Departamento de Economía
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Essays on Macroeconomics and Migration

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Chapter 1

Introduction

Migration is a topic in economics which has been recently attracting research from almost all economic fields, pointing out that migration is a relevant and delicate matter which involves several economic branches. Perhaps here lies the beauty and the complexity of migration in economics. The decision of migration is affected by the economic environment that surrounds it but, as an economic activity, migration also interacts within the international economy. So the decision of migration depends on economic, sociologic and political factors in an international economy which is becoming more globalized. To understand these ex-ante and ex-post relationships between migration and different economic variables remains a challenge and is the focus of this thesis.

It is surprising that the relationships between migration and many economic problems have not been studied intensively in a global macroeconomic framework. If one has to point out common features in previous works dealing with migration, one finds that most use static and partial equilibrium models. The second feature is the limited data available on this topic. To deal with migration in a general equilibrium model is not trivial, and it is even less so if the migration decision is endogenous, justifying the decisions made by previous studies which attempt to analyze migration. Nevertheless to study the relationships between migration and economic factors an international general equilibrium model is needed since only this framework is rich enough to analyze the numerous, complex interactions. This thesis presents an economic model in this line which can be used as an economic laboratory to investigate migration and its effects in different dimensions.

One may argue that the first attempt to investigate the relationships between migration and other economic variables should be through data and, effectively, there is extensive literature working from this approach. Unfortunately, however, data on migration in its different aspects is scarce and, when it exists, is very limited, restricting the capacity of empirical work, so a theoretical model is needed for different reasons. To be a complement in those cases where the data is rich enough to build a theory, and to answer those questions that the data cannot. Furthermore, a theoretical model can highlight new approaches that may help empirical work to progress. Obviously, these two ways to deal with the same problem must be seen as complementary rather than substitutive with both benefitting from mutual development.

This thesis investigates migration and its relationship with international trade, human capital and inequality. Though these are traditional and important topics in economics, only international trade has dealt with migration when considering complementarity and substitutability between trade and mobility of factors, though this has been mainly concentrated on physical capital mobility rather than human capital mobility.[1] It is remarkable that both the relationship between migration and human capital and between migration and inequality lack systematic research. Needless to say these relationships are of crucial importance, as this thesis highlights.

The second chapter of this thesis studies the relationship between migration and human capital accumulation. This chapter addresses the following questions: How is the investment in human capital affected by the possibility of future migration? Who is actually migrating? And, how are differences in output per capita affected by the mobility of human capital?

In order to answer the first question, two theories in the literature are contrasted: the brain drain theory and the induced education theory. According to the brain drain theory, migration has a negative effect on developing countries as the best and brightest leave the country.[2] In contrast, the induced education theory points to the fact that migration possibilities can generate incentives for everyone to invest in human capital with a potential overall positive effect on developing countries.[3]

The second question, who is actually migrating, is an important one in the migration literature. It responds to the question of whether the immigrants are negatively or positively self-selected, i.e. whether they have lower or higher human capital levels than those who do not migrate.[4]

Finally, the last question is within the framework of the traditional debate on why differences in output per capita are so big across countries. Two main theories are confronted. The theories which stress differences in TFP as the major explanation for differences in output per capita across countries and the theories which put forward differences in human capital across countries to justify differences in output per capita across them.[5] However, if one is concerned about human capital in international accounting, one must worry about migration because it is nothing else than the mobility of human capital across countries. This chapter contributes to this debate by quantifying the effect of migration on cross-country output differences.

The main features of the model economy presented in the second chapter are: (i) It is an international economy with two locations and perfect physical capital mobility. (ii) There are OG of dynasties composed by households. (iii) The

[1]A common assumption is that national factors such as physical capital and labor are perfect substitutes of such factors abroad. Although this assumption is trivial for the case of physical capital, it is controversial when considering labor as the factor which is moving.

[2]See Berry and Soligo (1969) for a detailed analysis where it is shown that migration can decrease the income per capita in the source country in a partial equilibrium model.

[3]The positive effect of brain drain comes up with the growth models of endogenous human capital accumulation and it is defined as the brain gain. One of this potential positive effects is the induced education hypothesis. Good surveys of this literature are Stark (2004) and Docquier and Rapoport (2004).

[4]The pioneering paper in this migration topic is Borjas (1987).

[5]See Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Bils and Klenow (2000) and Hendricks (2002) for works which support that differences in output per capita are due to differences in TFP. See Mankiw, Romer, and Weil (1992), Seshadri and Manuelli (2007) and Erosa, Koreshkova, and Restuccia (2007) for examples of the thesis of differences in human capital across countries accounting for across country output per capita differences.

households are heterogeneous and decide consumption, physical capital investment, human capital investment and migration. (iv) Human capital is produced using two inputs, time and expenditure in goods. (v) Migration is costly and two types of costs are considered, a pecuniary migration cost and a time migration cost that affects the effective units of labor. It is worth remarking that the heterogeneous agents decide endogenously investment in human capital and migration. This original approach permits us to answer to the above questions by linking two literatures, migration and economic growth.

To understand the mechanism and results in the model consider first the following comments. In the model migration is unidirectional, from the South to the North (the South economy has lower TFP than the North economy). The pecuniary migration cost is less important the higher is the TFP in the source country. For the time migration cost the opposite holds, it becomes more important the higher is the TFP in the source country. If there is a pecuniary migration cost then there exist a physical capital level beyond which the optimal decision is migration. It is impossible to find households at the steady state with physical capital above this level, implying that the pecuniary migration cost truncates the distribution at the steady state in the South. The time migration cost also truncates the distribution but this effect is less important compared to the previous one. Conversely to the pecuniary migration cost, the time migration cost affects the bottom of the distribution since for households with low initial levels of human capital the time migration cost is relatively lower.

Finally, due to restrictions imposed by the data on migration costs, the analysis treats them separately in order to stress the role of each migration cost. However, in this third chapter, the model is compared with evidence from Mexico and both costs are jointly considered. The results were able to reproduce the self-selection pattern for Mexican immigrants for acceptable values of migration costs. When considering the South three different TFP ratios with respect to the North are taken into account.

The chapter 2 shows that immigrants' self-selection is either positive or negative depending on: differences in the relative TFP of the two economies and the trade-off between migration costs, the pecuniary migration cost and the time migration cost. Immigrants are negatively self-selected when the differences in TFP between the source country and the host country are large. Conversely, when the TFP in the source country is close to that in the host country then immigrants are positively self-selected. This result is independent of the migration cost faced by immigrants although the mechanism behind the self-selection pattern differs depending on the migration cost supported. When there is a pecuniary migration cost households first afford this cost and then invest in human capital. For a country with low TFP after the pecuniary migration cost is paid households do not have resources to invest in human capital so immigrants are negatively self-selected. But for higher TFP levels of the source country it is possible that the households can afford the pecuniary migration cost and invest in human capital after having paid the pecuniary cost, so immigrants are positively self-selected.

