.

Second, as also shown by Docquier et al. (2008), the incentive effect that the possibility of emigration to a high-wage country induces, serves as a substitute for subsidies. The higher the migration rate, the higher the level of education of the *high*-ability individuals. A brain-gain thus brings the economy closer to its optimal average level of education, and a subsidy becomes less necessary. This effect, interacted with the higher tax burden for the remaining population has an additional negative effect on the optimal subsidy. With a higher migration rate, the *high*-ability individuals will invest more in education, thus receiving a higher subsidy. When some of those emigrate, the tax burden for the remaining population becomes even higher.

Third, part of the most skilled individuals will leave the country before they start their productive activities. The welfare effect that the subsidy has on these high-skilled emigrants is not accounted for, if the social planner cares only about the welfare of the post-emigration population. The emigrants will not experience the positive influence that the subsidy has on the source country's productivity, because they choose to work abroad.

Fourth, the high skilled emigrants do not pay taxes once they emigrated. The remaining population has thus to pay for the education subsidy that the emigrants received prior to their emigration. The higher the emigration rate, the higher the per capita tax rate will be, in order to finance the education subsidies. This will lead to a lower optimal education subsidy, in order to lower the taxes for the remaining population.

Fifth and last, the *high*-ability workers will invest more in education if they can emigrate at a certain probability. Those *high*-ability workers that stay behind, will have over-invested in education, because their actual private return to education α is lower than the expected private return $\alpha + p(\beta - \alpha)$. It is thus, *ex-post*, counter-productive to further increase their investment by subsidizing their education.[14]

Some of the channels are related, but not identical to the ones already identified in the literature. The high tax burden on the remaining population for example has been identified by Wildasin (2000) as one reason for why labor mobility will lower public education expenditure. In Wildasin (2000) however, the reason for the high tax burden is that national governments will lower taxes in order to attract high-skilled immigrants. This motive is absent in our analysis. In our model, the taxes for the *low* ability workers rise, because the tax-base shrinks due to emigration, not because of fiscal competition.

Proposition 2. *With p such that $\partial\bar{\theta}_1^*/\partial p < 0$, it may or may not be that the optimal education*

[14] See Appendix for an identification of the five distinct effects in equation (22).

subsidy is decreasing in p.

When we have a situation where the skilled emigration rate p is so high, that the source country experiences a net brain-drain, it depends on the parameters of the model, whether or not a further increase in the emigration rate will lower the optimal education subsidy. If the population of *low* ability workers N_l is large compared to the *high* ability group, it can be that the brain-drain effect on the education subsidy dominates the other effects. An additional condition for this to occur, is that η, the social return to education, must be relatively high compared to α and β, the domestic and foreign private return to education.

The intuition behind this is the following. If η is relatively high, compared to the private return to education, the difference between the optimal private amount of education and the social optimum will be very high. In such a scenario, the need for an education subsidy is especially important. With an important brain drain, a big fraction of the *high* ability workers will leave the country and not contribute to the average skill level of the source country. The social planner may then choose to increase the skill-level of the *low*-ability workers in order to boost the average skill level. Since we only allow for one subsidy, aimed both at *low* and *high* ability workers, it may then be, for large N_l, that the motive to fight off the brain drain by investing more in education, will dominate the other motives.[15]
For moderate values of η, the brain drain motive should typically not dominate the other motives.

3.4. Education policy of the host country without remittances

For the host country as well, we will start to analyze the case without remittances, i.e. $\delta = r = 0$. Taking the partial derivative of equation (17) with respect to s_2, the first order condition of the social planner can be calculated as

$$\begin{aligned}\frac{\partial \bar{W}_2}{\partial s_2}(s_2^*)|_{\delta=0} =& (L_2 + pN_h)\left(\frac{\eta}{\bar{\theta}_2^*(s_2^*)+1}\frac{\partial \bar{\theta}_2^*}{\partial s_2}\right) + L_2\left(\frac{\beta}{\theta_2^*(s_2^*)+1} - k_2\right)\frac{\partial \theta_2^*}{\partial s_2} \\ &\stackrel{!}{=} 0 \\ &\equiv g_2(s_2^*(p), p)|_{\delta=0}\end{aligned} \tag{26}$$

Proposition 3. *When the social planner of the destination country chooses its education policy in order to maximize the expected lifetime income of the post-immigration population in the host country, the optimal education subsidy s_2^* will be strictly decreasing in the skilled migration rate p, as long as $(1+\gamma)\theta_h^* > \theta_2^*$.*

Proof. Using equation (14) and noting that $\partial \theta_h^*/\partial s_2 = 0$, $\partial \theta_2^*/\partial s_2 > 0$ and that $\beta/(\theta_2^*+1) - k_2 = -s^*$, we can further simplify $g_2(s_2^*, p)$.

$$g_2(s_2^*(p), p)|_{\delta=0} = \frac{\eta}{\bar{\theta}_2^*(s_2^*)+1} - s_2^* \stackrel{!}{=} 0 \tag{27}$$

[15] This finding is related to Poutvaara (2008), who finds that a government will invest more in non-transferable skills. We find that, if the population of *low* ability workers, who by assumption cannot emigrate, is large, the provision of the subsidy will respond positively to emigration.

As in the previous section, we are now using the implicit function theorem on $g_2(s_2^*(p), p)$ in order to find $\frac{\partial s_2^*}{\partial p}$.
We first calculate $\frac{\partial g_2}{\partial s_2}$.

$$\frac{\partial g_2}{\partial s_2}(s_2^*(p), p)|_{\delta=0} = -\left(\frac{\eta}{(\bar{\theta}_2^*(s_2^*)+1)^2}\frac{L_2}{L_2+pN_h}\right)\frac{\partial \theta_2^*}{\partial s_2} - 1 < 0 \tag{28}$$

As before, average utility is a concave and increasing function of the subsidy, and there therefore exists a maximum. Taking the derivative of g_2 with respect to p, we obtain

$$\frac{\partial g_2}{\partial p}|_{\delta=0} = -\frac{\eta}{(\bar{\theta}_2^*(s_2^*)+1)^2}\frac{\partial \bar{\theta}_2^*}{\partial p} < 0 \tag{29}$$

Taken together with equation (28) and the implicit function theorem, this implies, that

$$\frac{\partial s_2^*}{\partial p}|_{\delta=0} < 0 \tag{30}$$

□

As for the source country, the education optimal education subsidy is thus found to be decreasing in the skilled migration rate p. For the host country, the reasoning behind this is different than for the sending country. Immigration increases the average level of education for the destination country unambiguously, as long as the loss in productivity that relocation induces does not set off the education advantage of the foreigners, i.e. as long as $(1-\gamma)\theta_h^* > \theta_2^*$. Therefore, high skilled immigration can be seen as a subsidy for education subsidies, that does not impose any costs on the host country. The country has to invest less in order to attain the educational level it is aiming for, if immigration is possible and can free-ride on the education policy of the source country.

3.5. The policy-effect of remittances

In the two previous sections, we have shown that in the absence of remittances, migration will unambiguously lower public education provision, both in the sending and in the host country. The problem becomes more complex, if we start to account for remittances.
We will first investigate the effect on the optimal policy of the sending country.

