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Migration, Congestion and Growth

Abstract

This article analyzes the effect of migration from a less advanced economy to a more advanced economy on economic growth. The analysis is performed in a two-country growth model with endogenous fertility, in which congestion diseconomies are incorporated. The model shows that out-migration increases fertility and reduces human capital in the source economy. At the same time, in-migration reduces fertility and can increase or decrease the average level of human capital in the host economy. I show how migration affects the inter-temporal evolution of human capital in the world economy. I also demonstrate that a tax imposed on immigrants in the host economy can increase human capital accumulation in the receiving and sending economies and the world as a whole.

JEL-Codes: D300, F220, J100, O000.

Keywords: migration, congestion diseconomies, fertility, human capital, growth, brain drain, brain dilution tax.

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1. Introduction

The number of international migrants increased by more than twofold during the last five decades and reached 214 million in 2010.[1] In high-income OECD countries the share of foreign-born in the population almost tripled between 1960 and 2010 and now is above 10 percent in most of the countries.[2] Akin to international migration, internal migration has also been on the rise. Thus, in 2015 there were 277.5 million internal migrant workers in China alone.[3] Similarly, tens of millions of people have migrated within the boundaries of the United States, European Union and Russia. Large flows of internal (and international) migration have also been recorded in Latin America, Asia and Africa. All over the world, the pattern of internal and international migration is similar: most people migrate from poorer, less developed regions and countries to wealthier, more developed regions and countries.

These flows of migration have also largely been considerably spatially concentrated. Thus, for international migration, it has been broadly argued that in most countries immigrants tend to be largely concentrated in particular areas, especially within major metropolitan agglomerations.[4] Similarly, a concentration of emigrants in particular areas within the source countries is a central element behind the theory of migration networks.[5] For internal migration, where people typically move from smaller urban and semi-urban localities to larger urban centers, spatial concentration of the migration flows is even more evident.

This article studies one of the classical questions in development economics: How does migration from a less advanced region or country to a more advanced region or

[1] According to the United Nations (http://esa.un.org/migration/index.asp), in 2010 Europe hosted the largest number of migrants (nearly 70 million people) followed by Asia (61 million) and North America (50 million).

[2] Over the same period, the proportion of immigrants originating from developing countries in the population of high-income OECD countries increased from 1.5 to 8 percent.

[3] In 2016, National Bureau of Statistic of China reported that out of 277.5 million migrant workers in China in 2015, migrant workers who left their home provinces accounted for nearly 169 million and migrant workers who worked within their home provinces reached 109 million. Estimates suggest that by 2025 Chinese cities will face an influx of additional 243 million migrants.

[4] See, for instance, Bartel (1989), Borjas (1998, 1999) and Saiz (2007) for evidence from the United States, Edin et al. (2003) for Scandinavia, Accetturo et al. (2014) for Italy, and Stark (1991) for a more general picture.

country affect economic growth? The analysis is performed in a two-country growth model with endogenous fertility in the tradition of Galor and Tsiddon (1997) building on Azarnert (2010a).[6] In this context, the particular contribution of the present study is to introduce "congestion diseconomies" – the concept that plays an important role in the urban economics literature, but up to the present was neglected by the voluminous literature on endogenous fertility, human capital and growth. (For surveys of the recent literature, see Galor (2011, 2012).) This extension is called for to properly integrate the consequences of population concentration in modern urbanized world into the long run dynamics of the models of endogenous economic growth.

A negative effect of the geographical concentration of economic agents in smaller, densely populated areas within economy has long been well recognized in the urban and regional economics and the new economic geography. Thus, for example, according to Henderson (2002), United Nations data (UNCHS) indicate that, typically around the world, moving from a city of 250,000 to one of 2.5 million is associated empirically with an 80 percent increase in commuting times and housing rental prices. Richardson (1987) argues from data for four developing countries that moving from a small city to a megacity raises per capita investment costs per family in urban infrastructure by threefold. Detailed arguments can be found, for instance, in Kanemoto (1980) and Fujita (1989).

This negative effect referred to as "congestion diseconomies", or "congestion costs" has been exploited in a large number of theoretical contributions, such as, for instance, Tabuchi (1998), Duranton and Puga (2004), Sato and Yamamoto (2005), Venables (2005), Henderson and Wang (2005), Sato (2007), Henderson and Venables (2009), among others. To model congestion, researchers usually assume that all production in a city occurs in a Central Business District (CBD). Surrounding the CBD there is a circle of residences, owned by absentee landlords, where each worker occupies one unit of land. This creates a per worker cost of urban living, which consists of the cost of commuting to the CBD and land rent. The commuting costs and the land rent are

[5] See, for example, Durand et al. (2001) and Hanson (2006) for evidence on spatial pattern of Mexican emigration to the United Sates and McKenzie and Rapoport (2010) for some references to the theory of migration networks.

[6] Other works in this context that the present model is connected to include Dahan and Tsiddon (1998), Morand (1999), Galor and Moav (2000, 2002), Moav (2005), Galor and Mountford (2006, 2008), Azarnert (2008, 2010c, 2016), Strulik and Weisdorf (2014), and Borissov (2016).

considered to increase with population concentration, which, in turn, reduces the workers' disposable time and income.

Although congestion itself is an intuitive cost of increased immigration, a stronger and more topical argument can also be made about the provision of public goods in general. Thus, for example, regional scientists have pointed to congestion in the transport infrastructure (rail and roads) for generations. (See, for instance, McCann and Shefer (2004), where references to the earlier literature can be found.) Similarly, a negative effect of overcrowding has also long been observed in the context of schools (e.g. Jepsen and Rivkin (2009) and references therein), hospitals (Derlet and Richards (2000), Schull et al. (2001), Trzeciak and Rivers (2003), Sprivulis et al. (2006), Richardson and Mountain (2006), among many others), local police and fire protection (Bruckner, 1981), as well as the provision of public recreation resources, such as parks, trails, and other types of recreational open space (Dahmann et al., 2010). In sum, as Barro and Sala-i-Martin (1992) have argued, almost all public services are characterized by some degree of congestion. In addition, it has also been broadly argued that along with a decline in the quality of public services established residents in immigration-receiving area may experience an increase in the burden of local taxation (e.g. Ladd, 1994).[7] With all these arguments in mind the present paper adopts the approach of the aforementioned urban and regional economics literature and uses the term “congestion” to refer to the costs associated with immigration. This allows us to concentrate on the pure effect of migration on human capital accumulation and avoid discussion of the reasons why government has not invested enough to cope with the increased demand of the larger population.

Of course, congestion diseconomies are not the major reason for an adverse effect of immigration on the local population. A more extensive list of the reasons includes, for instance, traditional economic reasons, such as a fiscal burden of immigration and labor market and welfare considerations, natives’ perception that immigration gives rise to delinquency and social insecurity, and non-economic reasons, such as cultural differences and changes in the general nature of the community. See Bauer et al. (2000), Scheve and Slaughter (2001), Gang et al. (2002), O’Rourke and Sinnott (2006), Dustmann and

Preston (2006; 2007), and Miguet (2008), among others. Researchers have also presented evidence that immigration have an impact on crime, in particular, property crimes and robbery (Bianchi et al. (2012) and Spenkuch (2014)), pushes up housing rental rates (Saiz, 2007), and causes the indigenous population to opt out of public schools to the expensive private education (Betts and Fairlie, 2003)[8] and resettle from immigrant-dense districts to other areas (Saiz and Wachter (2011), Accetturo et al. (2014) and references therein). For any reason that causes local agents to incur the costs associated with immigration the effect is the same, and this paper is about the effect, not about reasons.

Usually, the studies of the urbanization process consider interplay between the negative congestion diseconomies and positive agglomeration economies. However, it has been widely argued that the positive agglomeration effect prevailed in the early stages of economic development when an increase in urbanization was associated with industrialization. Later on, as countries developed economically, congestion diseconomies became dominant leading to deindustrialization of the large metropolitan areas, with manufacturing moving to suburban locations, smaller cities and semi-urban areas. (See, for example, Henderson (2010) for an extensive discussion and further references.) Therefore, for current wave of migration, where people mostly move to the large metropolitan areas where the benefits from agglomeration have been already exploited, their arrival is associated primarily with an increase in the costs of congestion, as has been assumed in the present model.