The time migration cost is relatively higher for households with higher human capital so it is expected that households with lower human capital migrate as is the case for South to North TFP ratios of 0.3 and 0.5. So immigrants are negatively self-selected. However, for a South to North TFP ratio of 0.7

they are positively self-selected. This is because they can compensate the time migration cost by investing more in human capital.

The model economy supports the induced education hypothesis. Investment in human capital increases when there is the possibility of future migration. The effect is quite significant, particularly when the migration cost is a time migration cost. Average years of schooling increases by 4, 3.6 and 2 years for South to North TFP levels of 0.7, 0.5 and 0.3 respectively. Although less important, migration with a pecuniary migration cost also makes the same households invest more in human capital in an open economy. The induced education effect does not depend on the self-selection pattern. Even when immigrants are negatively self-selected, average years of schooling for non-immigrants are higher than in a closed economy.

Finally, the effect of migration on differences in output per capita across country is quantified. When there is a pecuniary migration cost, migration increases output per capita differences between the South and the North by 40%. The opposite effect is true if there is a time migration cost. For this case migration decreases output per capita differences by 30%.

The third chapter analyzes how migration and inequality affect each other. First, it studies the effect of differences in within country inequality across countries on migration. Second, it studies the effect of migration on inequality in the immigrants' source country. So, more precisely, the questions addressed in the third chapter are: What is the effect of differences in inequality across countries on migration? What is the effect of migration on inequality? Surprisingly, this relationship between migration and inequality has, again, not been extensively studied, although the topic of inequality and its interactions with other economic variables has always attracted the attention of the profession. To know the channels through which migration and inequality are linked remains a challenge and is attracting more research. It is crucial for several relevant questions in literature on migration, development economics and inequality.

The relationship between migration and inequality is interesting since there is both an ex-ante and an ex-post relationship. For the first relationship the third chapter is focus on how differences in inequality between two economies affect the migration flow between them.[6] Once this question has been addressed, a second question naturally appears. How does migration affect inequality? This is what makes this topic so controversial since inequality between countries may affect migration but migration may, in turn, affect inequality.

The chapter 3 uses a model based on that of the previous chapter with two main differences. In the version presented in the the third chapter the international economy consists of a large economy (the North) and a small economy (the South), which, by definition, does not affect the former, and introduces a government that receives revenues from income taxes which are used to fund expenditure in education. The small economy differs in its TFP ratio to the large economy, with three different TFP ratios being considered, as in the second chapter.

The intuition behind the results is similar to the previous one. The chapter 3 concludes that: (i) The migration rates are higher when both economies, the source economy and the host economy, present similar inequality levels. (ii) Migration decreases inequality in the source country. The effect of migration

[6]For within country inequality the Gini index of earnings is considered.

on inequality depends on the trade-off between the two migration costs and the South to North TFP ratio. In an economy with a TFP ratio of 0.7 the time migration cost is relatively more important and therefore it prevents the distribution of the small open economy from differing much from the South distribution when migration is not feasible. In this case the pecuniary migration cost has a stronger effect in reducing inequality. The opposite is true if the TFP ratio between the South and the North is 0.3. In this case inequality decreases more when considering both migration costs together. (iii) This result is not sensitive to different degrees of inequality between the two locations. (iv) Migration reduces inequality relatively more in countries with lower TFP since for lower TFP levels the accumulation of assets is lower for immigrants and for non-immigrants. So a higher accumulation of assets at the steady state implies a higher Gini index and this happens for higher TFP values (equivalently, for TFP ratios closer to 1).

The last chapter of this thesis investigates the effects of trade barriers in international trade, considering labor mobility across countries. A well-known result in international trade theory is that if trade takes place between a large economy and a small economy, the former can improve its terms of trade by imposing trade barriers without incurring any costs. When considering migration flows this result does not hold, implying that if one is concerned about migration rates the problem may relapse on protectionism in international trade.

Even nowadays protectionism is significantly important although the way it is currently applied differs from the past. Two essential facts are: (i) Simultaneously with the tariff reduction alternatives policy instruments (quotas, regulations, etc.) have been developed affecting the final trade cost.[7] (ii) The developed countries concentrate trade barriers in those sectors in which many developing countries have comparative advantage, such as agricultural or textile products.[8]

The fourth chapter presents a dynamic model of international trade with two countries, the North and the South. The North is assumed to be a large economy which has a technological advantage in the production of capital goods and the South is a small economy. The North decides international prices through its trade policy. Households decide whether to migrate or to stay in their native country. The key elements of the model are that immigrants earn less than natives since migration is costly due to a productivity loss suffered by households when they migrate,[9] and there is a publicly provided good financed with income taxes implying a progressive fiscal system.

When migration flows across countries are not considered the result in chapter 4 is in line with traditional international trade theory. So the North can use trade barriers to improve its terms of trade and, consequently, worsen the South's terms of trade without any cost. The intuition is that a large economy (the North) improves its terms of trade if the other country is a small economy (the South) since the international prices are those of the large economy. This chapter shows that trade barriers increase the relative capital price in the South which discourages capital accumulation and decreases wages in the South. But, since trade barriers increase wage differences across both economies, the model

[7] Several studies have tried to estimate the tariff equivalent to trade barriers with quite surprising results. See for instance Anderson and van Wincoop (2004).

[8] See Messerlin (2002).

[9] See Borjas (1994) for the justification of this assumption.

allows for labor mobility across countries and finds that trade barriers foster migration from South to North. This represents a significant extra effect of trade barriers that should be considered. The result is that labor per capita decreases in the North due to migration and, therefore, per capita income and the per capita publicly provided good decreases too. Two assumptions about the productivity of immigrants abroad are considered, a permanent and a transitory productivity loss, but the intuition of the result does not depend on the assumed form.[10] Finally, an optimal tariff exercise concludes that the optimal tariff, when labor mobility is permitted, is always smaller than the optimal tariff when there is no labor mobility. This yields to a very clear policy implication, if one is concerned about migration the best one can do is to revise its trade policy.