3.5.1. Remittance effect sending country

The social planner's first order condition (19) changes to

$$
\begin{aligned}
\frac{d\bar{W}_1(s_1^*)}{ds_1} =&(L_1 - N_h)\Big(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial\bar{\theta}_1^*}{\partial s_1} + \big(\frac{\alpha}{\theta_l^*(s_1^*)+1} - k_l\big)\frac{\partial\theta_l^*}{\partial s_1}\Big) \\
&+(1-p)N_h\Big(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial\bar{\theta}_1^*}{\partial s_1} + \big(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial\theta_h^*}{\partial s_1}\Big) \\
&+pN_h\delta\Big(\frac{\eta}{\bar{\theta}_2^*(s_1^*)+1}\frac{\partial\bar{\theta}_2^*}{\partial s_1} + \big(\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial\theta_h^*}{\partial s_1}\Big) \\
&-pN_h(1-\delta)\left(s_1^*\frac{\partial\theta_h^*}{\partial s_1} + \theta_h^*(s_1^*)\right) \stackrel{!}{=} 0 \\
\equiv& g_1(s_1^*, p, \delta)
\end{aligned}
\tag{31}
$$

A rational social planner of the source country will take the influence of its education policy on the average foreign human capital level $\bar{\theta_2}$ into account. Increasing the education subsidy in the source country leads to a higher level of education among the emigrants, which will in turn have a positive impact on the average skill level in the destination country. Consequently, this will then also result in higher remittances.
The total influence of remittances on the optimal education policy is described by the following proposition.

Proposition 4. *If emigrants remit a fraction δ of their lifetime income to their country of origin, the optimal education subsidy of the sending country s_1^* will be unambiguously increasing in this fraction, if $\delta \leq 1/2$.*[16]

$$
\frac{\partial s_1^*}{\partial \delta} > 0 \tag{32}
$$

Proof. We make again use of the implicit function theorem and take the derivative of g_1 with respect to δ. As we have shown before, s_1^* describes a local welfare maximum, and it must again be that $\partial g_1(s_1^*)/\partial s_1 < 0$. The sign of $\partial g_1(s_1^*)/\partial\delta$ will thus be the same as for $\partial s_1^*/\partial\delta$. After

[16] Note that $\delta \leq 1/2$ is merely a sufficient, but by no means a necessary condition for $\frac{\partial s_1^*}{\partial\delta} > 0$. There are many parameter constellations for which $\frac{\partial s_1^*}{\partial\delta} > 0$ is indeed positive for $\delta \in (0,1)$.

some operations[17] we get the result that

$$\frac{\partial g_1(s_1^*)}{\partial \delta} =$$

$$\underbrace{-(L_1 - pN_h)\frac{\eta}{(\bar{\theta}_1^* + 1)^2}\frac{\partial \bar{\theta}_1^*}{\partial s_1}\frac{\partial \bar{\theta}_1^*}{\partial \delta}}_{>0} \quad \underbrace{-pN_h(1-\delta)(s_1^*\frac{\partial^2 \theta_h^*}{\partial s_1 \partial \delta} + \frac{\partial \theta_h^*}{\partial \delta})}_{>0}$$

$$\underbrace{+(1-p)N_h\Big((\frac{\eta}{\bar{\theta}_1^* + 1} + \frac{\alpha}{\theta_h^* + 1} - k_h)\frac{\partial^2 \theta_h^*}{\partial s_1 \partial \delta} - \frac{\alpha}{(\theta_h^* + 1)^2}\frac{\partial \theta_h^*}{\partial s_1}\frac{\partial \theta_h^*}{\partial \delta}\Big)}_{>0}$$

$$\underbrace{+pN_h\delta\Big(- \frac{\eta}{(\bar{\theta}_2^* + 1)^2}\frac{\partial \bar{\theta}_2^*}{\partial s_1}\frac{\partial \bar{\theta}_2^*}{\partial \delta} - \frac{(1-\varphi)\beta}{(\theta_h^* + 1)^2}\frac{\partial \theta_h^*}{\partial s_1}\frac{\partial \theta_h^*}{\partial \delta} - s_1^*\frac{\partial^2 \theta_h^*}{\partial s_1 \partial \delta}\Big)}_{>0}$$

$$\underbrace{+pN_h\Big(\frac{\eta}{\bar{\theta}_2^*(s_1^*) + 1}(\frac{\partial \bar{\theta}_2^*}{\partial s_1} + \delta\frac{\partial^2 \bar{\theta}_2^*}{\partial s_1 \partial \delta}) + \big(\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*) + 1} - (k_h - s_1^*)\big)(\frac{\partial \theta_h^*}{\partial s_1} + \delta\frac{\partial^2 \theta_h^*}{\partial s_1 \partial \delta}) + \theta_h^*(s_1^*)\Big)}_{\lesseqgtr 0} \tag{33}$$

We can show that the last line is unambiguously positive for $\delta \leq 1/2$.[18]
Thus, we find that

$$\frac{\partial g_1(s_1^*)}{\partial \delta}|_{\delta \leq \frac{1}{2}} > 0 \tag{34}$$

□

This proposition tells us, that the negative effect that skilled emigration has on education subsidies in the country of origin is countered by a positive remittance effect. Higher expected remittances imply, that the social planner of the sending country will put a greater weight on the influence that its education policy has on the lifetime earnings of emigrants. Indeed, for very large income differences between host and sending countries and at very high remittance rates, it is possible that the total effect of emigration on education subsidies is reversed by the remittance effect. In such a scenario, the tax burden and the appropriation effect are dominated by the increase in net remittances, that an increase in the education subsidies would imply.

Proposition 5. *For large enough differences in the effective private returns to education between sending and host countries,* $(1-\varphi)\beta >> \alpha$*, and for large enough remittance shares* δ*, it is possible that the optimal education policy of the sending country is increasing in p.*[19]

The intuition behind this proposition is, that at high remittance rates and high differences between foreign and domestic private returns to education, it is worthwhile to increase education subsidies, because the expected increase in remittances this causes will be larger than the net tax loss. While one might suspect that very high private education returns in the destination country would be sufficient to increase private investment in education to the desired point, this is not necessarily the case if the remittance rate is very high. Therefore, the social planner

[17] See Appendix
[18] See Appendix
[19] See Appendix for an illustration of this proposition

will want to subsidize education in order to give sufficient incentives for potential emigrants to invest in their education, thereby increasing the expected future remittances.

3.5.2. Remittance effect host country

In the destination country as well, remittances will influence the optimal education policy. To get the destination country's FOC with remittances, we take the derivative of equation (17) with respect to s_2.

$$\begin{aligned}\frac{\partial \bar{W}_2}{\partial s_2}(s_2^*) =&(L_2 + (1-\delta)pN_h)\left(\frac{\eta}{\bar{\theta}_2^*(s_2^*)+1}\frac{\partial \bar{\theta}_2^*}{\partial s_2}\right) + L_2\left(\frac{\beta}{\theta_2^*(s_2^*)+1} - k_2\right)\frac{\partial \theta_2^*}{\partial s_2} \\ &+ \delta\frac{pN_hL_2}{L_2+pN_h}(s_2^*\frac{\partial \theta_2^*}{\partial s_2} + \theta_2^*) \\ &\stackrel{!}{=} 0 \\ &\equiv g_2(s_2^*(p), p, \delta)\end{aligned} \tag{35}$$

It can be immediately seen from the last term, that at higher remittances, the net effect of subsidies on the tax burden is increasing. Since immigrants only spend part of their lifetime income in the destination country, the social planner will be willing to tax them more, in order to be able to afford more public education for the natives. At the same time, the social planner also cares less about the impact of the education induced productivity spillover of subsidies on the immigrants.
We can still formulate a clear proposition with respect to the effect of remittances on the destination country' s policy.