The recent migration literature has already considered congestion effect as one of many mechanisms through which migration can impact natives' welfare besides wages, technological progress, fiscal spillover etc. (See, for example, Desmet and Rossi-Hansberg (2015), Docquier et al. (2015), Delogu et al. (2015), among others.) However, all these studies focused only on congestion associated with the production function, where congestion operates through the diminishing returns to scale due to the existence of a fixed factor of production. This is another form of congestion that can be viewed as complementary to the formulation adopted in the present model. Moreover, although

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[7] In a two-period model where local public goods are financed by local public debt, Schultz and Sjorsrom (2001) show that immigration leads to over-accumulation of local debt, and that conditional on the inefficiently high level of debt there will be too few public goods.

these studies argue that, with the diminishing returns to scale in production, migration reduces wages in the destination countries and benefits non-migrants in the origin countries, they do not consider the resulting effect on fertility and investment in children's human capital, as has been done in the present work.

In this model, an increase in population density is associated with a reduction in fertility. Evidence supporting such a connection abounds (e.g. Murphy et al. (2008), Simon and Tamura (2009); cf. also Malmberg (2012) where further references can be found). In theoretical literature with congestion diseconomies a negative effect of population concentration on fertility has been shown in Sato and Yamamoto (2005) and Sato (2007). However, these two models abstract from investment in education and therefore do not consider human capital accumulation, which is the major theme of the present study.

This paper's major contribution is to the literature on migration and brain drain. From 1970s onward, the classical brain drain literature has considered international migration as a detrimental factor to the development of poor countries. This literature has argued that the level of human capital in developing countries is growing slowly because the developed countries "siphon off" their highly educated workers, thus increasing the productivity of developed world at the expense of the developing countries (Bhagwati and Wilson, 1989).

This view has recently been challenged in a range of theoretical publications, such as, for example, Mountford (1997), Stark et al. (1998), Beine et al. (2001), Stark and Wang (2002), Fan and Stark (2007), Mountford and Rapoport (2011), among others. This new literature has argued that the possibility of migration to a higher wage foreign country raises the return to education, thus leading to an increase in human capital formation, which can outweigh the negative effect of brain drain in the source economies. Within this context, it has also been argued that, although a brain gain may happen in the short run, relaxation of restrictions on the emigration of high-skilled workers will damage the economic growth a source country in the long run (Chen, 2006). In Azarnert (2012), I demonstrate that the possibility of a temporary low-skilled employment in a higher wage

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[8] For an analysis of the consequences of integration in public education for human capital accumulation and further references see Azarnert (2014).

foreign country lowers the relative attractiveness of acquiring human capital thus further reducing the number of skilled workers and the aggregate level of human capital in the source economy.[9]

The present paper abstracts from the possibility of a beneficial brain drain and follows the classical approach in the brain drain literature that a less developed economy open to out-migration loses its higher-skilled workers, as has been broadly established for both international (Miyagiwa, 1991) and internal (Zhang, 2002) types of migration.[10] To generate a positive self-selection among the migrants, the present model refers to the cost of migration.[11] This allows us to derive the threshold level of human capital that divides the source economy's population into two groups: the more skilled, for whom migration is optimal, and the less skilled, for whom migration is not worthwhile.[12]

In this model, brain drain migration always reduces the total (and average) human capital stock in the less developed source economy. At the same time, the effect of migration on the host economy's average level of human capital is uncertain. Thus, it can either be positive, if skilled emigrants from the less developed economy possess on average more human capital than the local agents in the more advanced economy, or negative, if the new-comers are on average less skilled than the indigenous population. Therefore, the analysis shows that, even if immigrants' skills are fully transferable across the boundaries, and hence migration involves no losses of human capital, nonetheless, it

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[9] Khrainche (2015) evaluates the optimal duration of a temporary worker permit from the point of view of the host country.

[10] Within this context, Beine et al. (2008) argue that among sending countries there appear to be more losers from brain drain than winners. Moreover, several case studies suggest that, in contrast to the beneficial brain drain hypothesis, the possibility of migration to a more developed economy, or, similarly, a more developed region within economy may reduce the incentive for acquiring human capital, as, for example, has been broadly found in the context of Mexican migration to the USA (e.g. Kandel and Kao, 2001; McKenzie and Rapoport, 2011; Antman, 2011) and rural-urban migration in China (de Brauw and Giles, 2016). For a general criticism of the beneficial brain drain hypothesis see Schiff (2005). For an assessment of the magnitude, intensity and determinants of the brain drain along with a review of the literature that amassed during four decades of economic research see Docquier and Rapoport (2012). De la Croix and Docquier (2012) argue that for the majority of developing countries some brain drain is inevitable, as a corollary of poverty.

[11] The cost of migration can be substantial. Thus, for example, for the US interstate migration, Bayer and Juesson (2012) obtain a cost estimate close to US$ 35,000 or roughly two thirds of an average annual household income. For a discussion of the direct and indirect costs associated with migration see, for example, Borjas (2015) where further references can be found.

[12] The aforementioned literature on brain drain with brain gain typically assumes that all agents in the less advanced economy would want to migrate, but that migration is possible only for an exogenously given

can lead to a reduction in the average levels of human capital in both the sending and receiving economies.[13] I derive the exact condition that guarantees an increase/ decrease in the host society's average human capital level as a result of immigration. I also show how migration affects the inter-temporal evolution of human capital in the world economy. I derive conditions for migration that takes place in one period of time to increase or decrease the average level of human capital in the next period and further on.

In this work, I also analyze the effect of migration on the levels of individuals' utility. As their optimal choice, migration always increases utility of the migrants themselves. The effect of migration on individuals who do not migrate is, however, uncertain. Thus, for individuals who remain in the less advanced economy, the out-migration of the agents with superior skills generates two conflicting effects. First, it decreases the average level of human capital in the society, thereby reducing the return on investment in their offspring's education, which, in turn, reduces the resulting children's human capital stock. Second, it also reduces population concentration in the source economy. As follows from the resulting reduction in congestion diseconomies, this increases the remaining individuals' disposable time available for work and parenting, thereby increasing the adult agents' consumption along with the number of their children. Following the same idea, immigration increases population concentration in the receiving economy. As a consequence, the resulting increase in the cost of congestion reduces the indigenous agents' disposable time and hence decreases their consumption and fertility. At the same time, immigration from the less developed economy may increase or decrease the average level of human capital in the more developed economy, thereby increasing or decreasing the local agents' offspring's human capital stock via a human capital externality. I derive the exact conditions for migration to increase or decrease utility among individuals who do not migrate in the sending and receiving economies. I also

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fraction of skilled agents. Zhang (2002) argues that there exists a unique level of human capital that makes migration worthwhile for agents with human capital above it, but does not compute this threshold explicitly.

[13] The negative effect of immigration on the host society's average human capital is consistent, for example, with the situation in the United States, where, after a reversal in the quality of immigration in the 1980s, immigrants on average are less skilled than the US natives (Borjas, 1999). Similarly, immigrants from the former republics of the Old Soviet Union to Russia also typically possess less human capital than the Russian natives. In their studies of the global migration, Docquier et al. (2015) and Delogu et al. (2015) argue that in general new migrants are slightly more educated than those left behind in their origin countries (i.e., there exists a positive selection in emigration), but less educated than natives in the host countries (i.e., there is a negative selection in immigration).

consider a public policy intervention to help mitigate a possible negative effect of migration.

The idea of an income tax paid by highly skilled emigrants to compensate their home-country society for the negative externality imposed by their out-migration on those left behind has been actively debated since 1970s, when it was originally proposed by Jagdish Bhagwati. (See, for example, McHale (2009) and Docquier and Rapoport (2012), where some further references can be found.)

In this work, I extend the discussion toward a tax imposed on immigrants to compensate the indigenous population in the host economy for the in-migration-driven negative externality. By analogy with the brain drain, or Bhagwati tax, this type of redistribution can be referred to as a "brain dilution tax". This type of taxation is close in spirit to the current practices in several countries, in particular, in Europe, where a legal status is provided to foreign investors.[14] I present and analyze the effect of such tax on human capital accumulation in the receiving and sending economies and the world as a whole. The analysis demonstrates that for the receiving economy, the effect of taxation is twofold: First, the tax increases the threshold level of human capital, above which migration is worthwhile, which reduces the size of immigration and increases the average quality of the immigrants. Second, redistribution of the proceeds to the local agents stimulates growth of the high skilled population in the more advanced economy. At the same time, for the source economy, a tax imposed on the immigrants in the host economy decreases the out-migration-driven reduction in the average level of human capital in the source economy, thereby encouraging its economic growth. Moreover, if the out-migration of the agents with superior skills reduces the levels of utility among individuals who remain in the poor source economy, the brain dilution tax can have a positive effect on their utility as well.[15]

The remainder of the article is organized as follows. Section 2 develops the basic model and analyzes the consequences of migration for the sending and receiving

[14] Within this context, a notorious example is the United Kingdom, where passports are "sold" for 1 million British pounds.