Two of the most classical papers in the literature of international trade and factors mobility are Mundell (1957) and Markusen (1983). The first shows that substitution between trade and migration holds in the Heckscher-Ohlin's model and, the second, finds that they are complementaries in five different models under free trade and identical factor endowments. The aim of this chapter is not to investigate if migration and international trade are substitutes or complementaries, in fact this chapter considers a Ricardian trade model and treats migration and international trade as imperfect substitutes. The main contribution of this chapter is to highlight the negative consequences that the own protectionist policies imply for the developed countries.[11]

[10]In the case of immigrants' transitory productivity loss the previous result is even stronger since migration flows affects the North's factor prices because of the higher propensity to consume of immigrants since their labor income profile is increasing.

[11]The protectionist measures used by developed countries to the developing countries have important and known negative consequences for the development and convergence of developing countries.

Chapter 2

Quantitative Analysis on Immigrants' Self-Selection and its Implications

2.1 Introduction

How is the investment in human capital affected by the possibility of future migration? Who is actually migrating? And, how are differences in output per capita affected by the mobility of human capital? The brain drain theory suggests that migration of people with higher human capital has a negative effect in the source country. On the other hand, the possibility of migration may have the positive effect on the source country, if it generates more investment in human capital. To contrast these two theories I present a model economy with heterogeneous agents who endogenously decide investment in human capital and migration. This original approach permits me to answer the above questions by linking two literatures, migration and economic growth.

Are immigrants positive or negative self-selected? This is a traditional question in migration literature. It is important because the effects of international migration depend critically on the pattern of immigrants' self-selection. Although the migration literature usually has focused on the effects of immigrants in the host country, international migration has effects in the source country too. The brain drain theory stresses this idea and suggests that the migration of population that has relatively high human capital has negative effects on the source country. However, this can be disputed. If people become more educated because they know that in the future they will migrate, it is possible that the brain drain can have positive effects. This is called the induced education effect. Obviously, in order to test all these ideas it is necessary to have a model where accumulation of human capital and migration decisions are endogenous. Finally, once one knows who is migrating and what determines the pattern of immigrants' self-selection, one can quantify the effects of migration in differences in output per capita across countries and can use the model as a laboratory economy to do optimal migration policies.

The main features of the model economy are: (i) It is an international model with two economies and perfect physical capital mobility. (ii) There are OG of dynasties composed by households. (iii) Households are heterogeneous and decide consumption, physical capital investment, human capital investment and migration. (iv) Human capital is produced using two inputs, time and expenditure in goods. (v) Migration is costly. I will consider two types of costs. A pecuniary migration cost and a time migration cost that affects the effective units of labor.

In this model migration is unidirectional from the South to the North. The role of migration costs are very important in the results. Since data on migration costs is very limited, I study them separately in order to stress the effect of each migration cost. If there is only a pecuniary migration cost, then there exist an asset level above which all households decide to migrate. The asset and the human capital distribution in the South is truncated because beyond that level all those households are in the North at the steady state. The time migration cost has the effect that for households with a higher initial level of human capital migration is costlier. In this case the South distribution is truncated but from the bottom because the time migration cost is relatively less important for households with low initial levels of human capital. So at the steady state these households are in the North.

I find that immigrants are negatively self-selected when the differences in TFP between the source country and the host country are large. Conversely, when the TFP in the source country is close to that in the host country then immigrants are positively self-selected. This result is independent of the migration cost faced by immigrants although the mechanism behind the self-selection pattern differs depending on the migration cost considered. When there is a pecuniary migration cost households first pay this cost and then invest in human capital. For a country with low TFP after the pecuniary migration cost is paid households do not have resources to invest in human capital so immigrants are negatively self-selected. But for higher TFP levels of the source country it is possible that the households can afford the pecuniary migration cost and invest in human capital, so immigrants are positively self-selected. The time migration cost is relatively higher for households with higher human capital so it is expected that households with lower human capital migrate as is the case for South to North TFP ratios of 0.3 and 0.5. So immigrants are negatively self-selected. However, for a South to North TFP ratio of 0.7 they are positively self-selected. This is because they can compensate the time migration cost by investing more in human capital.

The model economy supports the induced education hypothesis. Investment in human capital increases when there is the possibility of future migration. The effect is quite significant, particulary when the migration cost is a time migration cost. Average years of schooling increases by 4, 3.6 and 2 years for South to North TFP levels of 0.7, 0.5 and 0.3 respectively. Although less important, migration with a pecuniary migration cost also makes the same households invest more in human capital in an open economy. The induced education effect does not depend on the self-selection pattern. Even when immigrants are negatively self-selected, average years of schooling for non-immigrants are higher than in a closed economy. When there is a pecuniary migration cost migration increases output per capita differences between the South and the North by 40%. The opposite happens if there is a time migration cost. For this case migration decreases output per capita differences by 30%. Finally I compare the model with evidence from Mexico. The model is able to reproduce the self-selection pattern for Mexican immigrants for acceptable values of migration costs.

The brain drain theory suggests that migration has a negative effect on developing countries as the best and brightest leave the country. Berry and Soligo (1969) show that migration can decrease the income per capita in the source country in a partial equilibrium model. Bhagwati and Hamada (1974) study fiscal policies that compensate the brain drain in the source country. The positive effect of brain drain comes up with the growth models of endogenous human capital accumulation and it is called the brain gain. Good surveys of this literature are Stark (2004) and Docquier and Rapoport (2004). The idea is simple, migration can affect the accumulation of human capital. In fact, the source country may invest more in human capital due to the possibility of future migration and, under certain assumptions, this has a positive effect in the sending country. For instance, Mountford (1997) finds that, depending on the migration probability, the induced education effect by migration dominates the loss of human capital. Stark, Helmenstein, and Prskawetz (1997) points out that in the case of asymmetric information and different incentive structure the brain gain can compensate the brain drain. In Beine, Docquier, and Rapoport (2001) they distinguish between two effects, an ex ante brain effect (migration increases investment in education because of higher returns abroad), and an ex post drain effect (because of actual migration flows). Obviously, if the former dominates the second the overall effect is positive for the developing country. A more pessimistic view on the benefits of brain drain is given by Haque and Kim (1994). They argue that brain drain may have the effect of a reduction in the steady state growth rate of the country of emigration. All these models differ with respect to my model in the sense that all of them are static partial equilibrium models. Beine, Docquier, and Rapoport (2008) find evidence of a positive effect of skilled migration on investment in human capital in a cross-section of 127 developing countries. They find that countries combining relatively low levels of human capital and low skilled emigration rates are likely to experience a net gain, and vice versa. Taking into account that the largest developing countries are all among the winners, they argue that brain drain increases the number of skilled workers both worldwide and in the developing countries.