Proposition 6. *If immigrants remit a fraction δ of their lifetime income to their country of origin, the optimal education subsidy in the destination country will be increasing in this remittance rate.*

$$\frac{\partial s_2^*}{\partial \delta} > 0 \tag{36}$$

Proof. We can rewrite equation (35), making use of the fact that $\frac{\beta}{\theta_2^*(s_2^*)+1} - k_2 = -s_2^*$ and that $\partial \bar{\theta}_2^*/\partial s_2 = L_2/(L_2+pN_h)(\partial \theta_2^*/\partial s_2)$.

$$g_2(s_2^*, p, \delta) = \frac{L_2}{L_2+pN_h}\Big((L_2+(1-\delta)pN_h)\underbrace{(\frac{\eta}{\bar{\theta}_2^*(s_2^*)+1} - s_2^*)}_{<0}\frac{\partial \theta_2^*}{\partial s_2} + \delta pN_h\theta_2^*(s_2^*)\Big) \stackrel{!}{=} 0 \tag{37}$$

The term we have pointed out has to be strictly negative for equation (37) to hold.
We now take the derivative with respect to δ, noting that $\frac{\partial \theta_2^*}{\partial \delta} = 0$ and $\frac{\partial \bar{\theta}_2^*}{\partial \delta} < 0$.

$$\begin{aligned}\frac{\partial g_2(s_2^*, p, \delta)}{\partial \delta} =&pN_h\Big(-(\frac{\eta}{\bar{\theta}_2^*(s_2^*)+1} - s_2^*)\frac{\partial \theta_2^*}{\partial s_2} + \theta_2^*(s_2^*)\Big) \\ &-(L_2+(1-\delta)pN_h)\frac{\eta}{(\bar{\theta}_2^*+1)^2}\frac{\partial \theta_2^*}{\partial s_2}\frac{\partial \bar{\theta}_2^*}{\partial \delta} > 0\end{aligned} \tag{38}$$

Together with the condition that $\partial g_2/\partial s_2 < 0$, the implicit function theorem then tells us that

$$\frac{\partial s_2^*}{\partial \delta} > 0 \tag{39}$$

□

There are thus indeed two effects of remittances on the optimal subsidy in the destination country. First, there is the direct effect, that with higher remittances, less of the lifetime income of the immigrants stays in the host economy. The social planner thus cares less about the lifetime income of immigrants. He will then raise higher taxes in order to subsidize the education of natives. Second, sine remittances decrease the incentives for immigrants to invest in education, the average level of education of immigrants will be lower if their families expect remittance payments. To counter this effect, the social planner of the host country will then increase education subsidies, in order to increase the education of the natives.
As for the sending country, it is possible that this remittance effect leads to an overall positive influence of immigration on education subsidies.

Proposition 7. *For large remittance rates δ and $\partial\bar{\theta}_2^*/\partial p$ small enough, it is possible that $\partial s_2^*/\partial p > 0$.*

We illustrate this in the appendix. This reversal can only occur, if the effective skill difference between sending and host country $(1-\gamma)\theta_h^* - \theta_2^*$ is very small, such that the free-ride motive of the host-country's education policy gets dominated by the remittance-driven tax motive.

3.6. A global view on education subsidies

We have shown above that national educational policies depend on the degree of openness of the economies. If migration between the two economies is possible, both have an incentive to lower or increase their educational subsidies, depending on the level of remittances.
We now want to ask the question of whether this national behavior is optimal from an aggregate view. As has been shown by Justman and Thisse (2000), Poutvaara (2008), Egger et al. (2012), and Demange et al. (2014), if countries are symmetric and national governments take the education spending of the other country as given, than the equilibrium education expenditure in each country will be lower than the globally optimal expenditure. With symmetric countries, this is driven by two main channels. First, each country is concerned about losing its investment, if skilled workers are mobile. Second, with symmetry between countries, the migration decision is typically endogenous. The national governments will then engage in a fiscal race to the bottom and lower expenditures and taxes in order to become attractive for potential immigrants.
We now want to show that the finding, that in a mobile world national public education provision will be lower than globally optimal, also holds for highly asymmetric countries, where the migration is an exogenous variable. As we have shown, in the absence of remittances migration decreases the incentive of each region to invest in education. We will now compare the national education policies, with the one chosen by a social planner, who aims at maximizing the global lifetime income per capita.
We look at a scenario, in which the social planner can set an optimal subsidy in each country

and finance it by raising taxes in both countries. The social planner will then set an education policy in order to maximize global per capita lifetime income $\bar{W}_G$

$$\begin{aligned}\bar{W}_G =& \frac{1}{L_1+L_2}[L_2\left(\eta\ln(\bar{\theta}_2^*(s_1,s_2)+1)+\beta\ln(\theta_2^*(s_2)+1)-\tau_2-(k_2-s_2)\theta_2^*(s_2)\right)\\ &+pN_h(1-\delta)\left(\eta\ln(\bar{\theta}_2^*(s_1,s_2)+1)+(1-\varphi)\beta\ln(\theta_h^*(s_1)+1)-\tau_2-(k_h-s_1)\theta_h^*(s_1)\right)\\ &+(1-p)N_h\left(\eta\ln(\bar{\theta}_1^*(s_1)+1)+\alpha\ln(\theta_h^*(s_1)+1)+r-\tau_1-(k_h-s_1)\theta_h^*(s_1)\right)\\ &+N_l\left(\eta\ln(\bar{\theta}_1^*(s_1)+1)+\alpha\ln(\theta_l^*(s_1)+1)+r-\tau_1-(k_l-s_1)\theta_l^*(s_1)\right)]\end{aligned} \tag{40}$$

The global inter-temporal budget constraint [20] is then the following:

$$L_2s_2\theta_2^*+N_hs_1\theta_h^*+N_ls_1\theta_l^*\leq(L_2+pN_h)\tau_2+(L_1-pN_h)\tau_1 \tag{41}$$

The remittance constraint as described by equation (10) remains unchanged. Setting the two constraints into the objective function, equation (40) simplifies to

$$\begin{aligned}\bar{W}_G =& \frac{1}{L_1+L_2}[L_2\left(\eta\ln(\bar{\theta}_2^*(s_1,s_2)+1)+\beta\ln(\theta_2^*(s_2)+1)-k_2\theta_2^*(s_2)\right)\\ &+pN_h\left(\eta\ln(\bar{\theta}_2^*(s_1,s_2)+1)+(1-\varphi)\beta\ln(\theta_h^*(s_1)+1)-k_h\theta_h^*(s_1)\right)\\ &+(1-p)N_h\left(\eta\ln(\bar{\theta}_1^*(s_1)+1)+\alpha\ln(\theta_h^*(s_1)+1)-k_h\theta_h^*(s_1)\right)\\ &+N_l\left(\eta\ln(\bar{\theta}_1^*(s_1)+1)+\alpha\ln(\theta_l^*(s_1)+1)-k_l\theta_l^*(s_1)\right)]\end{aligned} \tag{42}$$

From this we see that the average welfare is only indirectly affected by the policy, through the education choice of the individuals.

We will now compare the globally optimal policies for each country with those chosen by the national governments. First we take the derivative of the global objective function with respect to the subsidy imposed on the sending country.

$$\begin{aligned}\frac{d\bar{W}_G}{ds_1} =& (L_2+pN_h)\frac{\eta}{\bar{\theta}_2^*(s_{G,1}^*)+1}\frac{\partial\bar{\theta}_2^*}{\partial s_1}+(N_l+(1-p)N_h)\frac{\eta}{\bar{\theta}_1^*(s_{G,1}^*)+1}\frac{\partial\bar{\theta}_1^*}{\partial s_1}\\ &+N_l\left(\frac{\alpha}{\theta_l^*(s_{G,1}^*)+1}-k_l\right)\frac{\partial\theta_l^*}{\partial s_1}+(1-p)N_h\left(\frac{\alpha}{\theta_h^*(s_{G,1}^*)+1}-k_h\right)\frac{\partial\theta_h^*}{\partial s_1}\\ &+pN_h\left(\frac{(1-\varphi)\beta}{\theta_h^*(s_{G,1}^*)+1}-k_h\right)\frac{\partial\theta_h^*}{\partial s_1}\stackrel{!}{=}0\\ &\equiv g_{G,1}(s_{G,1}^*,p)\end{aligned} \tag{43}$$

Proposition 8. *The globally optimal education subsidy for the source country $s_{G,1}^*$ will be strictly higher than the optimal national policy s_1^* if the skilled migration rate is strictly positive,*

[20] Note that, if we chose the somewhat stronger budget constraint, that every region has to have a balanced budget, this would not change the result, because both budget constraints cancel out. See Appendix for proof.

$p > 0$, *for all* $\delta \in (0,1)$.