[15] In their study of comparative economic development, Ashraf et al. (2010) argue that geographic isolation (i.e., in the context of the present paper, higher migration costs) has generated a persistent beneficial effect on the process of development and contributed to the contemporary variation in the standards of living across countries.

economies and the world as a whole. Section 3 introduces the brain dilution tax and explores its effect on human capital accumulation. Section 4 considers an incomplete assimilation of the migrants' offspring in the host economy. Section 5 concludes.

2. The Basic Structure of the Model

Consider an overlapping-generations economy, in which activity extends over an infinite discrete time. In every period the economy produces a single homogenous good using a constant-returns-to-scale technology with human capital as the only input. In each generation, agents live for two periods: childhood and adulthood. During childhood, individuals acquire human capital. During adulthood, they work, become parents and bring up their offspring. As parents, adult individuals allocate a positive fraction of their time to feeding and raising their children and invest in the education of their children.

Suppose the world that consists of two entities: a more advanced, more developed economy denoted by MD, and a less advanced, less developed economy denoted by LD. For some exogenous reason, in the more developed economy wages and the average level of human capital are higher than those in the less developed economy.

To specify the pattern of migration, suppose that in the beginning of the second period of life, young adult individuals from the poorer less developed economy can migrate to the richer more developed economy. If young adults migrate, they work, become parents, bring up and educate their children at their destination.

2.1. Congestion diseconomies, wages and the cost of migration

Suppose that in any economy i ($i = MD, LD$), an adult individual incurs the basic cost of living that includes land rent, i.e., the costs of living space rented from the absentee landlords, who keep their rental revenues “outside the model”, and commuting costs to the business district for work and shopping and to the recreational area for relaxation. These costs represent congestion diseconomies, as is commonly assumed in the urban economics literature (e.g. Kanemoto (1980), Fujita (1989), Tabuchi (1998), Duranton and Puga (2004), Sato and Yamamoto (2005), Venables (2005), Henderson and Wang (2005), Sato (2007), Henderson and Venables (2009), among others). Furthermore, as consistent with the aforementioned urban economics literature, it is assumed that the costs of congestion diseconomies increase with population density, which implies that an increase in the population size in any economy reduces each individual's disposable time and income in that economy.

More specifically, the basic cost of living, or congestion diseconomies, is measured here in terms of work (or parenting) time forgone at a_t^i per individual living in economy i $(i = MD, LD)$ at time t, where $a_t^i \in [a^{i,\min}, a^{i,\max}]$ is a positive, strictly increasing function of the population size in that economy, L_t^i:

$$a_t^i = a^i(L_t^i), \qquad (1)$$

where $\forall L_t^i \geq 0$, $a^i(L_t^i) \geq 0$, $a^{i'}(L_t^i) > 0$, $\lim_{L_t^i \to 0} a^i(L_t^i) = a^{i,\min}$, $\lim_{L_t^i \to \infty} a^i(L_t^i) = a^{i,\max}$, $0 \leq a^{i,\min} < a^{i,\max} < 1$.

In anticipation of the further discussion of migration the following is assumed:

A1. *The wage per efficiency unit of labor in the more developed economy,* w^{MD}*, is higher than the wage per efficiency unit of labor in the less developed economy,* w^{LD}*, and the wage differential is large enough, so that in period* t*,* $w^{MD}(1-a_t^{MD}) > (1-a_t^{LD})w^{LD}$.

This assumption reflects the fact that, in general, the net return to human capital, i.e., the workers' real wages in the richer more developed regions and, especially, countries are higher than in the poorer less developed regions and countries. In either economy, the wage per efficiency unit of labor, w^i, is fixed over time, as follows from, for instance, the assumption of a CRS technology with a single factor of production.

To complete the description of the world economy, we also suppose that, to migrate to the more developed economy, a young adult individual born in the less developed economy must pay the amount m that covers the costs of migration. I also assume that migration involves no losses of human capital, so that, after migration to the more developed economy, any unit of human capital acquired in the less developed economy prior to migration is as productive, as the locally acquired skills.[16]

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[16] Assuming that the migrants' skills are not fully transferable will strengthen this work's major insight.

Since by construction in this model, only migration from the poorer less developed economy to the richer more developed economy is worthwhile, in the world economy there are potentially three types of individuals: (1) MD, individuals born in the more developed economy, who always remain in the economy where they were born, (2) LD, individuals born in the less developed economy who remain in the economy where they were born, (3) M, individuals born in the less developed economy who migrate to the more developed economy. The conditions that lead to the decision to migrate are analyzed below in Section 2.5.

2.2. The Formation of Human Capital

In any period t, an adult of type j ($j = MD, LD, M$) born in economy i ($i = MD, LD$) is characterized by a skill level h_t that is distributed according to the cumulative density function $F_t^i(\cdot)$ over the strictly positive support $[h_t^{i,\min}, h_t^{i,\max}]$. It is assumed throughout that in period t, the average level of human capital in the more developed economy is higher than that in the less developed economy; $\bar{h}_t^{MD} > \bar{h}_t^{LD}$.

In each period of life individuals are endowed with one unit of time. In the first period, children devote their entire time for the acquisition of human capital. The acquired human capital increases if their time investment is supplemented with real resources invested in their education.

The human capital level of a child, who becomes an adult in period $t+1$, depends on the parental real expenditure on the child's education, e_t^j, and on the average level of human capital of all adult individuals residing in economy i in period t, which is defined as $\bar{h}_t^i = \int h_t dF_t^i(h^i),\ \ i = MD, LD$, according to the human capital production function, or learning technology described by

$$h_{t+1} = \Theta(e_t^j, \bar{h}_t^i). \qquad (2)$$

This learning technology captures an external spillover effect that arises from the average society's level of human capital, $\bar{h}_t$. Such formulation is consistent with the so-called global or atmospheric externality, which implies that an increase in the average level of human capital in the society as a whole increases the rate of return on investment in human capital for the children's generation. First introduced by Tamura (1991), the assumption that the average level of human capital in society is an input in the production of human capital for each individual became common in the literature. This externality has been utilized, e.g. by Tamura (1996), Galor and Tsiddon (1997), Morand (1999), Viaene and Zilcha (2002), de la Croix and Doepke (2003), Henderson and Wang (2005), Azarnert (2008, 2009, 2010a), among many others.

A particular form of human capital production function is specified below in equation (9).

2.3. The Optimization of Parents

Agents of any type derive utility from their own consumption in adulthood and from the net total future income of their children in the economy where the children were born.[17] The utility function of an individual of any type j ($j = MD, LD, M$) born at time $t-1$ is therefore

$$U_t^j = (1-\beta)\log C_t^j + \beta \log(I_{t+1}^{N,j}), \tag{3}$$

where C_t^j is an individual's own consumption, $I_{t+1}^{N,j}$ is the net future income of that individual's offspring and $\beta \in (0,1)$ captures the relative weight given to children.[18]

In every period *t*, adult individuals are endowed with one unit of time. From this unit the basic costs of living associated with congestion diseconomies measured in terms of work time foregone at a_t^i per individual living in economy i, are deducted. The remainder of their time adults allocate between childbearing and labor force participation. In either economy, the cost of feeding and raising children is measured in terms of work time foregone at δ per child. The cost of acquiring human capital in any economy i is measured in units of the wage per efficiency unit of labor in that economy, w^i.

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17 This assumption rules out the situation when parents, who do not find it worthwhile to migrate to the MD economy, will consider the possibility of migration for their offspring. This anticipates the further assumption (Section 2.9) that migration is possible in period t only. Assuming that parents take the possibility of their offspring's migration into account will change the threshold level of human capital, above which agents migrate, without altering the qualitative nature of this paper's results.

18 In the utility function postulated by Galor and Moav (2002) individuals differ with respect to the relative weight given to the quality of their children. In the utility function used in Azarnert (2010b), where the choice is between giving birth to one child per parent or remaining childless, individuals differ with respect to the weight given to the child.