Borjas (1994) was the pioneer in the migration literature. He tried to answer the self-selection question using a partial static model derived from the Roy model. He finds that immigrants are positively self-selected when the correlation of skills between countries is sufficiently high and the distribution of earnings is more unequal in the hosting country. But if the source country has a higher earnings dispersion than the host country then immigrants are negatively self-selected. Borjas defines positive self-selection as having above average earnings in both the source and the host country and in an equivalent way for negative self-selection. This chapter considers positive self-selection if immigrants have on average higher human capital than non-immigrants. Independently of where they will finish in the distribution of human capital in the host country.[1] Since, usually, the dispersion of the earnings distribution is lower in the U.S. than

[1] Since the seminal work of Borjas, studies related to this topic have concentrated their effort on the self-selection pattern of immigrants but without considering where immigrants finish in the distribution of the host country. The most common definition of self-selection is if immigrants have more human capital or have higher skills than non-immigrants. So the self-selection can be on observable or unobservable skills.

dispersion of earnings distribution in developing countries, Borjas' model seems to give support to the thesis of negative self-selection. But there is a high brain drain in the Caribbean, in some African countries and in India and the dispersion of earnings in these economies is higher than in the U.S.. In Katz and Stark (1986) and Katz and Stark (1987) the idea is that in case of asymmetric information it is possible to have negative self-selection since employers cannot know the type of the immigrant. Other statistical models are Chiswick (1999) and Bellettini and Ceroni (2007). Chiswick argues that there is positive self-selection and Belletini and Ceroni find that the lower the wage level in the hosting country the higher the percentage of skilled immigrants. In all these works there is no investment in human capital and there is no migration decision. They perform a statical comparison of earnings in both countries and study under which conditions earnings are higher in the foreign country.

In the closest work to mine, Urrutia (2007) analyzes in a dynastic OG model the effect of migration costs on the self-selection of immigrants. In his model there are two migration costs. A fixed cost and a loss of ability. He finds that when the fixed cost is relatively low, immigrants are selected from the bottom of the distribution of abilities while if the fixed cost is relatively high then the opposite happens. In his model the ability is exogenous while in my model investment in human capital is endogenous. So, he can not address the relationship between investment in human capital and migration which may be affecting the self-selection of immigrants.

A paper where migration is endogenous is Klein and Ventura (2007). They are interested in studying an efficient reallocation of labor in the world. In this chapter agents are endowed with efficiency units of labor dependent on their birth place. Again, there is no accumulation of human capital. Another difference to this paper is that in their model there is no migration at the steady state. In Díaz, López-Real, and Perera-Tallo (2009) migration is endogenous and it exists at the steady state but the paper focuses on the effect of international trade on the migration flows.

There is a long debate on why differences in output per capita are so big across countries. Mankiw, Romer, and Weil (1992) used an augmented Solow model and estimated that output differences were caused by human capital differences. On the other hand Klenow and Rodriguez-Clare (1997), Hall and Jones (1999) and Bils and Klenow (2000) support that differences in output per capita are due to differences in TFP. The most recent work is Hendricks (2002) who estimates the human capital of different countries from immigrants in the U.S. job market doing the same work.work. The results in the chapter support the TFP thesis. For the production function of human capital I will follow Seshadri and Manuelli (2007) and, mainly Erosa, Koreshkova, and Restuccia (2007). These authors stress the idea of the importance of education quality. Once they take into account that education quality may differ among countries they conclude that relatively small differences in TFP levels account for big output differences across countries. In Erosa et al. the model economy produces a TFP elasticity of output per worker of 2.8 which implies that in order for the model to produce a factor of 20 difference in output per worker, a factor of 3 difference in TFP is needed. However, if we are concerned about human capital in international accounting we must worry about migration because migration is nothing else that mobility of human capital across countries. This chapter contributes to this debate by quantifying the effect of migration in cross-country output differences.

The chapter is organized as follows. Section 2.2 describes the model economy. In section 2.3 I show the calibration procedure, the targets and their values and the North benchmark economy is presented. Section 2.4 presents the results for the immigrants' self-selection depending on the migration cost faced. Section 2.5 uses the model to compare the Mexican case (self-selection pattern of immigrants from Mexico to the U.S.). In section 2.6 the induced education hypothesis is tested. Section 2.7 quantifies the effect of mobility of human capital on cross-country output differences and section 2.8 concludes.

2.2 The Model Economy

2.2.1 Locations

This chapter considers two locations, indexed by $i \in \{0, 1\}$ with $i = 0$ indicating a developing country and $i = 1$ a developed country. Following the common practice of international economics literature I will refer to country 0 as the South and country 1 as the North. North and South only differ in two features, their TFP level and their natural population growth rates. I will be more precise in how they differ in the following sections. Finally, physical capital is perfectly mobile in the world economy.

2.2.2 Technologies

There are two technologies. One for goods and another for human capital. Output is produced in each economy according to the the technology

$$Y_i \quad = \quad A_i K_i^{\alpha} H_i^{1-\alpha} \quad for \quad i \in \{0, 1\}, \tag{2.1}$$

where Y_i is output and K_i and H_i are aggregated physical capital and aggregated human capital respectively in economy i.[2] I make the assumption that the North is more productive than the South economy, $A_1 > A_0$.

Following Erosa, Koreshkova, and Restuccia (2007) [hereafter E-K-R] in modelling the production function of human capital, per capita human capital is produced with two inputs, time $s \in [0, 1]$ and expenditure on goods allocated to education e. The production function is given by:

$$h^{'} \quad = \quad z^{'}(s^{\eta} e^{1-\eta})^{\xi} \quad \eta, \xi \in (0, 1), \tag{2.2}$$

where $z^{'}$ is a stochastic shock that refers to the individual ability to accumulate human capital.

2.2.3 Demographic Structure

Each economy is modelled as an overlapping generation of dynasties that are altruistic toward the dynasty. There is a large number of dynasties composed of households. Agents live for two periods and are young in the first period and

[2]Note that factor shares are equal in both economies. Gollin (2002) supports the assumption that labor shares are equal in both economies. He suggests a more carefully data analysis taking into account differences in self-employment across countries. He finds that labor shares for most countries fall in the range of 0.65 to 0.80.

old in the second. Each household always has an old and a young agents. In the first period young agents live in a household with an old agent. When they become old in the second period, they form a new household.