Proof. We simplify equation (43), using equation (19) and compare it to $g_1(s^*_{G,1}, p)$ as defined in equation (31).

$$
\begin{aligned}
& g_{G,1}(s^*_{G,1}, p) = \\
& g_1(s^*_{G,1}, p) + (L_2 + (1-\delta)pN_h)\frac{\eta}{\bar{\theta}^*_2(s^*_{G,1}) + 1}\frac{\partial \bar{\theta}^*_2}{\partial s_1} \\
& + (1-\delta)pN_h\Big(\underbrace{\big(\frac{(1-\varphi)\beta}{\theta^*_h(s^*_{G,1}) + 1} - (k_h - s^*_{G,1})\big)}_{>0}\frac{\partial \theta^*_h}{\partial s_1} + \theta^*_h(s^*_{G,1})\Big) \overset{!}{=} 0
\end{aligned}
\tag{44}
$$

The global FOC is the same as for the sending country if $p = 0$, since $\frac{\partial \bar{\theta}^*_2}{\partial s_1}|_{p=0} = 0$. Under autarky, the global government and the national government would thus choose the same education policy.
The second term and third term are strictly positive for $p > 0$ and $\delta < 1$. For the FOC to be fulfilled, it has to be that $s^*_{G,1} > s^*_1$ for $p > 0$, because $\partial g_1 / \partial s_1 < 0$. □

From this we can conclude, that the globally optimal education policy that the government of the source country sets, given that $p > 0$, will be strictly lower than the subsidy which maximizes global welfare. This is driven by the fact that the global social planner takes the effect of the subsidy on the lifetime income of the emigrants fully into account, whereas the national social planner cares only about the fraction that is remitted. Furthermore, the global social planner also considers the spillover effect that the subsidy of the sending country has on the average level of education in the host country and thus on the income of the foreign natives. Additionally the tax motive for subsidy reduction does not exist anymore. The national planner does not take into account that emigrants have a direct income effect from the subsidy, which cancels out the higher tax burden on the non-migrants.
This discrepancy between globally and nationally optimal education policy becomes smaller as remittances increase. With a high δ, the social planner of the source country will care more about the effect that its policy has on the lifetime income of the emigrants, because they will send a significant part of this income back home. Also, the tax motive to reduce education subsidies decreases when remittances increase. Note however that even at a remittance rate of 100 percent, the nationally optimal education subsidies will be lower than the global optimum. This is the case, because the national social planner does not take the international spillover effect of its subsidy on the income of the foreign-born citizens of the host country into account.

We now investigate the globally optimal education subsidy for the host country. Taking the

derivative of (42) with respect to s_2, we get that

$$\begin{aligned}\frac{\partial \bar{W}_{Global}}{\partial s_2} =&(L_2 + pN_h)\left(\frac{\eta}{\bar{\theta}_2^*(s_{G,2}^*)+1}\frac{\partial \bar{\theta}_2^*}{\partial s_2}\right) + L_2\left(\frac{\beta}{\theta_2^*(s_{G,2}^*)+1} - k_2\right)\frac{\partial \theta_2^*}{\partial s_2} \\ &\stackrel{!}{=} 0 \\ &\equiv g_{G,2}(s_{G,2}^*, p)\end{aligned} \tag{45}$$

where the subscript $G,2$ identifies this as a function that determines the globally optimal policy for country 2.

Proposition 9. *Without remittances, the globally optimal education subsidy for the host country $s_{G,2}^*$ is identical to the optimal national policy s_1^*.*
With strictly positive remittances and migration rate, $\delta > 0, p > 0$, $s_{G,2}^*$ is strictly smaller than the optimal national policy s_1^*.

Proof. Comparing equation (26) with (45), we see directly that $g_{G,2}(s_2^*(p), p) = g_2(s_2^*(p), p)$ if $\delta = 0$. This implies that the subsidy that the global social planner will impose on the host economy will be the same as the country would choose itself, if there are no remittances.
With remittances, we have that

$$\begin{aligned}&g_{G,2}(s_{G,2}^*, p) = \\ &g_2(s_{G,2}^*, p) + \frac{\delta p N_h L_2}{L_2 + pN_h}\Big(\underbrace{\left(\frac{\eta}{\bar{\theta}_2^*(s_{G,2}^*)+1} - s_{G,2}^*\right)}_{\leq 0}\frac{\partial \theta_2^*}{\partial s_2} - \theta_2^*(s_{G,2}^*)\Big) \stackrel{!}{=} 0\end{aligned} \tag{46}$$

For the FOC to be fulfilled, it has to be that $s_{G,2}^* < s_1^*$ for $p > 0, \delta > 0$, because $\partial g_2/\partial s_2 < 0$. □

Under autarky, we find again that the optimal national education policy for the host country is the same as the optimal global policy. With migration and no remittances, the optimal policies are still the same, since the policy of the host country does not have any spillover effects on the source country, and the social planner weights immigrants' and natives' income in the same way. Once remittances become possible and anticipated, the optimal global education subsidy of the host country will be smaller than the one set by the national social planner. This is the case, because the national social planner will put a lesser weight on the income of immigrants if they remit part of their earnings back home. The social planner thus sets an inefficiently high education subsidy that is cross-financed by higher taxes at the cost of the immigrants. As a result, only the level of education of the natives increases, but both immigrants and natives have to pay more for it.

We can draw another conclusion from this analysis.

Proposition 10. *Under national education regimes and without remittances, the average level of education in each country $\bar{\theta}_j$, $j \in (1,2)$ is strictly lower than under the globally optimal*

subsidies, if $p > 0$.

$$\bar{\theta}_j^*(s_j^*) < \bar{\theta}_j^*(s_{G,j}^*) \quad j \in (1,2) \tag{47}$$

Proof. As we have shown in proposition 8, $s_{G,1}^* > s_1^*$. We then have that

$$\begin{aligned} \bar{\theta}_1^*(s_1^*) &= \frac{N_l\theta_l^*(s_1^*) + (1-p)N_h\theta_h^*(s_1^*)}{N_l + (1-p)N_h} \\ &< \frac{N_l\theta_l^*(s_{G,1}^*) + (1-p)N_h\theta_h^*(s_{G,1}^*)}{N_l + (1-p)N_h} = \bar{\theta}_1^*(s_{G,1}^*) \end{aligned} \tag{48}$$

because both θ_l^* and θ_h^* are strictly increasing in s_1.
For the host country, we have that

$$\begin{aligned} \bar{\theta}_2^*(s_1^*) &= \frac{L_2\theta_2^*(s_2^*) + (1-\gamma)pN_h\theta_h^*(s_1^*)}{L_2 + pN_h} \\ &< \frac{L_2\theta_2^*(s_{G,2}^*) + (1-\gamma)pN_h\theta_h^*(s_{G,1}^*)}{L_2 + pN_h} = \bar{\theta}_2^*(s_{G,1}^*) \end{aligned} \tag{49}$$

which holds because θ_h^* is strictly increasing in s_1 and $\theta_2^*(s_2^*) = \theta_2^*(s_{G,2}^*)$.

□

The intuition behind this proposition is clear for the source country. Since it invests less in education than what would be globally optimal, the average education level is lower. For the host country, the intuition is less clear. Even though it spends as much in education as is globally optimal, the average education level is lower than in the globally optimal equilibrium. The reason for this is, that due to the low education subsidies of the source country, the skill-level of the immigrants will be lower than under the global optimum. This then lowers the average education rate of the host country.
Note that the skill-level of the immigrants in the host country is by assumption still higher than the average of the population of the host country. Thus immigration still increases the average skill level in the destination country. It just increases it less than what would be globally optimal.

With remittances, the proposition becomes less clear.