Individuals are assumed to behave as atomistic agents, so that the migrants neglect the effect of their migration on the basic cost of living, a_t^i, and the average level of human capital, $\bar{h}_t^i$, in the economies of their origin and destination, Similarly, all agents neglect the effect of their decision with respect to the number of their offspring on the basic cost of living and the average level of human capital in the children's generation.

To maximize utility, an adult of any type j simultaneously chooses a current consumption, C_t^j, the number of children, N_t^j, and invests e_t^j units of w^i in each child's education subject to the following budget constraint:[19]

$$C_t^j + w^i(\delta h_t + e_t^j)N_t^j \leq w^i h_t(1-a_t^i), \text{ if } j = i = MD, LD,$$
$$C_t^j + w^i(\delta h_t + e_t^j)N_t^j \leq w^i h_t(1-a_t^i) - m, \text{ if } j = M \text{ and } i = MD. \tag{4}$$

The right-hand side of equation (4) represents an adult's income net of the costs associated with congestion diseconomies in the economy where that individual lives, a_t^i, which is allocated between consumption and the total cost of rearing children.

The total potential future income of the individual's offspring net of the basic costs associated with congestion diseconomies in either economy in children's generation, a_t^i, is:

$$I_{t+1}^{N,j} = N_t^j h_{t+1} w^i (1-a_{t+1}^i), \quad j = i = MD, LD. \tag{5}$$

2.4. Quantity - Quality Tradeoff

From optimization, an adult's consumption is

$$C_t^j = (1-\beta)\begin{cases} h_t w^i(1-a_t^i), & \text{if } j = i = MD, LD \\ h_t w^i(1-a_t^i) - m, & \text{if } j = M \text{ and } i = MD. \end{cases} \tag{6}$$

That is, a fraction $1-\beta$ of an adult's net full income is devoted to consumption and hence a fraction β is devoted to childrearing.

[19] The time constraint requires that $0 \leq 1 - a_t^i - h(\delta + e_t^j / h_t)N_t^j \leq 1 - a_t^i$, if $j = i = MD, LD$, and $0 \leq 1 - a_t^i - (m / w^i h_t) - (\delta + e_t^j / h_t)N_t^j \leq 1 - a_t^i - (m / w^i h_t)$, if $j = M$ and $i = MD$.

In order to allocate resources between children's quantity and quality, an adult makes two simultaneous decisions. First, he decides how much consumption to forego during his adulthood to rear a family. Second, he decides what amount of resources to invest in the education of his children to increase their skill level.

For an individual of any type in the case of a non-corner solution, the standard condition of setting the marginal rate of substitution between quality and quantity equal to the price implies that

$$\frac{h_{t+1}}{N_t^j} - \frac{\delta h_t + e_t^j}{N_t^j \big/ \left(dh_{t+1} / de_t^j \right)} = 0 \quad \text{if} \quad e_t^j > 0, \tag{7}$$

where h_{t+1} / N_t^j is the marginal rate of substitution between quality and quantity, $w^i(\delta h_t + e_t^j)$ is the cost of an additional child for a given level of parental investment in the child's education and $w^i N_t^j / [dh_{t+1} / de_t^j]$ is the marginal cost of children's quality (human capital) for a given number of children.

From equation (7), optimization with respect to child's quality thus implies that

$$h_{t+1} = \left(\delta h_t + e_t^j \right) \frac{dh_{t+1}}{de_t^j}. \tag{8}$$

The next subsection discusses the solution for the parents' optimization problem for a particular form of the human capital production function.

2.5. *Choice of Fertility and Investment in Education*

To characterize optimal choices of fertility and investment in education, suppose that in either economy all children born in this economy have access to the same technology of human capital production:

$$h_{t+1} = (\mu + e_t^j)^\gamma \,\overline{h}_t^i, \quad 0 < \gamma < 1, \; 0 < \mu < 1, \text{ where } i = MD, LD \text{ and } j = MD, LD, M. \tag{9}$$

This learning technology implies that children of the migrants from the LD economy born in the MD economy become similar to the indigenous population of the MD economy. I relax this assumption below in Section (4).

Given (9), the optimal choice of investment in the children's education of an individual of any type in either economy is[20]

$$e_t^j = \frac{\gamma\delta h_t - \mu}{1-\gamma} \quad , \quad j = LD, MD, M \ . \tag{10}$$

so that, according to (10),

$$h_{t+1} = \left(\frac{\gamma}{1-\gamma} (\delta h_t - \mu) \right)^{\gamma} \bar{h}_t^i \ , \quad i = LD, MD \ . \tag{11}$$

Given the amount of resources allocated to children's education, the desired fertility is

$$N_t^j = \begin{cases} \dfrac{\beta(1-\gamma)}{\delta - (\mu/h_t)}(1-a_t^i) \ , & \text{if} \quad j = i = MD, LD \\ \dfrac{\beta(1-\gamma)}{\delta - (\mu/h_t)}(1-a_t^i - \dfrac{m}{w^i h_t}) \ , & \text{if} \quad j = M \text{ and } i = MD. \end{cases} \tag{12}$$

Equation (10) shows that the optimal choice of investment in the offspring's education and hence the children's human capital levels (Eq. 11) is positively related to the parent's human capital, although parental human capital does not enter the learning technology directly. Equation (12) displays the traditional negative relationship between the parental level of human capital and the choice of fertility.[21]

In the next section, I derive conditions that lead to the decision to migrate.

2.6. The Decision to Migrate

To characterize individuals' choice with respect to migration, recall that by definition in this model the average level of human capital in the more developed economy is higher than that in the less developed economy; $\bar{h}_t^{MD} > \bar{h}_t^{LD}$. This implies that, for any given fraction of the parental income invested in the offspring's education, $e_t w^i$, the human capital production function (9) yields a higher level of the child's human capital in the

[20] An assumption that $h_t^{i,\min} > \mu/\gamma\delta$ ensures that all parents invest in the education of their children.

[21] A lower fertility of the immigrants relative to that of the similar indigenous agents is a natural result of the assumption that immigrants, whose incomes are reduced by the costs of migration, have the same preferences as the indigenous agents. Any modification of the model so as to obtain a higher fertility among the migrants, for instance, through an assumption that they put a higher weight on children (a higher β), or

more developed economy. Similarly, assumption A1 implies that the net wage per unit of efficiency labor in the more developed economy is also higher than that in the less developed economy; $w^{MD}(1-a_t^{MD}) > w^{LD}(1-a_t^{LD})$. As a consequence, in the world economy under consideration only one way of migration from the LD economy to the MD economy is worthwhile. At the same time, a migrant should pay the cost of migration, m. Therefore, a young adult individuals from the LD economy decide to migrate if their utility in the case of migration is higher than their utility in the LD economy; $U_t^M > U_t^{LD}$.

Substituting an individual's own consumption along with that individual's offspring's net potential income in the case of migration, as shown in equations (4) and (5), respectively ($j = M$), into the utility function (3) and comparing the result to the level of utility in the case of no migration ($j = LD$) allows us to compute the following threshold level of human capital:[22]

$$\hat{h}_t = \frac{m}{w^{MD}(1-a_t^{MD}) - w^{LD}(1-a_t^{LD})\left(\dfrac{\bar{h}_t^{LD}(1-a_{t+1}^{LD})}{\bar{h}_t^{MD}(1-a_{t+1}^{MD})}\right)^{\beta}} . \qquad (13)$$

Notice that, since the negative denominator of equation (13) implies that the other way of migration – from the MD to the LD economy – is worthwhile, which is ruled out by definition in this model, this threshold is either positive or meaningless. Therefore, the further analysis is performed under assumption that in the threshold equation the denominator is positive.[23]

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have lower costs of child rearing (a lower δ), will strengthen this paper's result with respect to the brain dilution effect of migration without generating additional insights.