Inside the household all decisions are made by the old agent who decides where the young agents start the new households.[3] Using in advance the result that the migration pattern is from economy 0 to economy 1 (from South to North) I can write the population dynamics in each economy as:

$$N_1^{'} = (1 + n_1)N_1 + m(1 + n_0)N_0, \tag{2.3}$$

and

$$N_0^{'} = (1 + n_0)(1 - m)N_0 \tag{2.4}$$

where N_i is total population and n_i denotes natural population growth rate in country i. I assume that natural population growth rate is higher in country 0 (see appendix for a full description of population dynamics and its implications). Since migration is unidirectional m stands for the proportion of households in country 0 that decide to leave the native country and establish in country 1.[4]

2.2.4 Preferences and Endowments

The household gets utility from consumption. The instantaneous utility function takes the form:

$$u(c) \quad = \quad \frac{c^{1-\gamma}}{1-\gamma}. \tag{2.5}$$

Young agents receive an idiosyncratic shock to their ability $z \in \mathcal{Z} = \{z_1, ..., z_n\}$. The shock is the same for all members of the household and is unobservable for old agents. It follows a markov process with transition matrix $\pi_{z,z'}$ and I assume that the markov process is the same in both locations.

2.2.5 The Household's Problem

There are two types of agents living in a household, the young and the old. In the second period of their life young agents become old and start a new household. Old agents make all the decisions inside the household and are altruistic toward their descendants. Specifically, an old agent decides per capita consumption c and per capita assets for the next period $a^{'}$. Note that $a^{'}$ will be the bequest for the next generation. Furthermore, they decide how much time and expenditure in goods must be allocated in the human capital production function of their children.

Finally, old agents decide where their descendants are going to start the new household. Since I denote by i the current location, $i^{'}$ stands for location next period. So, if $i^{'} \neq i$ it means migration from location i to location $i^{'}$ has occurred. When the old agent makes the migration decision all the young

[3]It is the old agent who decides if the young agents migrate. The alternative that young agents decide to migrate does not change results but is computationally costlier.

[4]Since the number of young agents per household is constant and equal for all the dynasties the proportion of households that migrate is the same that the proportion of population migrating.

agents, his descendants, migrate and start households the next period in the new location.

I consider two migration costs. The first cost is a fixed migration cost θ_f which can be interpreted as the travel expenses between the locations. The literature always relates the fixed migration cost with the distance between the source country to the host country and some other factor. For example, Urrutia (2007) defines this cost as travel expenses and the cost of keeping in contact with the native country. The second cost θ_t represents a loss in the effective labor hours of the old agent. This cost can be interpreted as the time that a household expends to make all the preparations needed to leave the native country, for instance: to look for a visa, to look for a job in the hosting country, to cancel contracts in the native country, etc. Moreover, literature on migration uses a cost that represents a percentage of losses of earnings in the hosting country due to, for example, languages difficulties. In some sense one can see these two ways of modelling as equivalent. The current strategy, however, is computationally much simpler than the alternative.

Household income consists of earnings from old agent and young agents and income from assets. I assume that young agents have a lower labor market productivity relative to old agents $\psi < 1$.

The state of a household is completely characterized by its initial assets, the old agent's human capital, the current value of the stochastic shock and current location. This is given by (a, h, z, i). So the problem faced by a household in country 1 taking into account that they do not migrate $(i = i^{'} = 1)$ is:

$$V(a,h,z,1) = \max_{c,e,s,a^{'}} \{u(c) + \beta(1+n_1)\sum_{z^{'}} \pi_{z,z^{'}} V(a^{'}, h^{'}, z^{'}, 1)\} \tag{2.6}$$

s.t.

$$c + (1+n_1)e + (1+n_1)a^{'} \leq w_1 h + (1+n_1)(1-s)w_1\psi + Ra, \tag{2.7}$$

$$h^{'} = z^{'}(s^{\eta}e^{1-\eta})^{\xi}, \tag{2.8}$$

$$a^{'}, e \geq 0 \quad and \quad s \in [0,1]. \tag{2.9}$$

The problem faced by a household in country 0 is similar but in addition the household decides where to start the next period. In this case, $i = 0$ and, if the decision of migration is made, then $i^{'} = 1$ and it has to be paid θ_f and is experienced a reduction in effective labor hours due to θ_t. The problem therefore becomes:

$$V(a,h,z,0) = \max\{V^M(a,h,z,0), V^S(a,h,z,0)\} \tag{2.10}$$

where

$$V^M(a,h,z,0) = \max_{c,e,s,a^{'}} \{u(c) + \beta(1+n_0)\sum_{z^{'}} \pi_{z,z^{'}} V(a^{'}, h^{'}, z^{'}, 1)\} \tag{2.11}$$

s.t.

$$c + (1+n_0)e + (1+n_0)a^{'} \leq$$

$$w_0 h + (1+n_0)(1-s)w_0\psi + Ra - (\theta_f + \theta_t w_0 h), \tag{2.12}$$

$$h^{'} = z^{'}(s^{\eta}e^{1-\eta})^{\xi}, \tag{2.13}$$
$$a^{'}, e \geq 0 \quad and \quad s \in [0,1], \tag{2.14}$$

$$V^{S}(a,h,z,0) = \max_{c,e,s,a^{'}} \{u(c) + \beta(1+n_0)\sum_{z^{'}} \pi_{z,z^{'}} V(a^{'},h^{'},z^{'},0)\} \tag{2.15}$$

s.t.

$$c + (1+n_0)e + (1+n_0)a^{'} \leq w_0 h + (1+n_0)(1-s)w_0\psi + Ra, \tag{2.16}$$
$$h^{'} = z^{'}(s^{\eta}e^{1-\eta})^{\xi}, \tag{2.17}$$
$$a^{'}, e \geq 0 \quad and \quad s \in [0,1], \tag{2.18}$$

and the policy function for migration is defined as:

$$i^{'} = \begin{cases} 1 & \text{if } V^{M}(a,h,z,0) \geq V^{S}(a,h,z,0), \\ 0 & otherwise. \end{cases} \tag{2.19}$$

2.2.6 Steady State Equilibrium

For notation purpose I set $x = \{a,h,z,i\}$ and $X = \{[0,\infty] \times [0,\infty] \times \mathcal{Z} \times \{0,1\}\}$. Let $\mathcal{B}$ be the $\sigma - algebra$ generated in X by the Borel subsets. A probability measure μ over $\mathcal{B}$ describes the economy by stating how many households there are of each type. Let $P(x,B)$ denote the transition function. Function P describes the conditional probability for a type x household to have a type in the set $B \subset \mathcal{B}$ tomorrow and describes how the economy moves over time by generating a probability measure for tomorrow, $\mu^{'}$, given a probability measure, μ today. So, $\mu^{'}(B) = \int_X P(x,B)d\mu$ is tomorrow's distribution of households $\mu^{'}$ as a function of today's distribution μ and the Markov chain. Let X_0 be $X \mid_{i=0}$ and X_1 be $X \mid_{i=1}$ and equivalently for x_i. Set $g^{j}(x)$ as the policy function for $j = \{c, a^{'}, h^{'}, e, s, i^{'}\}$. The steady state equilibrium for this economy is a set of functions for the household's problem $\{V(x)$, $g^{c}(x)$, $g^{a^{'}}(x)$, $g^{h^{'}}(x)$, $g^{e}(x)$, $g^{s}(x)$, $g^{i^{'}}(x)\}$, prices w_i and r and a measure of households, μ, such that:

1. Markets are competitive and there are no arbitrage opportunities. Note that since capital is perfectly mobile, capital rental price must equalize across countries. Factors prices are given by:

$$r = \alpha A_0 \left(\frac{K_0}{H_0}\right)^{\alpha-1} = \alpha A_1 \left(\frac{K_1}{H_1}\right)^{\alpha-1}, \tag{2.20}$$

and

$$w_i = (1-\alpha)A_i \left(\frac{K_i}{H_i}\right)^{\alpha} \quad for \quad i \in \{0,1\}. \tag{2.21}$$

2. Given prices, the functions $\{V(x)$, $g^{c}(x)$, $g^{a^{'}}(x)$, $g^{h^{'}}(x)$, $g^{e}(x)$, $g^{s}(x)$, $g^{i^{'}}(x)\}$ solve the household's problem.

3. Population growth rates are equal in both economies, equation (2.29) holds.

4. Markets clear:

$$H_1 = \int_{X_1} h \quad d\mu(x_1) + \int_{X_1} (1 - g^s(x_1))\psi \quad d\mu(x_1), \tag{2.22}$$

$$H_0 = \int_{X_0} h \quad d\mu(x_0) + \int_{X_0} (1 - g^s(x_0))\psi - \int_{X_0} g^{i'}(x_0)\theta_t h, \tag{2.23}$$

$$K_0 + K_1 = \int_X a \quad d\mu(x), \tag{2.24}$$

and

$$I = \int_X [g^{a'}(x) - (1-\delta)a] \quad d\mu(x). \tag{2.25}$$

5. The world resource constraint is satisfied:

$$Y_0 + Y_1 = \int_X [g^c(x) + g^e(x)] \quad d\mu(x) + I + \int_{X_0} g^{i'}(x_0)\theta_f \quad d\mu(x_0). \tag{2.26}$$

6. The measure of households is stationary $\mu(B) = \int_X P(x, B) \quad d\mu$.[5]

2.3 Calibration

2.3.1 Parameters and Targets

In this section I calibrate the model using U.S. cross-sectional data and will present all the parameters of the model and all the targets. In the following section I will show how the benchmark economy matches the targets.

The calibration procedure has two steps. First, I calibrate the benchmark economy to match U.S. data in a closed economy and then I calibrate the open economy with labor mobility. The open economy requires some additional parameter values, such as natural population growth rate in the South and the migration costs. For the moment I focus on the calibration of the closed economy.

I model the life of an agent from age 6 to age 66 with each period lasting 30 years. The model starts from age 6 to better capture the human capital investment decision, as this is a common strategy in human capital literature. Age 66 is chosen as it is roughly the age of retirement. For population growth rate, the US natural population growth rate n_1 is 0.59% and population growth

[5]The function $P(x, B)$ is determined by the optimal decisions on assets, human capital and migration and by the exogenous transition probabilities on the ability shock z. So $P(x, B) = Prob[\{z' \in \mathcal{Z} : (g^{a'}(x), g^{h'}(x), g^{i'}(x), z') \in B\} \mid z]$, where the relevant probability is the conditional probability that describes the behavior of the Markov process z.

rate n_1^p is 0.92%.[6] I set $\delta = 0.0668$ and $\alpha = 0.33$ following Cooley and Prescott (1995). I normalize TFP of country 1 to 1 ($A_1 = 1$). The coefficient of the CRRA utility function σ is set equal to 2, which is in the range of usually accepted values in this literature.[7] I calibrate β to match an annual interest rate of 5%. The parameters and their values are presented in table 2.1. All the values are in annual terms.

TABLE 2.1: *Parameters and their values in the Benchmark Economy.*

Parameter		Value
TFP	A_1	1
U.S. natural population growth rate	n_1	0.59%
U.S. population growth rate	n_1^p	0.92%
Discount Factor	β	0.949
CRRA	σ	2
Physical capital share	α	0.33
Physical capital depreciation	δ	0.0668

The parameters related to the human capital investment are: η, ξ, ψ and the shock z for the ability. I calibrate the shock z as in E-K-R where ability follows in logs an AR(1) process:

$$log(z^{'}) \quad = \quad \rho_z log(z) + \epsilon_z, \quad \text{where} \quad \epsilon_z \sim N(0, \sigma_z^2).$$

I use 5 shocks to approximate this process with a Markov chain. To calibrate the shocks I use the procedure in Tauchen (1986). This process implies 2 additional parameters values ρ_z and σ_z^2. Then, I have to calibrate 5 parameter values. To do this I use U.S. cross-sectional data. The targets are:

1. The average years of education of 12.9, taken from the U.S. Department of Education (2004).[8]

2. An intergenerational correlation of log-earnings of 0.5 from Mulligan (1997).[9]

3. The variance of log-earnings of 0.36, taken from Mulligan (1997).

4. The percentage of people with at least some college or university education or higher, which is equal to 54%, taken from the U.S. Census Bureau, Current Population Survey (2004).[10]

[6] U.S. Census Bureau, International Data Base, year 2005.

[7] See for instance Keane and Wolpin (2001), Klein and Ventura (2007) or Erosa, Koreshkova, and Restuccia (2007).

[8] E-K-R take the same target. In Seshadri and Manuelli (2007) average years of education is 12.08 from Barro and Lee (1996).

[9] See Mulligan (1997), table 7.5, page 202.

[10] Primary school is from the age of 6 years to 14 and Secondary, or High School, is from the age of 14 to 18. Finally, above the age of up 18 I consider College, Bachelor's degree, Master's degree, Doctoral degree and Professional degree. Note that in this model the age of a young agent starts at 6 years old, when primary school begins.

5. The ratio of earnings primary to secondary for full time workers is 0.65 taken from the U.S. Department of Education (2005). Institute of Education Sciences.[11]

2.3.2 The North Benchmark Economy

In table 2.2 I link each target with its parameter (P) and its value (V). I also compare U.S. data for each parameter with data from the benchmark economy (B.E.).