Proposition 11. *Under national education regimes and with remittances, the average level of education in the source country* $\bar{\theta}_1$ *is strictly lower than under the globally optimal subsidies, if* $p > 0$.

$$\bar{\theta}_1^*(s_{1,\delta}^*) < \bar{\theta}_1^*(s_{G,1,\delta}^*) \tag{50}$$

The average level of education in the host country $\bar{\theta}_2$ *is higher or lower than under the globally optimal subsidies, if* $p > 0$.

$$\bar{\theta}_2^*(s_{1,\delta}^*, s_{2,\delta}^*) \lessgtr \bar{\theta}_2^*(s_{1,\delta}^*, s_{G,2,\delta}^*) \tag{51}$$

Proof. For $\bar{\theta}_1^*$ the proof remains the same, since $s_{1,\delta}^* < s_{G,1,\delta}^*$ for $\delta \in (0,1)$. For $\bar{\theta}_2^*(s_{1,\delta}^*, s_{G,2,\delta}^*)$ it depends on whether the effect of the increase in the foreign subsidy offsets the decrease in the national subsidy. □

With remittances, the level of human capital in the sending country under the policy of a national social planner will still be unambiguously lower than what would be globally optimal. The gap is however becoming smaller if remittances are higher.
For the level of education in the host country, it depends on the level of remittances and on the total number of immigrants. If remittances are not excessively high, we should still see the previous finding, that the average education level in the host country is lower than globally optimal: For non-excessive remittance rates, the effect of the less than globally optimal education subsidy of the sending country will dominate the more than globally optimal spending of the host country .

3.7. Extension for $(1-\gamma)\theta_h^* < \theta_2^*$

It might be argued that the adaption cost of immigration is so large that even the high skilled immigrants will effectively be less productive abroad than the average native. In such a scenario, immigration will lower the average skill level in the host country.[21] We have shown in the previous section of this paper that the social planner of the destination country will lower the education subsidy as a result of immigration, if remittances are not too high. This was driven by the assumption that high skilled immigration will increase the average skill-level of the economy and therefore serve as a substitute for subsidies. If however immigration lowers the average skill level, the optimal policy response should change.
In such a case, where $\theta_2^* > (1-\gamma)\theta_h^*$, we can see from equation (29), that whether or not the optimal policy response to immigration changes signs depends also on the incentive effect of emigration on the migrant's education decision. We rewrite equation (29) to see this.

$$\frac{\partial g_2}{\partial p} = -\frac{\eta}{(\bar{\theta}_2^*(s_2^*)+1)^2}\frac{N_h}{L_2+pN_h}(-\bar{\theta}_2^*(s_2^*)+(1-\gamma)\theta_h^*+(1-\gamma)p\frac{\partial \theta_h^*}{\partial p}) \tag{52}$$

Equation (52) implies that even if $(1-\gamma)\theta_h^* < \theta_2^*$, it might be that $\partial\bar{\theta}_2^*/\partial p > 0$, if the difference between $(1-\gamma)\theta_h^*$ and θ_2^* is small and p is large. This is the case, because additional immigrants will have a lower level of education than the native population, but the level of education of the immigrants is increasing in their education prospects.
For $(1-\gamma)\theta_h^* << \theta_2^*$, equation (52) becomes positive. This shows that if more immigration leads to a lower aggregate level of education in the host country, the social planner will react by increasing education expenditure. The host country can then no longer boost its productivity by skilled immigration, but instead has to invest more in order to react to the lower average education by making education cheaper for its own native population.

This result does not have any implications for the difference between the globally optimal education policy and the national ones. The host country will adopt the policy that maximizes global welfare, as long as there are no remittances, and spend more than globally optimal, if remittances are positive. We can immediately see this from proposition 9.

[21] As Benhabib (1996) shows, in such a case immigration might still be beneficial for some of the natives, if skill-rates are heterogeneous and skills complementary. Thus, even if immigration decreases the aggregate skill-level, a positive amount of immigration can still be a desirable policy for the host country.

4. Conclusion

This paper has demonstrated, that both source and host countries will lower their optimal education subsidies as a response to high skilled migration, if remittances are not excessively high. In the case of the source country, this behavior implies that not only do they lose part of their *high*-ability workers, but also, the *low*-ability workers that stay behind will have a lower than optimal level of education. With lower education subsidies, the *low*-ability individuals will choose to invest less in education than they would under autarky, because the subsidy is decreasing in the level of skilled migration. For the remaining *high*-ability workers, it might be that the possibility to emigrate will give them a sufficient incentive to invest more in education, despite the low subsidy.

What we find suggests, that migration from third to first world does not only entail a direct brain-drain effect, but also, it will lead to a lower public investment in education in the source country. Even if the incentive effect of migration on the private education decision of the *high*-ability workers outweighs the loss of skilled workers, the additional decrease in public funding makes it highly unlikely that migration will have a beneficial brain-gain effect on the poor source countries. The "brains" will already be "drained" before they are formed, because of the insufficient public incentives to invest in their education. This effect is especially strong when there are two groups of workers, one with the prospect of migration, and one without it. The potential migrants might still attain a high level of education, because the motivation to earn a high salary abroad can set off the lacking public education provision. Those that do not consider emigration an option however, will unambiguously suffer from migration for three reasons. First and foremost, they will attain a lower level of education, because public education provision decreases. Second, they will have to pay higher taxes in order to cover the free education that the high-skilled emigrants have enjoyed. Third, if the decrease in education subsidies and the loss of skilled migrants outweighs the private incentive effect of the non-migrants, their productivity will be lower, because the average education level and thus the level of technology in the economy will be lower.

On the other hand, we have shown that these findings can be mediated, and even potentially reversed, once the policymakers anticipate that migrants will send remittances to their families back home. For the source country, anticipated remittances will imply that the social planner cares about the income of the emigrants, since they will send part of their earnings to the source country. Since these earnings depend on the emigrants education, and thus on the education policy in the source country, the social planner can increase the expected remittance payments by setting higher education subsidies. For high enough income differences between country of origin and destination, and for high remittance rates, this effect can even dominate the negative direct effect of emigration on education subsidies.
For the host country, remittances imply that less of the income of the immigrants will be spend domestically. The social planner will anticipate this and therefore care less about the impact of taxes on the earnings of the immigrants. He will then set higher taxes, and finance higher education subsidies for the natives, thereby decreasing the remittances to the source country.

This analysis has severe policy implications. If there are very asymmetric migration streams between two countries, driven by high income differences, then the education policy should absolutely be coordinated between the two countries. Poutvaara (2008) has shown for the case of two symmetric countries, with endogenous migration decisions, that graduate taxes might be one way to overcome the dilemma of an underprovision of public funding for education. In our case, this would only resolve one of the five reasons that drive an underinvestment in the source country. However, encouraging migrants to send back remittances will have beneficial effects from a global point of view. Therefore, it would be very helpful to facilitate financial transactions between host countries and countries of origins. Additionally, the host country will have an incentive to contribute to the education expenditures of the source country, because the skill-level of the immigrants it receives will be higher, if they have acquired a better education. One way to encounter this problem, that might be beneficial to all, could be to link development aid to a binding commitment of the developing countries to invest a considerable amount of the aid in education.

If however remittances are not sufficient and it is not possible to find a way to successfully coordinate education policy between sending and host countries, the repercussions are particularly grim for the source countries. As we have argued, human capital formation is key to economic growth and technological innovation. However, if the social returns to human capital formation outweigh the private returns, there will be an underinvestment in education if it is not publicly financed. Decreasing education expenditures as a response to labor mobility will thus lead to an inefficiently low level of human capital in the developing countries, and thereby decrease their chances of ever catching up with the industrial countries. Furthermore, it is the remaining individuals of the poor source economy who finance the education for the emigrants, which essentially benefits the richer country and the emigrants who are better off than the population of the source country. From an egalitarian point of view, this injustice is yet another reason that necessitates the international coordination of public education expenditures.