[22] To derive the threshold, note that $U_t^M > U_t^{LD}$ if the following condition holds:

$$(1-\beta)\log((1-\beta)w^{MD}h_t(1-a_t^{MD}) - m)$$
$$+\beta\log\left(\frac{\beta(1-\gamma)}{\delta-(\mu/h_t)}(1-a_t^{MD} - \frac{m}{w^{MD}h_t})(\frac{\gamma}{1-\gamma}(\delta h_t-\mu))^{\gamma}\,\bar{h}_t^{MD}(1-a_{t+1}^{MD})w^{MD}\right)$$
$$> (1-\beta)\log((1-\beta)w^{LD}h_t(1-a_t^{LD})) + \beta\log\left(\frac{\beta(1-\gamma)}{\delta-(\mu/h_t)}(1-a_t^{LD})(\frac{\gamma}{1-\gamma}(\delta h_t-\mu))^{\gamma}\,\bar{h}_t^{LD}(1-a_{t+1}^{LD})w^{LD}\right).$$

[23] As follows from assumption A1, $w^{MD}(1-a_t^{MD}) > w^{LD}(1-a_t^{LD})$. Therefore, to ensure that the denominator is positive it is enough to assume that $\bar{h}_t^{MD} \geq \bar{h}_t^{LD}(1-a_{t+1}^{LD})/(1-a_{t+1}^{MD})$.

This threshold level divides the LD population into two groups:

1. *Individuals with human capital levels lower than the threshold* $\hat{h}_t$ who choose to remain in the LD economy.
2. *Individuals with human capital levels greater than the threshold* $\hat{h}_t$ who choose to migrate to the MD economy.

2.7. The Effect of Migration on Individuals' Consumption, Fertility and Per-Child Human Capital Levels

To establish the effect of migration on individual agents' optimal choice of their own consumption at adulthood, the number of children and the offspring' per-child human capital levels, compare the results of optimization in the case of migration to those that are obtained in the absence of migration. For comparison, denote the case of migration by the superscript M and the case of no migration by the superscript NM.

From equation (6), subtracting an adult individual's level of consumption in the case of migration (C_t^M) from that in the absence of migration (C_t^{NM}), one can obtain that for the indigenous population in the MD economy, as well as for individuals who remain in the LD economy

$$\Delta C_t^{j,M} \equiv C_t^{j,M} - C_t^{j,NM} = (1-\beta) w^i h_t (a_t^{i,NM} - a_t^{i,M}), \quad j = i = MD, LD. \tag{14}$$

Similarly, from equation (12),

$$\Delta N_t^{j,M} \equiv N_t^{j,M} - N_t^{j,NM} = \frac{\beta(1-\gamma)}{\delta - (\mu/h_t)} (a_t^{i,NM} - a_t^{i,M}), \quad j = i = MD, LD. \tag{15}$$

Migration from the LD economy to the MD economy increases the congestion costs in the MD economy, while reducing these costs in the LD economy, so that in period t, $a_t^{MD,M} > a_t^{MD,NM}$ and $a_t^{LD,M} < a_t^{MD,NM}$. Therefore, from equations (13) and (14), it is evident that migration reduces fertility and adults' consumption in indigenous population in the MD economy, while increasing fertility and consumption among individuals who remain in the LD economy.

From equation (11),

$$\Delta h_{t+1}^{j,M} \equiv h_{t+1}^{j,M} - h_{t+1}^{j,NM} = \left(\frac{\gamma}{1-\gamma}(\delta h_t - \mu)\right)^{\gamma} (\bar{h}_t^{i,M} - \bar{h}_t^{i,NM}), \quad j = i = MD, LD. \tag{16}$$

Since, as established in Section 2.6, for agents with human capital levels above the threshold $\hat{h}_t$ it is worthwhile to leave the LD economy, migration always reduces the average level of human capital in this economy, $\bar{h}_t^{LD,NM} > \bar{h}_t^{LD,M}$. As a consequence, in the case of the out-migration from this economy, the per-child human capital levels of the offspring of the agents who remain in the LD economy decline. As to the offspring of individuals born in the MD economy, their per-capita human capital levels can either increase, if the average level of in-migrants' human capital is higher than the average level of human capital of the indigenous population, $\bar{h}_t^{M} > \bar{h}_t^{MD}$, or decrease, if, on the average, the migrants are less skilled than the indigenous population, $\bar{h}_t^{M} < \bar{h}_t^{MD}$. The exact condition for $\bar{h}_t^{M}$ to be higher or lower than $\bar{h}_t^{MD}$ is established below in equations (A3) and (A4) in Appendix A.

Proceeding to the migrants themselves, from equation (6),

$$\Delta C_t^M \equiv C_t^M - C_t^{LD} = (1-\beta)h_t((w^{MD}(1-a_t^{MD,M}) - (m/h_t)) - w^{LD}(1-a_t^{LD,M})). \tag{17}$$

This allows us to conclude that among migrants consumption increases among individuals with human capital levels above the threshold $\hat{h}_t'$:

$$\hat{h}_t' = \frac{m}{w^{MD}(1-a_t^{MD}) - w^{LD}(1-a_t^{LD})} \tag{18}$$

and decreases among individuals with human capital levels below this threshold.[24]

Following the same steps as in the case of the MD and LD groups, in the case of the migrants,

$$\Delta N_t^M \equiv N_t^M - N_t^{LD} = \frac{\beta(1-\gamma)}{\delta - (\mu/h_t)}(a_t^{i,NM} - a_t^{i,M} - (m/w^{MD}h_t)) \tag{19}$$

and

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[24] Note that if $\bar{h}_t^{MD} \geq \bar{h}_t^{LD}(1-a_{t+1}^{LD})/(1-a_{t+1}^{MD})$, $\hat{h}_t' > \hat{h}_t$ and, therefore, consumption among immigrants with human capital levels that fall in the range of $[\hat{h}_t, \hat{h}_t'[$ is lower in the case of migration. For these migrants with relatively low human capital the positive effect on their utility through the increase of their children's quality (Eq. 20) outweighs the negative effect through the reduction in their own consumption and the quantity of their offspring.

$$\Delta h_{t+1}^{M} \equiv h_{t+1}^{MD,M} - h_{t+1}^{LD,NM} = \left(\frac{\gamma}{1-\gamma}(\delta h_t - \mu)\right)^{\gamma} (\bar{h}_t^{MD,M} - \bar{h}_t^{LD,M}), \tag{20}$$

which implies that migration reduces their fertility, while increasing their children's human capital levels.

Note also that for all three groups of population, the effect of migration on the adults' consumption and their children's per-capita human capital stock is stronger the higher is the agent's level of human capital. In contrast, in the case of fertility, the effect of migration weakens with the agents' human capital.

2.8. The Effect of Migration on Individuals' Utility

As their optimal choice, migration always increases the level of utility of the individuals who decide to migrate, so that $U_t^M > U_t^{LD}$. It however can either increase or decrease the levels of utility for the other two groups in population.

Thus, for individuals who remain in the LD economy, the level of utility can increase if the negative effect of the decline in the average level of human capital in their economy caused by the out-migration of the agents with superior skills is not sufficiently large, so as to outweigh the positive effect of the corresponding reduction in congestion. Therefore, comparing the corresponding levels of utility with and without migration, $U_t^{LD,M} > U_t^{LD,NM}$, and thereby individuals who remain in the LD economy are better off with the out-migration if

$$\frac{\bar{h}_t^{LD,NM}}{\bar{h}_t^{LD,M}} < \left(\frac{1-a_t^{LD,M}}{1-a_t^{LD,NM}}\right)^{\frac{1}{\beta}} \frac{1-a_{t+1}^{LD,M}}{1-a_{t+1}^{LD,NM}}. \tag{21}$$

On the other hand, the level of utility of individuals in the MD economy can increase with migration if and only if the positive effect of the increase in the average level of human capital in this economy owing to the in-migration is sufficiently large, so as to outweigh the negative effect of the corresponding increase in congestion. Comparing the levels of utility with and without migration, $U_t^{MD,M} > U_t^{MD,NM}$ if

$$\frac{\bar{h}_t^{MD,M}}{\bar{h}_t^{MD,NM}} > \left(\frac{1-a_t^{MD,NM}}{1-a_t^{MD,M}}\right)^{\frac{1}{\beta}} \frac{1-a_{t+1}^{MD,NM}}{1-a_{t+1}^{MD,M}}. \tag{22}$$

If these conditions do not hold, i.e., inequalities (21) and (22) are reversed, the populations in the origin and host economies can be worse off with free uncontrolled migration.

2.9. The Dynamical System

This section analyzes the dynamic behavior of the society's average level of human capital. To characterize the effect of migration on the inter-temporal evolution of human capital in the world economy, I examine the effect of migration in period t on the average level of human capital in the next period, in which migration is impossible.[25] I consider first the world as a whole. Next, I proceed to the analysis of each of the economies separately.