TABLE 2.2: *Targets, U.S. data, benchmark economy data, parameters and parameters' values.*

Target	U.S. data	B.E.	P	V
Av. years of schooling	12.9	13	ψ	0.107
Intergenerational corr. of log-earnings	0.5	0.5	ρ_z	0.49
Variance of log-earnings	0.36	0.36	σ_z	0.25
Ratio earnings primary to secondary	0.65	0.65	ξ	0.71
People with college education or higher	54%	54%	η	0.71

The benchmark economy replicates well all the targets. Moreover, this simple model matches relative earnings between different degrees of education attainment. The model has been calibrated to match the earnings ratio of primary to secondary education, but it also matches exactly the earnings ratio of college to secondary education which is 1.86 (from the same data source used for the target of the ratio of earnings primary to secondary for full time workers).[12]

I have calculated some others facts for which the model has not been calibrated. Psacharopoulos (1994) estimates a Mincer return of 10% for the US for the period (1990-1995). In the benchmark economy Mincer returns are 7.2% so the model underestimates Mincer returns although it is not obvious how to relate data on Mincer returns with data from the model given different period lengths. As a measure of inequality I computed the Gini index of 0.27 for the benchmark economy but this number underestimates the source Gini index for earnings of 0.49 from Díaz and Luengo-Prado (2006). The reason is that in order to match the Gini I need more people in the bottom of the earnings distribution and the earnings have to be more concentrated in the top of the distribution. Finally, I have calculated expenditures in education as a ratio to GDP and I get a ratio of 2.9%, close to Seshadri and Manuelli (2007) that use as a target that expenditures in schooling as a fraction to GDP is 3.77% from OECD.

[11]Table: Distribution of earnings and median earnings of persons 25 years old and over, by highest level of education attainment (2005).

[12]It is important to note that there is always a problem when linking data with model data when time is continuous and does not take into account completion of degrees. For each ratio I have calculated a lower bound and an upper bound using data on some degree of completion for the lower bound and full completion for the upper bound. My results always fall in the interval formed by these two bounds.

2.4 Results on the Immigrants' Self-Selection

2.4.1 The South Benchmark Economies

In this section three different closed economies are presented that differ in two features with respect to the North benchmark economy. These features are natural population growth rate and TFP. The outcome will provide benchmark economies for the South without migration. With this information it will be possible to compare results from economies without migration to results from economies where migration is feasible.

As previously mentioned, the South differs with respect to the North in two features, TFP and natural population growth rate. The natural population growth rate of the South is ($n_0 = 0.95\%$). The next section will highlight more precisely where this number comes from. TFP takes three different values 0.3, 0.5 and 0.7 (one for each of the South benchmark economies). Since the TFP level in the North benchmark economy has been normalized to 1, the ratio South to North TFP for each value is the same as the TFP level in the South. Table 2.3 presents the results for the North and for the three different South economies. It shows the output per capita ratio between the South and the North, the interest rate, the average years of schooling and Mincer returns for each economy.

Table 2.3: *Results in a closed economy for different TFP values.*

TFP	1	0.7	0.5	0.3
Output ratio	1	0.59	0.37	0.19
r	5%	5.05%	5.08%	4.96%
Av. years of schooling	13	8.9	6.3	3.8
Mincer returns to schooling	7.2%	9.9%	13.5%	21.2%

The porpoise behind this exercise is to check if this model effectively captures the values for the South without migration by only changing the TFP[13] and the natural population growth rate since in the next sections I will use these results as the South benchmark economies when migration is not allowed.

In line with E-K-R results, output per capita ratios obtained by the calibration are lower than TFP ratios. This points out the amplification effect of human capital. The amplification effect of human capital indicates that with minor differences in TFP it is possible to get substantial differences in output per capita across countries. Human capital investment is amplifying TFP differences. E-K-R find an output ratio of 0.13 and 0.30 for TFP ratios of 1/3 and 1/2 respectively. In this chapter, the model economy finds ratios of 0.18 and 0.37 for TPF ratios of 0.3 and 0.5 respectively. The higher ratios imply a lower amplification effect of human capital. The reason for this is that in E-K-R's model the time that an agent invests in human capital accumulation is also costly. It makes the amplification effect higher.

Average years of schooling are in concordance with previous works. For instance, Seshadri and Manuelli (2007) report for an output per worker ratio

[13] This simplification can be justified since the focus of the chapter is on the effect of differences in TFP across countries.

for the US of 0.146 for 4.64 average years of schooling. For an output per ratio of 0.244 they report 5.18 average years of schooling. Generally, an output ratio of 0.38 correspond to average years of schooling in the interval of (5.88-7.54) and an output per worker ratio of 0.6 corresponds broadly to 8.5 average years of schooling. In this chapter, for an output ratio of 0.38, 6.3 years of average schooling is found and for a 0.6 output per worker ratio, 8.9 years of average schooling is found. E-K-R find 4.3 average years of schooling for a TFP ratio of 1/3 and 7.1 average years of schooling for a TFP ratio of 1/2. Hall and Jones (1999) estimate TFP differences across countries and report also average years of schooling for 127 countries. Examples of countries with a TFP ratio to the U.S. of around 0.7 are Taiwan, Malta and Finland. Average years of schooling for these countries are in the interval [7 , 9.49]. For a TFP ratio of around 0.3, India, Jamaica and Nicaragua have average years of schooling in the interval [3 , 4.16].

Mincer returns decreases with higher average years of education. The model gives Mincer returns of 9.9%, 13.5% and 21.2% for TFP ratios of 0.7, 0.5 and 0.3. These results are very similar to those of E-K-R. They estimate Mincer returns of 14.5 and 22.6 for TFP ratios of 1/2 and 1/3. To give some examples take into account that for instance Bils and Klenow (2000) estimate Mincer returns of around 14% for Mexico, Guatemala and Colombia and mincer returns higher than 20% for Jamaica or Cote d'Ivoire.

Finally, for the endogenous interest rate the same discount factor is fixed in the South economies as in the North and the equilibrium interest rate is found. Note that the benchmark economy is calibrated to match an interest rate of 5%.

Not attempting to explain everything by differences in TFP across countries, this chapter argues that this simple model based on differences in TFP is able to generate numbers that are in line with previous works and with data (Nevertheless it is clear, not all the particular cases can be explained). At this point it is practical to deal with a simple model as migration introduces additional complications as shown in the next section

2.4.2 The Effect of a Pecuniary Migration Cost on Immigrants' Self-selection

This section studies the role that the pecuniary migration cost plays in the immigrants' self-selection. In the next section the same is done with the time migration cost. To deal with both cost separately helps to stress the effect of each migration cost in the self-selection pattern.