A. Appendix

A.1. Showing that $\partial g_1/\partial s_1 < 0$

We take the derivative of $g_1(s_1^*)$ with respect to s_1 in order to make sure that s_1^* is a local maximum.

$$\begin{aligned}\frac{\partial g_1}{\partial s_1} =&(L_1 - pN_h)\left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial^2\bar{\theta}_1^*}{\partial s_1^2} - \frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\frac{\partial\bar{\theta}_1^*}{\partial s_1}\frac{\partial\bar{\theta}_1^*}{\partial s_1}\right)\\ &+(L_1 - N_h)\left(\left(\frac{\alpha}{\theta_l^*(s_1^*)+1} - k_l\right)\frac{\partial^2\theta_l^*}{\partial s_1^2} - \frac{\alpha}{(\theta_l^*(s_1^*)+1)^2}\frac{\partial\theta_l^*}{\partial s_1}\frac{\partial\theta_l^*(s_1^*)}{\partial s_1}\right)\\ &+(1-p)N_h\left(\left(\frac{\alpha}{\theta_l^*(s_1^*)+1} - k_h\right)\frac{\partial^2\theta_h^*}{\partial s_1^2} - \frac{\alpha}{(\theta_h^*(s_1^*)+1)^2}\frac{\partial\theta_h^*}{\partial s_1}\frac{\partial\theta_h^*}{\partial s_1}\right)\\ &-pN_h\left(2\frac{\partial\theta_h^*}{\partial s_1} + s_1\frac{\partial^2\theta_h^*}{\partial s_1^2}\right)\end{aligned} \tag{53}$$

Noting that

$$\frac{\partial^2\bar{\theta}_1^*}{\partial s_1^2} = \frac{(L_1 - N_h)\frac{\partial^2\theta_l^*}{\partial s_1^2} + (1-p)N_h\frac{\partial^2\theta_h^*}{\partial s_1^2}}{L_1 - pN_h} \tag{54}$$

and making use of the fact that $\frac{\alpha}{\theta_l^*(s_1)+1} - k_l = -s_1$ and that $\frac{\alpha}{\theta_h^*(s_1)+1} - k_h = -(s_1 + (k_h - s_1)\frac{p(\beta-\alpha)}{\alpha+p(\beta-\alpha)})$ we can simplify the equation.

$$\begin{aligned}\frac{\partial g_1}{\partial s_1} =&\left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1} - s_1^*\right)\left((L_1 - N_h)\frac{\partial^2\theta_l^*}{\partial s_1^2} + (1-p)N_h\frac{\partial^2\theta_h^*}{\partial s_1^2}\right)\\ &-p(1-p)N_h\frac{\partial^2\theta_h^*}{\partial s_1^2}\frac{(k_h - s_1^*)(\beta-\alpha)}{\alpha+p(\beta-\alpha)} - pN_h\left(2\frac{\partial\theta_h^*}{\partial s_1} + s_1^*\frac{\partial^2\theta_h^*}{\partial s_1^2}\right)\\ &-(L_1 - pN_h)\frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\left(\frac{\partial\bar{\theta}_1^*}{\partial s_1}\right)^2 - (L_1 - N_h)\frac{\alpha}{(\theta_l^*(s_1^*)+1)^2}\left(\frac{\partial\theta_l^*}{\partial s_1}\right)^2\\ &-(1-p)N_h\frac{\alpha}{(\theta_h^*(s_1^*)+1)^2}\left(\frac{\partial\theta_h^*}{\partial s_1}\right)^2\end{aligned} \tag{55}$$

Using the convenient transformation of

$$\frac{\partial^2\theta_j^*}{\partial s_1^2} = \frac{2}{k_j - s_1^*}\frac{\partial\theta_j^*}{\partial s_1} \quad j \in (h,l) \tag{56}$$

Using equation (19) and modifying it slightly, we can then rewrite equation (55) as

$$\begin{aligned}\frac{\partial g_1}{\partial s_1} =&\frac{2}{k_h - s_1^*}\left(g_1(s_1^*) - pN_h\right)\\ &-(L_1 - pN_h)\frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\left(\frac{\partial\bar{\theta}_1^*}{\partial s_1}\right)^2 - (L_1 - N_h)\frac{\alpha}{(\theta_l^*(s_1^*)+1)^2}\left(\frac{\partial\theta_l^*}{\partial s_1}\right)^2\\ &-(1-p)N_h\frac{\alpha}{(\theta_h^*(s_1^*)+1)^2}\left(\frac{\partial\theta_h^*}{\partial s_1}\right)^2 < 0\end{aligned} \tag{57}$$

It is immediately clear that this has to be negative since $g_1(s_1^*) = 0$ follows from the first order condition.

A.2. From equation (22) to (23)

Using equation (5), we can make the following simplification.

$$\frac{\partial^2 \bar{\theta}_1^*}{\partial s_1 \partial p} = \frac{N_h}{L_1 - pN_h} \frac{\partial \bar{\theta}_1^*}{\partial s_1} + \frac{(1-p)N_h \frac{\partial^2 \theta_h^*}{\partial s_1 \partial p} - N_h \frac{\partial \theta_h^*}{\partial s_1}}{L_1 - pN_h} \tag{58}$$

As a last step, we then note that

$$-\big(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial \theta_h^*}{\partial s_1} = s_1^* \frac{\partial \theta_h^*}{\partial s_1} + p\frac{\partial \theta_h^*}{\partial p} \tag{59}$$

Substituting equation (58) and (59) into equation (22), this results into equation (23) after reshuffling terms.

A.3. The five channels through which migration lowers the optimal education subsidy.

We rewrite equation (22) in order to identify the different influences of migration on the optimal subsidy.

$$\begin{aligned}
\frac{\partial g_1}{\partial p}(s_1^*(p), p) =& (N_l + (1-p)N_h) \Bigg(\underbrace{\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial^2 \bar{\theta}_1^*}{\partial s_1 \partial p}}_{\textit{1st effect: Appropriation}} - \underbrace{\frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\frac{\partial \bar{\theta}_1^*}{\partial s_1}\frac{\partial \bar{\theta}_1^*}{\partial p}}_{\textit{2nd effect: Substitute for subsidies}} \Bigg) \\
& \underbrace{- N_h \left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial \bar{\theta}_1^*}{\partial s_1} + \big(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial \theta_h^*}{\partial s_1} \right)}_{\textit{3rd effect: Subsidy's influence on emigrants' welfare}} \\
& \underbrace{- N_h \left(s_1^* \frac{\partial \theta_h^*}{\partial s_1} + \theta_h^*(s_1^*) \right) - \underbrace{pN_h \left(s_1^* \frac{\partial^2 \theta_h^*}{\partial s_1 \partial p} + \frac{\partial \theta_h^*}{\partial p} \right)}_{\textit{Interaction term: Brain-gain x Tax burden}}}_{\textit{4th effect: Tax burden}} \\
& \underbrace{- (1-p)N_h \left(\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p}\big(k_h - \frac{\alpha}{\theta_h^*(s_1^*)+1}\big) + \frac{\alpha}{(\theta_h^*(s_1^*)+1)^2}\frac{\partial \theta_h^*}{\partial s_1}\frac{\partial \theta_h^*}{\partial p} \right)}_{\textit{5th effect: Overeducation of high-ability stayers}}
\end{aligned} \tag{60}$$

For the *appropriation* effect, we have that

$$\frac{\partial^2 \bar{\theta}_1^*}{\partial s_1 \partial p} = \frac{N_h}{N_l + (1-p)N_h} \Big(\underbrace{-\big(\frac{\partial \theta_h^*}{\partial s_1} - \frac{\partial \bar{\theta}_1^*}{\partial s_1}\big)}_{\textit{Subsidy effect is lost on high-ability}} + \underbrace{(1-p)\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p}}_{\textit{p magnifies subsidy's impact on h stayers}} \Big) \tag{61}$$

For a high brain-gain effect, it can be, that the second part dominates the first. In total, all the five channels together imply that migration has a negative effect on the optimal subsidy.