The average human capital level in period $t+1$ is defined as

$$\bar{h}_{t+1} \equiv \int h_{t+1} dF_{t+1}(h) = \int N_{t+1} h_{t+1} dF_t(h) \Big/ \int N_{t+1} dF_t(h). \tag{23}$$

Distinguishing parents of each type and denoting the world economy by the superscript W, the average level of human capital in the world as a whole in period $t+1$ in the case of migration, $\bar{h}_{t+1}^{W,M}$, is

$$\bar{h}_{t+1}^{W,M} = \frac{\int N_t^{MD,M} h_{t+1} dF_t^{MD}(h^{MD}) + \int\limits_{h_t^{LD} > \hat{h}_t} N_t^{M} h_{t+1} dF_t^{LD}(h^{LD}) + \int\limits_{h_t^{LD} \leq \hat{h}_t} N_t^{LD,M} h_{t+1} dF_t^{LD}(h^{LD})}{\int N_t^{MD,M} dF_t^{MD}(h^{MD}) + \int\limits_{h_t^{LD} > \hat{h}_t} N_t^{M} dF_t^{LD}(h^{LD}) + \int\limits_{h_t^{LD} \leq \hat{h}_t} N_t^{LD,M} dF_t^{LD}(h^{LD})}. \tag{24}$$

Correspondingly, in the absence of migration, the average level of human capital in the world economy, $\bar{h}_{t+1}^{W,NM}$, is

$$\bar{h}_{t+1}^{W,NM} = \frac{\int N_t^{MD,NM} h_{t+1} dF_t^{MD}(h^{MD}) + \int N_t^{LD,NM} h_{t+1} dF_t^{LD}(h^{LD})}{\int N_t^{MD,NM} dF_t^{MD}(h^{MD}) + \int N_t^{LD,NM} dF_t^{LD}(h^{LD})}. \tag{25}$$

Given the number of children and the levels of human capital investment among the three types of agents, as determined in Section 2.5, the average human capital levels in period $t+1$ in both cases are, respectively,

$$\bar{h}^{W,M}_{t+1} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \left[\bar{h}^{MD,M}_t \left(\int (1-a^{MD,M}_t) h_t (\delta h_t - \mu)^{\gamma-1} dF^{MD}_t \right.\right.$$

$$+ \int_{h^{LD}_t > \hat{h}_t} (1-a^{MD,M}_t - (m/w^{MD} h_t)) h_t (\delta h_t - \mu)^{\gamma-1} dF^{LD}_t)$$

$$\left. + \bar{h}^{LD,M}_t \int_{h^{LD}_t \le \hat{h}_t} (1-a^{LD,M}_t) h_t (\delta h_t - \mu)^{\gamma-1} dF^{LD}_t \right] \Big/ \tag{26}$$

$$\left[\int (1-a^{MD,M}_t)(\delta - (\mu/h_t))^{-1} dF^{MD}_t + \int_{h^{LD}_t > \hat{h}_t} (1-a^{MD,M}_t - (m/w^{MD} h_t))(\delta - (\mu/h_t))^{-1} dF^{LD}_t \right.$$

$$\left. + \int_{h^{LD}_t \le \hat{h}_t} (1-a^{LD,M}_t)(\delta - (\mu/h_t))^{-1} dF^{LD}_t \right]$$

and

$$\bar{h}^{W,NM}_{t+1} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \left[\bar{h}^{MD,NM}_t \int (1-a^{MD,NM}_t) h_t (\delta h_t - \mu)^{\gamma-1} dF^{MD}_t \right.$$

$$\left. + \bar{h}^{LD,NM}_t \int (1-a^{LD,NM}_t) h_t (\delta h_t - \mu)^{\gamma-1} dF^{LD}_t \right] \Big/ \tag{27}$$

$$\left[\int (1-a^{MD,NM}_t)(\delta - (\mu/h_t))^{-1} dF^{MD}_t + \int (1-a^{LD,NM}_t)(\delta - (\mu/h_t))^{-1} dF^{LD}_t \right].$$

Comparing the levels of human capital in the case of migration ($\bar{h}^{W,M}_{t+1}$) to that in the absence of migration ($\bar{h}^{W,NM}_{t+1}$), as shown above in equations (26) and (27), allows us to determine precisely whether migration increases or decrease the average level of

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[25] As follows from the property of the learning technology (9) with respect to the average level of human capital in the society, the effect of migration on human capital levels in each of the economies evolves

human capital in the world as a whole. Thus, if $\bar{h}_{t+1}^{W,M} > \bar{h}_{t+1}^{W,NM}$, migration increases the world economy's level of human capital. In contrast, if $\bar{h}_{t+1}^{W,M} < \bar{h}_{t+1}^{W,NM}$, the average level of human capital in the world is higher in the absence of migration.

Proceeding now to the analysis of each of the economies separately, let us recall that by construction in this model migration always decreases the level of human capital at origin. Therefore, for $\bar{h}_{t+1}^{W,M} > \bar{h}_{t+1}^{W,NM}$, a migration-driven positive effect on the average level of human capital in the MD economy in period $t+1$ should necessarily be large enough, so as to outweigh its negative effect on the LD economy. On the other hand, if $\bar{h}_{t+1}^{W,M} < \bar{h}_{t+1}^{W,NM}$, the host economy's average level of human capital in period $t+1$ can increase with migration, if $\bar{h}_{t+1}^{MD,M} > \bar{h}_{t+1}^{MD,NM}$, or decrease if $\bar{h}_{t+1}^{MD,M} < \bar{h}_{t+1}^{MD,NM}$. The exact condition is relegated to Appendix A.

Moreover, although in this framework migration does not alter the total amount of human capital in the world in the period when it takes place, nonetheless it can lead to a reduction in the average human capital levels in both the sending and receiving economies in this period. Thus, if, on the average, the migrants are less skilled than the relatively highly skilled indigenous population in the destination economy, $\bar{h}_t^{M} < \bar{h}_t^{MD,NM}$, their arrival can reduce the average level of human capital in the host economy as well. The exact condition for $\bar{h}_t^{MD,M}$ to be higher or lower than $\bar{h}_t^{MD,NM}$ is established in equations (A3) and (A4) in Appendix A.

3. Public Policy Intervention

As shown previously in Section 2.8, free uncontrolled migration can lead to a reduction in the utility of the populations in the migrants' origin and destination economies. Similarly, as shown in Section 2.9, from the children's generation on, it can be conductive to a decline in the average per-capita human capital levels not only in the source economy, but also in the host economy and in the world as a whole. In this case, an income

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further from one generation to the next.

redistribution financed by taxes levied on the migrants, who by definition always gain from migration, can help mitigate the negative effect of their migration.

In this Section, I consider a tax imposed on immigrants to compensate the indigenous population in the host economy for the in-migration-driven negative externality. By analogy with the brain drain, or Bhagwati tax, this type of redistribution can be referred to as a "brain dilution tax". I present and analyze the effect of this tax on human capital accumulation in the destination economy and in the world as a whole. I also shed some light on the effect of taxation in one economy on human capital accumulation (and utility) in the other.

To specify the tax-transfer scheme, suppose that in period t in the host economy there is one common lump-sum tax, T_t, levied on any immigrant with the proceeds redistributed as a lump-sum subsidy, S_t, to any indigenous adult individual born in this economy.[26] This scheme yields that the brain dilution tax imposed on an immigrant in period t is

$$T_t = \frac{\int S_t N_t^{MD} dF_{t-1}^{MD}(h^{MD})}{\int_{h_t^{LD} > \hat{h}_t} N_t^{LD} dF_{t-1}^{LD}(h^{LD})} \ , \tag{28}$$

where the number of immigrants $\int_{h_t^{LD} > \hat{h}_t} N_{t-1}^{LD} dF_{t-1}^{LD}(h^{LD})$ is either positive, or meaningless.

[26] The standard brain drain tax, as proposed by Bhagwati and followers, is usually modeled as an income tax paid by emigrants on top of their regular income tax. However, in a model with endogenous fertility and explicit quantity-quality tradeoff a labor-income tax appears to be inferior to a lump-sum tax, because taxation of labor income increases the relative cost of child quality, thus reducing the parental per-child investment in the education of the tax-payers' offspring. Similarly, if the proceeds are distributed proportionally to the labor income of the local agents, this increases the relative cost of the quantity of their children, which further reduces their optimal fertility choice, thereby amplifying the negative effect of immigration on the size of the local population in the MD economy.