A.4. Proof for $\frac{\partial g_1}{\partial p} < 0$ when $\frac{\partial \bar{\theta}_1^*}{\partial p} > 0$

Proof. We can write equation (23) as

$$\begin{aligned}\frac{\partial g_1}{\partial p} = &-(L_1 - pN_h)\left(\frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\frac{\partial \bar{\theta}_1^*}{\partial s_1}\frac{\partial \bar{\theta}_1^*}{\partial p}\right)\\ &-(1-p)N_h\frac{\alpha}{(\theta_h^*(s_1^*)+1)^2}\frac{\partial \theta_h^*}{\partial s_1}\frac{\partial \theta_h^*}{\partial p} - N_h\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial \theta_h^*}{\partial s_1}\\ &-(1-p)N_h\Big(s_1^* + \frac{(k_h - s_1^*)p(\beta-\alpha)}{\alpha + p(\beta-\alpha)}\Big)\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p} - pN_h s_1^*\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p}\\ &+N_h\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}(1-p)\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p} - N_h\theta_h^*(s_1^*)\end{aligned} \tag{62}$$

Since the first row of (62) is strictly negative, it is sufficient to show that the last two lines are negative for all p. We denote the last two lines as $\Delta(s_1, p)$. Δ can be written as

$$\begin{aligned}\Delta(s_1^*, p) = &\underbrace{N_h(1-p)\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p}}_{Ib}\underbrace{\Big(\big(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1} - s_1^*\big) - p\big(\frac{(k_h - s_1^*)(\beta-\alpha)}{\alpha + p(\beta-\alpha)}\big) - \frac{p}{1-p}s_1^*\Big)}_{IIb}\\ &-\underbrace{N_h\theta_h^*(s_1^*)}_{IIIb}\end{aligned} \tag{63}$$

We can now compare Δ to the FOC g_1. For this purpose, we rewrite g_1.

$$\begin{aligned}g_1(s_1^*, p) = &\underbrace{N_h\frac{(1-p)}{p}\frac{\partial \theta_h^*}{\partial s_1}}_{I,\ >0}\underbrace{\Big(\varepsilon(p)\big(\underbrace{\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}}_{\geq 0} - s_1^*\big) - p\big(\frac{(k_h - s_1^*)(\beta-\alpha)}{\alpha + p(\beta-\alpha)}\big) - \frac{p}{1-p}s_1^*\Big)}_{II,\ \geq 0}\\ &-\underbrace{N_h\theta_h^*(s_1^*)}_{III,\ >0} \stackrel{!}{=} 0\end{aligned} \tag{64}$$

where $\varepsilon(p) = \frac{(L_1 - N_h)\frac{\partial \theta_l^*}{\partial s_1} + (1-p)N_h\frac{\partial \theta_h^*}{\partial s_1}}{(1-p)N_h\frac{\partial \theta_h^*}{\partial s_1}} > 1$. We can thus see that $III = IIIb$, $II > IIb$ and $I > Ib$ because $\frac{\partial \theta_h^*}{\partial s_1} \geq p\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p}$. It must thus be that

$$\Delta(s_1^*, p) < 0 \tag{65}$$

This concludes the proof. □

A.5. Calculations and proof propostion 4

First note that

$$\begin{aligned}\frac{\partial\theta_h^*}{\partial\delta} &= -\frac{p(1-p)\big((1-\varphi)\beta-\alpha\big)}{(k_h-s_1)(1-\delta p)^2} < 0\\ \frac{\partial^2\theta_h^*}{\partial s_1\partial\delta} &= -\frac{p(1-p)\big((1-\varphi)\beta-\alpha\big)}{\big((k_h-s_1)(1-\delta p)\big)^2} = \frac{1}{k_h-s_1}\frac{\partial\theta_h^*}{\partial\delta} =< 0\end{aligned} \tag{66}$$

$\frac{\partial g_1(s_1^*)}{\partial\delta}$ is calculated as

$$\begin{aligned}&\frac{\partial g_1(s_1^*)}{\partial\delta} =\\ &-(L_1-pN_h)\frac{\eta}{(\bar\theta_1^*+1)^2}\frac{\partial\bar\theta_1^*}{\partial s_1}\frac{\partial\bar\theta_1^*}{\partial\delta}\\ &+(1-p)N_h\Big((\frac{\eta}{\bar\theta_1^*+1}+\frac{\alpha}{\theta_h^*+1}-k_h)\frac{\partial^2\theta_h^*}{\partial s_1\partial\delta}-\frac{\alpha}{(\theta_h^*+1)^2}\frac{\partial\theta_h^*}{\partial s_1}\frac{\partial\theta_h^*}{\partial\delta}\Big)\\ &+pN_h\Big(\frac{\eta}{\bar\theta_2^*(s_1^*)+1}\frac{\partial\bar\theta_2^*}{\partial s_1}+\big(\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*)+1}-(k_h-s_1^*)\big)\frac{\partial\theta_h^*}{\partial s_1}+\theta_h^*(s_1^*)\Big)\\ &-pN_h(1-\delta)(s_1^*\frac{\partial^2\theta_h^*}{\partial s_1\partial\delta}+\frac{\partial\theta_h^*}{\partial\delta})\\ &+pN_h\delta\Big(\frac{\eta}{\bar\theta_2^*+1}\frac{\partial^2\bar\theta_2^*}{\partial s_1\partial\delta}-\frac{\eta}{(\bar\theta_2^*+1)^2}\frac{\partial\bar\theta_2^*}{\partial s_1}\frac{\partial\bar\theta_2^*}{\partial\delta}+\big(\frac{(1-\varphi)\beta}{\theta_h^*+1}-k_h\big)\frac{\partial^2\theta_h^*}{\partial s_1\partial\delta}-\frac{(1-\varphi)\beta}{(\theta_h^*+1)^2}\frac{\partial\theta_h^*}{\partial s_1}\frac{\partial\theta_h^*}{\partial\delta}\Big)\end{aligned} \tag{67}$$

We know from the social planner's first order condition that at $p=0$ we have that $\frac{\eta}{\theta_1^*+1} = k_h - \frac{\alpha}{\theta_h^*+1}$. We know that $\frac{\partial\bar\theta_1^*}{\partial p} < \frac{\partial\theta_h^*}{\partial p}$, and can thus easily show that

$$\frac{d\frac{\eta}{\theta_1^*+1}}{dp} = -\frac{\eta}{(\bar\theta_1^*+1)^2}\frac{\partial\bar\theta_1^*}{\partial p} < \frac{d(k_h-\frac{\alpha}{\theta_h^*+1})}{dp} = \frac{\alpha}{(\theta_h^*+1)^2}\frac{\partial\bar\theta_h^*}{\partial p} \tag{68}$$

We can thus state that for $p>0$, $\frac{\eta}{\theta_1^*+1}+\frac{\alpha}{\theta_h^*+1}-k_h<0$. This ensures, that the second term is positive.

In a next step, we add up line three and five, and add and subtract $s_1^*\frac{\partial^2\theta_h^*}{\partial s_1\partial\delta}$. The new line four of equation (33) is easily seen to be unambiguously positive. Line five of equation (33) can be expressed as

$$pN_h\Big(\frac{\big((1-\gamma)pN_h}{L_2+pN_h}\frac{\eta}{\bar\theta_2^*(s_1^*)+1}+\big(\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*)+1}-(k_h-s_1^*)\big)\big)(\frac{\partial\theta_h^*}{\partial s_1}+\delta\frac{\partial^2\theta_h^*}{\partial s_1\partial\delta})+\theta_h^*(s_1^*)\Big) \tag{69}$$

It can also easily be shown that

$$\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*)+1}-(k_h-s_1^*) = \frac{(k_h-s_1^*)(1-p)\big((1-\varphi)\beta-\alpha\big)}{\alpha+p\big((1-\varphi)(1-\delta)\beta-\alpha\big)} > 0 \tag{70}$$

We then have that $\frac{\partial\theta_h^*}{\partial s_1}+\delta\frac{\partial^2\theta_h^*}{\partial s_1\partial\delta} > 0$ is a suffcient condition for the entire expression to be

positive. At $\delta \leq 1/2$ this is fulfilled for all $p \in (0,1)$.