Within the framework of the present model, a labor-income tax at the rate τ_t imposed on immigrants reduces their per-child educational investment to

$$e_t^M = \frac{\gamma \delta h_t (1-\tau_t) - \mu}{1-\gamma} \ ,$$

while a subsidy at the rate s_t to the local agents' labor income reduces the number of their children to

$$N_t^{MD} = \frac{\beta(1-\gamma)}{\delta - (\mu / ((1+s_t)h_t))} (1 - a_t^{MD,M}) \ .$$

With the tax-transfer scheme specified above, following the same steps as in Section 2.5, the number of children in the indigenous population in the MD economy increases to

$$N_t^{MD,M} = \frac{\beta(1-\gamma)}{\delta-(\mu/h_t)}(1-a_t^{MD,M} + \frac{S_t}{w^{MD}h_t}) \tag{29}$$

and among immigrants declines to

$$N_t^{M} = \frac{\beta(1-\gamma)}{\delta-(\mu/h_t)}(1-a_t^{MD,M} - \frac{m+T_t}{w^{MD}h_t}), \tag{30}$$

while the per-child investment in children's education in both groups of agents remains unaffected as shown in equation (10).

Therefore, in this case, denoted by the superscript K, following the same steps as in Section 2.8, the average level of human capital in the MD economy in period $t+1$ is

$$\bar{h}_{t+1}^{MD,MK} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \left[\bar{h}_t^{MD,MK} \left(\int (1-a_t^{MD,MK} + \frac{S_t}{w^{MD}h_t}) h_t (\delta h_t - \mu)^{\gamma-1} dF_t^{MD} \right.\right.$$
$$\left.\left. + \int_{h_t^{LD} > \hat{h}_t^K} (1-a_t^{MD,MK} - \frac{m+T_t}{w^{MD}h_t}) h_t (\delta h_t - \mu)^{\gamma-1} dF_t^{LD} \right) \right] \Bigg/ \tag{31}$$
$$\left[\int (1-a_t^{MD,MK} + \frac{S_t}{w^{MD}h_t})(\delta-(\mu/h_t))^{-1} dF_t^{MD} + \right.$$
$$\left. \int_{h_t^{LD} \le \hat{h}_t^K} (1-a_t^{LD,MK} - \frac{m+T_t}{w^{MD}h_t})(\delta-(\mu/h_t))^{-1} dF_t^{LD} \right],$$

while the average level of human capital in the world economy as a whole is

$$\bar{h}_{t+1}^{W,MK} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \left[\bar{h}_t^{MD,MK} \left(\int (1-a_t^{MD,M} + \frac{S_t}{w^{MD}h_t}) h_t (\delta h_t - \mu)^{\gamma-1} dF_t^{MD} \right.\right.$$
$$\left. + \int_{h_t^{LD} > \hat{h}_t^K} (1-a_t^{MD,MK} - \frac{m+T_t}{w^{MD}h_t}) h_t (\delta h_t - \mu)^{\gamma-1} dF_t^{LD} \right)$$

$$+\bar{h}_t^{LD,M} \int_{h_t^{LD} \le \hat{h}_t^K} (1-a_t^{LD,M}) h_t (\delta h_t - \mu)^{\gamma-1} dF_t^{LD} \Bigg] \Bigg/ \tag{32}$$

$$\Bigg[\int (1-a_t^{MD,MK} + \frac{S_t}{w^{MD} h_t})(\delta - (\mu/h_t)^{-1} dF_t^{MD}$$

$$+ \int_{h_t^{LD} > \hat{h}_t^K} (1-a_t^{MD,MK} - \frac{m+T_t}{w^{MD} h_t})(\delta - (\mu/h_t))^{-1} dF_t^{LD} + \int_{h_t^{LD} \le \hat{h}_t^K} (1-a_t^{LD,MK})(\delta - (\mu/h_t))^{-1} dF_t^{LD} \Bigg],$$

where

$$\hat{h}_t^K = \frac{m+T_t}{w^{MD}(1-a_t^{MD,MK}) - w^{LD}(1-a_t^{LD,MK}) \left(\frac{\bar{h}_t^{LD,MK}(1-a_{t+1}^{LD,MK})}{\bar{h}_t^{MD,MK}(1-a_{t+1}^{MD,MK})} \right)^{\beta}} \tag{33}$$

and

$$T_t^K = \frac{\int S_t (1-a_{t-1}^{MD})(\delta - (\mu/h_{t-1}))^{-1} dF_{t-1}^{MD}}{\int_{h_t^{LD} > \hat{h}_t^k} (1-a_{t-1}^{LD})(\delta - (\mu/h_{t-1}))^{-1} dF_{t-1}^{LD}} \ . \tag{34}$$

Comparing the average levels of human capital in the MD economy and the world as a whole, as shown above in equations (31) and (32), respectively, to those in the absence of migration, as shown in equations (A1) in Appendix and (27), the brain dilution tax can be set in such a manner, so that $\bar{h}_{t+1}^{MD,MK} \ge \bar{h}_{t+1}^{MD,NM}$ and $\bar{h}_{t+1}^{W,MK} \ge \bar{h}_{t+1}^{W,NM}$.[27]

Similarly, the amount of taxation can be set so as to fully neutralize the negative effect of in-migration on the local agents' consumption and fertility.[28] With redistribution it is also possible to achieve the same level of utility for the local agents in the host economy in period t, when migration takes place, as in the absence of migration, or even

[27] If taxation is relatively high, it is also possible that there will be no migration in the equilibrium and, thus, the average level of human capital in the world will be exactly the same as shown in equation (27). Arithmetically, this happens when $h_t^{LD,\max} \le \hat{h}_t^K$.

[28] In this particular case, the necessary amount of the subsidy, so that with the subsidy $C_t^{MD,MK} = C_t^{MD,NM}$ and $N_t^{MD,MK} = N_t^{MD,NM}$, is $S_t = w^{MD} h_t (a_t^{MD,MK} - a_t^{MD,NM})$.

make them better off with migration. The average level of human capital in the world economy with the subsidy that equalizes the levels of utility of the adult agents in the MD economy with and without migration is shown in Appendix B.

The reciprocal effect of the redistribution in one economy on human capital accumulation in the other is also worthy of mention. Thus, for example, the brain dilution tax imposed on the immigrants in the host economy increases the human capital threshold, which discourages migration of individuals, whose human capital levels fall in the range of $]\hat{h}_t, \hat{h}_t^K]$. This, in turn, decreases the out-migration-driven reduction in the average level of human capital in the source economy, thereby encouraging its economic growth. Likewise, an exit tax imposed on the emigrants in the source economy also increases that threshold in a similar way. This makes migration undesirable for potential migrants with lower levels of human capital, thus increasing the average level of human capital of the migrants who arrive at the MD economy.

Following the same intuition, if migration is associated with a reduction in the levels of utility among individuals who do not migrate, a tax on the migrants in one economy can have a positive effect on the local agents' utility in the other.

4. Incomplete Assimilation

In previous sections we assumed that the migrants fully assimilate in their host economy, and that their children born in the MD economy becomes similar to that economy’s indigenous population. It has however been broadly argued in the literature that the human capital of an individual’s ethno-cultural group is an important input in the formation of that person’s own human capital (e.g. Borjas (1992, 1995), among others).

To consider an incomplete assimilation of the migrants’ offspring in their host economy, the human capital production function (9) can be re-formulated, so as to allow for a partial dependence of their human capital levels on the average level of human capital at their parent’s origin:[29]

$$h_{t+1} = (\mu + e_t^j)^\gamma (\psi \bar{h}_t^{MD} + (1-\psi)\bar{h}_t^{LD}), \quad 0 \le \psi \le 1, \quad 0 < \gamma < 1, \; 0 < \mu < 1. \tag{38}$$

[29] Bisin and Verdier (2011) provide an extensive review of the literature on the transmission of cultural, ethnic and religious traits across generations.