$$\frac{\partial \theta_h^*}{\partial s_1} + \delta \frac{\partial^2 \theta_h^*}{\partial s_1 \partial \delta}|_{\delta \leq \frac{1}{2}} = \frac{(1-p)\alpha + p(1-\varphi)\beta(1-2\delta+p\delta^2)}{\big((k_h - s_1)(1-\delta p)\big)^2} > 0 \tag{71}$$

A.6. Illustration of proposition 5

It is sufficient to show that $\frac{\partial g_1}{\partial p} > 0$ is possible for some values of $(1-\varphi)\beta$ and δ. With remittances equation (22) becomes

$$\begin{aligned}
&\frac{\partial g_1}{\partial p}(s_1^*(p), p) = \\
&(L_1 - pN_h)\left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial^2 \bar{\theta}_1^*}{\partial s_1 \partial p} - \frac{\eta}{(\bar{\theta}_1^*(s_1^*)+1)^2}\frac{\partial \bar{\theta}_1^*}{\partial s_1}\frac{\partial \bar{\theta}_1^*}{\partial p}\right) \\
&-N_h\left(\frac{\eta}{\bar{\theta}_1^*(s_1^*)+1}\frac{\partial \bar{\theta}_1^*}{\partial s_1} + \big(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial \theta_h^*}{\partial s_1} + (1-\delta)\Big(s_1^*\frac{\partial \theta_h^*}{\partial s_1} + \theta_h^*(s_1^*)\Big)\right) \\
&+(1-p)N_h\left(\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p}\big(\frac{\alpha}{\theta_h^*(s_1^*)+1} - k_h\big) - \frac{\alpha}{(\theta_h^*(s_1^*))^2}\frac{\partial \theta_h^*}{\partial s_1}\frac{\partial \theta_h^*}{\partial p}\right) \\
&-(1-\delta)pN_h\left(s_1^*\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p} + \frac{\partial \theta_h^*}{\partial p}\right) \\
&+\delta N_h\Big(\frac{\eta}{\bar{\theta}_2^*(s_1^*)+1}\frac{\partial \bar{\theta}_2^*}{\partial s_1} + \big(\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial \theta_h^*}{\partial s_1}\Big) \\
&+\delta p N_h\Big(\frac{\eta}{\bar{\theta}_2^*(s_1^*)+1}\frac{\partial^2 \bar{\theta}_2^*}{\partial s_1 \partial p} - \frac{\eta}{(\bar{\theta}_2^*(s_1^*)+1)^2}\frac{\partial \bar{\theta}_2^*}{\partial s_1}\frac{\partial \bar{\theta}_2^*}{\partial p} \\
&\quad + \big(\frac{(1-\varphi)\beta}{\theta_h^*(s_1^*)+1} - k_h\big)\frac{\partial^2 \theta_h^*}{\partial s_1 \partial p} - \frac{(1-\varphi)\beta}{(\theta_h^*(s_1^*)+1)^2}\frac{\partial \theta_h^*}{\partial s_1}\frac{\partial \theta_h^*}{\partial p}\Big)
\end{aligned} \tag{72}$$

It is clear that for very large $(1-\varphi)\beta$ and δ, the two last terms of the above expression can dominate the entire equation, and change its sign.

A.7. Illustration of proposition 7

Equation (35) can be written as

$$g_2(s_2^*(p), p, \delta) = \big(\frac{\eta}{\bar{\theta}_2^*(s_2^*)+1} - s_2^*\big)\frac{\partial \theta_2^*}{\partial s_2} + \frac{\delta p N_h}{L_2 + pN_h}\big(s_2^*\frac{\partial \theta_2^*}{\partial s_2} + \theta_2^*\big) \stackrel{!}{=} 0 \tag{73}$$

Noting that $\frac{\partial \theta_2^*}{\partial p} = 0$, we can then calculate the derivative with respect to p as

$$\frac{\partial g_2(p,\delta)}{p} = -\frac{\eta}{(\bar{\theta}_2^*(s_2^*)+1)^2}\frac{\partial \bar{\theta}_2^*}{\partial p}\frac{\partial \theta_2^*}{\partial s_2} + \frac{\delta N_h}{(L_2 + pN_h)^2}\big(s_2^*\frac{\partial \theta_2^*}{\partial s_2} + \theta_2^*\big) \tag{74}$$

It is then clear that, if $\frac{\partial \bar{\theta}_2^*}{\partial p}$ is small, it is possible that $\frac{\partial g_2(p,\delta)}{p} > 0$ for δ sufficiently large.

A.8. Showing that national budget constraints lead to the same result as a global budget constraint

The budget constraint for the destination country is

$$s_2\theta_2 L_2 \leq \tau_2(L_2 + pN_h) \tag{75}$$

At a balanced budget, this implies that it will set the following taxes.

$$\tau_2 = s_2\theta_2 \frac{L_2}{L_2 + pN_h} \tag{76}$$

For the source country, the budget constraint is given by

$$s_1\big(N_h\theta_h + (L_1 - N_h)\theta_l\big) \leq \tau_1\big((1-p)N_h + (L_1 - N_h)\big) \tag{77}$$

At a balanced budget, this results in the following tax.

$$\tau_1 = s_1 \frac{N_h\theta_h + (L_1 - N_h)\theta_l}{(1-p)N_h + (L_1 - N_h)} \tag{78}$$

Even though this implies that the net income effect of education policy on the remaining population in the source country is negative, i.e. that they pay in total more in taxes than they receive in education subsidies, this negative effect is set off if we take into account the effect on the emigrants, who receive the education subsidy from the source country, but pay their taxes abroad. The net income effect of the subsidy for all four groups is calculated as

$$\begin{aligned}\sum_{i\in(1,2)} (s_i\theta_i - \tau_i) = &\underbrace{L_2(s_2\theta_2 - s_2\theta_2 \frac{L_2}{L_2 + pN_h})}_{\textit{natives receiving country}} + \underbrace{pN_h(s_1\theta_h - s_2\theta_2 \frac{L_2}{L_2 + pN_h})}_{\textit{emigrants}} \\ &+ \underbrace{(1-p)N_h(s_1\theta_h - s_1 \frac{N_h\theta_h + (L_1 - N_h)\theta_l}{(1-p)N_h + (L_1 - N_h)})}_{\textit{high abilitiy workers, source country}} \\ &+ \underbrace{(L_1 - N_h)(s_1\theta_l - s_1 \frac{N_h\theta_h + (L_1 - N_h)\theta_l}{(1-p)N_h + (L_1 - N_h)})}_{\textit{low abilitiy workers, source country}} = 0\end{aligned} \tag{79}$$

Thus, in total, the income effect of education subsidies is zero, if each country balances its budget. Clearly, there are several groups that fare better than others. The natives of the receiving country make a net benefit, whereas the low ability workers of the source country cross-subsidize the high education of the skilled emigrants[22]. Setting equation (79) into equation

[22] This result can also be found in Wildasin (2000)

(40), we then get

$$\begin{aligned}\bar{W}_G =& \frac{1}{L_1+L_2}[L_2\left(\beta\ln(\theta_2^*+1)+\eta(\bar{\theta}_2^*+1)-k_2\theta_2^*\right)\\ &+pN_h\left(\beta\ln(\theta_h^*+1)+\eta(\bar{\theta}_2^*+1)-k_h\theta_h^*\right)\\ &+(1-p)N_h\left(\eta\ln(\bar{\theta}_1^*+1)+\alpha\ln(\theta_h^*+1)-k_h\theta_h^*\right)\\ &+(L_1-N_h)\left(\eta\ln(\bar{\theta}_1^*+1)+\alpha\ln(\theta_l^*+1)-k_l\theta_l^*\right)]\end{aligned} \tag{80}$$

which is the same as equation (42). We have thus shown, that a balanced global budget leads to the same result as balanced national budgets.

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