It this case, denoted by the superscript A, a human capital threshold that makes migration worthwhile becomes

$$\hat{h}_t^A = \frac{m}{w^{MD}(1-a_t^{MD}) - w^{LD}(1-a_t^{LD})\left(\frac{\bar{h}_t^{LD}(1-a_{t+1}^{LD})}{(\psi\bar{h}_t^{MD}+(1-\psi)\bar{h}_t^{LD}(1-a_{t+1}^{MD})}\right)^{\beta}}. \qquad (39)$$

Note that for any $\psi \in (0,1)$, $\hat{h}_t^A > \hat{h}_t$, as specified in equation (13), which discourages migration of individuals, whose human capital levels fall in the range of $]\hat{h}_t, \hat{h}_t^A]$.

This allows us to postulate that an incomplete assimilation of the migrants and their locally born offspring in the more developed host economy has a positive effect on the human-capital-based growth in the less developed source economy. On the other hand, for the more developed host economy, an incomplete assimilation generates two conflicting effects. First, it is associated with an increase in the levels of the migrants' human capital. Second, it reduces the levels of human capital of the migrants' offspring, which can have negative consequences for the human-capital-based growth in the host economy in the future.

5. Conclusion

This article analyzes the effect of migration from a less developed economy to a more developed economy on economic growth. The analysis is performed in the context of a growth model with endogenous fertility, in which congestion diseconomies are incorporated. The model shows that out-migration increases fertility and reduces the total (and average) human capital stock in the source economy. At the same time, immigration reduces fertility and can either increase or decrease the average level of human capital in the host economy. I derive a condition that determines precisely whether immigration increases or decreases the average level of human capital in the receiving economy. I show how migration affects the inter-temporal evolution of human capital levels in the world economy. I also demonstrate that a tax imposed on the immigrants in the host economy can increase human capital accumulation in the destination and source economies and the world as a whole. Moreover, this tax can also have a positive effect on the utility of individuals who remain in the poor source economy.

Appendix A. *Average levels of human capital in the* MD *economy with and without free uncontrolled in-migration*

Following the same steps as in Section 2.9, the average level of human capital in the MD economy in period $t+1$ in the absence of migration is

$$\bar{h}_{t+1}^{MD,NM} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \bar{h}_t^{MD,NM} \int h_t(\delta h_t - \mu)^{\gamma-1} dF_t^{MD} \Bigg/ \int (\delta - (\mu/h_t))^{-1} dF_t^{MD} \qquad \text{(A1)}$$

while the corresponding average level of human capital in presence of migration is

$$\bar{h}_{t+1}^{MD,M} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \Bigg[\bar{h}_t^{MD,M} \Big(\int (1-a_t^{MD,M}) h_t(\delta h_t - \mu)^{\gamma-1} dF_t^{MD}$$

$$+ \int_{h_t^{LD} > \hat{h}_t} (1-a_t^{MD,M} - (m/w^{MD} h_t)) h_t(\delta h_t - \mu)^{\gamma-1} dF_t^{LD} \Big) \Bigg] \Bigg/$$

$$\left[\int (1-a_t^{MD,M})(\delta - (\mu/h_t))^{-1} dF_t^{MD} + \int_{h_t^{LD} > \hat{h}_t} (1-a_t^{MD,M} - (m/w^{MD} h_t))(\delta - (\mu/h_t))^{-1} dF_t^{LD} \right]$$

(A2)

Comparing the level of human capital in the case of migration, $\bar{h}_{t+1}^{MD,M}$, to that in the absence of migration, $\bar{h}_{t+1}^{MD,NM}$, as shown above in equations (A2) and (A1), respectively, allows us to determine precisely whether migration increases or decreases the average level of human capital in the MD economy in period $t+1$.

Similarly, in period t, $\bar{h}_t^{MD,M}$ is higher or lower than $\bar{h}_t^{MD,NM}$ if the average level of the immigrants' human capital, $\bar{h}_t^{M}$, as shown below in Eq. (A3), is higher or lower than the average level of the indigenous population, $\bar{h}_t^{MD}$, as shown in Eq. (A4), correspondingly:

$$\overline{h}_t^M = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \overline{h}_{t-1}^{LD} \int_{h_t^{LD} > \hat{h}_t} h_{t-1}(\delta h_{t-1} - \mu)^{\gamma-1} dF_{t-1}^{LD} \Bigg/ \int_{h_t^{LD} > \hat{h}_t} (\delta - (\mu/h_t))^{-1} dF_{t-1}^{LD} \tag{A3}$$

and

$$\overline{h}_t^{MD} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \overline{h}_{t-1}^{MD} \int h_{t-1}(\delta h_{t-1} - \mu)^{\gamma-1} dF_{t-1}^{MD} \Bigg/ \int (\delta - (\mu/h_{t-1}))^{-1} \overline{h}_{t-1}^{MD} dF_{t-1}^{MD} \ . \tag{A4}$$

Appendix B. *The average levels of human capital in the world economy with the subsidy that equalizes* $U_t^{MD,M}$ and $U_t^{MD,NM}$

To compute the amount of the subsidy that is necessary to neutralize the negative effect of migration on the utility of individuals in the host economy, compare the levels of their utility in the case with migration and subsidy and in the absence of migration. With the lump-sum subsidy, S_t, given to the adult agents in the MD economy, $U_t^{MD,M} = U_t^{MD,NM}$ if

$$S_t = \left[(1-a_t^{MD,NM})\left(\frac{\overline{h}_t^{MD,NM}(1-a_{t+1}^{MD,NM})}{\overline{h}_t^{MD,M}(1-a_{t+1}^{MD,M})}\right)^{\beta} - (1-a_t^{MD,M})\right] w^{MD} h_t \ . \tag{A5}$$

In this case, denoted by the superscript 1, the average level of human capital in the world economy as a whole in period $t+1$ is

$$\overline{h}_{t+1}^{W,M1} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma} \Bigg[\overline{h}_t^{MD,M1} \Bigg(\int (1-a_t^{MD,M1})(\delta h_t - \mu)^{\gamma-1} \left(\frac{\overline{h}_t^{MD,NM}(1-a_t^{MD,NM})}{\overline{h}_t^{MD,M1}(1-a_t^{MD,M1})}\right)^{\beta} h_t dF_t^{MD}$$

$$+ \int_{h_t^{LD} > \hat{h}_t^1} (1-a_t^{MD,M1} - ((m+T_t^1)/w^{MD} h_t)) h_t (\delta h_t - \mu)^{\gamma-1} dF_t^{LD} \Bigg)$$

$$+ \overline{h}_t^{LD,M1} \int_{h_t^{LD} \le \hat{h}_t^1} (1-a_t^{LD,M1})(\delta h_t - \mu)^{\gamma-1} h_t dF_t^{LD} \Bigg] \Bigg/ \tag{A6}$$

$$\Bigg[\int (1-a_t^{MD,M1})(\delta - (\mu/h_t))^{\gamma-1} \left(\frac{\overline{h}_t^{MD,NM}(1-a_t^{MD,NM})}{\overline{h}_t^{MD,M1}(1-a_t^{D,M1})}\right)^{\beta} dF_t^{MD}$$

$$+ \int_{h_t^{LD} > \hat{h}_t^1} (1 - a_t^{MD,M1} - ((m + T_t^1)/w^{MD} h_t)) dF_t^{LD} + \int_{h_t^{LD} \le \hat{h}_t^1} (1 - a_t^{LD,M1})(\delta - (\mu/h_t))^{-1} dF_t^{LD} \Bigg],$$

where

$$\hat{h}_t^1 = \frac{m + T_t^1}{w^{MD}(1 - a_t^{MD,M1}) - w^{LD}(1 - a_t^{LD,M1}) \left(\frac{\bar{h}_t^{LD,M1}(1 - a_{t+1}^{LD,M1})}{\bar{h}_t^{MD,M1}(1 - a_{t+1}^{MD,M1})} \right)^{\beta}}$$

and

$$T_t^1 = \int \left[\frac{1 - a_{t-1}^{MD,NM}}{\delta - (\mu/h_t)} \left(\frac{\bar{h}_t^{MD,NM}(1 - a_t^{MD,NM})}{\bar{h}_t^{MD,M1}(1 - a_t^{MD,M1})} \right)^{\beta} (1 - a_t^{MD,NM}) - (1 - a_t^{MD,M1}) \right] h_t dF_{t-1}^{MD} w^{MD} \Bigg/$$

$$\int_{h_t^{LD} > \hat{h}_t^1} (1 - a_{t-1}^{LD})(\delta - (\mu/h_{t-1}))^{-1} dF_{t-1}^{LD} .$$

The average level of human capital in the destination or source economies separately can easily be computed following the same steps.

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