An international open economy with migration presents a complication with respect to a closed economy. Equation (2.29) must hold in a open economy with migration at the steady state equilibrium. This equation relates natural population growth rates and migration in order to keep constant North and South ratios over the world population or, equivalently, to equalize population growth rates in both economies. This means that the migration rate, the natural population rates and the relative size of each country cannot be chosen independently. There are two different approaches to proceed since the natural population growth rate in the North and also the population growth rate in the North have already been fixed in the North benchmark economy in the previous section. Either, the South natural population growth rate is fixed implying a migration rate, or a target for the migration rate is fixed implying a South natural population growth rate.

In this chapter the second option is chosen, fixing as a target a migration rate from the South and this implies, given the natural population growth rate and the population growth rate in the North, a natural population growth rate in the South. The target for the migration rate is 1% of immigrants with respect to the South population. Since the model period is 30 years, it means broadly 0.033% of immigrants per year. The South natural population growth rate implied by this target is $n_0 = 0.953\%$ which is the number used in the previous sections. To compare this number with the data take, for instance, the case of Mexico. Mexico presents the highest migration rate to the U.S. which is 0.15% per year and Mexico's natural population growth rate is 1.6% (from U.S. Census Bureau, 2005). Migration rates for other countries with high migration rates to the U.S. are very close to the target used here. Finally, all the parameter values for the population dynamics imply that the North's relative size with respect to the South in equilibrium is $\phi_1 = 0.097$. This may be a limitation of the model and needs special attention for two reasons. First, it may be argued that one does not expect the relative size of the North with respect to the world population being so small and, second, the relative sizes of each economy affect the results. Unfortunately these numbers cannot be chosen independently from the rest of the population values, which justifies the procedures taken in the following sections.

TABLE 2.4: *Results in an open economy with pecuniary migration cost for different TFP values.*

TFP	0.7	0.5	0.3
r	5.9%	5.8%	5.6%
South non-immigrants av. years of schooling	2.9	1.8	1.7
Immigrants av. years of schooling	4.1	1.4	0.3
θ	2.14	1.28	0.8

In order to highlight the role of the pecuniary migration cost in the model, the time cost of a reduction of effective labor hours is set to zero, i.e. $\theta_t = 0$. In this case the unique migration cost is the pecuniary migration cost. After fixing a migration target, the pecuniary migration costs which implies 1% of immigrants is found for each level of TFP. The pecuniary migration cost is calibrated proportionally to the average annual earnings in the North benchmark economy. So the pecuniary migration cost is defined as $\theta_f = \theta\bar{w}_1$ where $\bar{w}_1$ is per year average earnings of an old agent in the North benchmark economy. Then θ is calibrated to match 1% of immigrants for each TFP value. The Advantage of this method is that it keeps the relative size of populations constant across different TFP levels. Results are presented in table 2.4.

A household that can afford the pecuniary migration cost decides to migrate. Household's income comes from wages and assets so if the household has either enough assets or enough earnings to pay the pecuniary migration cost the optimal decision is migration. This is shown in figure 4.1 which presents the migration policy functions for different initial shocks to ability, for an economy with a TFP of 0.5. Each line is for a different initial shock. Note that the shock can have 5 possible values. To the left of each line there are all the households that, for those initial years of schooling and those initial asset levels, do not migrate. Each line indicates the pairs of initial years of schooling and initial assets for which migration begins to be the optimal policy and all households to the right of each line optimally chose to migrate. So each line limits households for which optimal decision is not to migrate with households for which the optimal decision is migration. The lines move to the left as higher years of schooling imply higher earnings, making it easier to afford the pecuniary migration cost. The same mechanism explains the movement across lines with increases in the initial ability shock. For the same initial years of schooling and assets the pecuniary migration cost is less important as the initial shock increases.

The migration policy functions affect the steady state distribution in the South. When migration is possible the steady state distribution in the South is truncated. More precisely, it is truncated from the top of years of schooling and assets. There is a threshold asset level above which all households decide to migrate. Since no household that can afford the pecuniary migration cost decides to stay in the South, these households are not in the steady state of the South. Additionally, since households have additional income from human capital, for each initial asset level there exist a threshold years of schooling level beyond which all the households migrate. So the results can be explained by the fact that at the steady state there are households that cannot not pay the migration costs.

The first remark on the results is on the calibrated pecuniary migration cost which implies 1% of immigrants from the South. The pecuniary migration cost for a TFP level of 0.3 is 0.8 (80% of per year average earnings of an old agent in the North benchmark economy). Note that in order to keep constant the migration rates across the different TFP levels it is necessary to increase the pecuniary migration cost for higher TFP values. Keeping all else constant asides from the TFP level, for higher TFP values the pecuniary migration cost is relatively less important. The results are that the pecuniary migration cost can take a value within the range of 0.8 to 2.14 times the average earnings of an old agent in the North benchmark economy. Although it is very hard to find estimations of migration costs in the literature, there are few recent works that report estimates for migration costs between U.S. states. Davies, Greenwood, and Li (2001) and Kennan and Walker (2003) estimate that migration costs are between 4 and 6 times U.S. average annual household income. Bayer and Juessen (2008) estimate a lower number in a structural model adjusting by dynamic self-selection. They find migration costs to be less than one-half of U.S. average annual household income. The migration costs attained by the model are in line with this literature. Though there is no obvious relation between these estimates and migration costs across countries, the estimates may be a good proxy for a lower bound of migration costs since it is unlikely that migration costs across countries are lower than across U.S. states.

For the same migration rate from the South to the North immigrants are positively self-selected for higher TFP values and negatively self-selected for lower TFP values. Since at the steady state the South distribution is truncated at the top of human capital and assets level, average years of schooling are much lower compared to the South benchmark economies. When a household can afford the pecuniary migration cost then the optimal decision of the household is to migrate. For lower TFP values after the household pays the migration cost there are not enough resources to invest in human capital so immigrants are negatively self-selected with respect to human capital. When the TFP is sufficiently high, after a household pays the migration cost, there are still enough resources to invest in human capital and potentially, as it is the case for a TFP of 0.7, immigrants can invest more in human capital than non-immigrants which are those in the bottom of the distribution. Moreover, when households migrate in this scenario they do it without physical capital.

Two final remarks are in order. First, an economy with a TFP of 0.5 and an economy with a TFP of 0.7. These two economies differ in two respects, in TFP and in the calibrated pecuniary migration cost. To get the 1% migration target in the economy with higher TFP the pecuniary migration cost must be also higher. The results suggest that the effect of higher TFP dominates the effect of higher pecuniary migration cost since immigrants are able to invest in human capital even after they have paid the migration cost. Imagine an economy with a TFP of 0.7 but with the the calibrated migration cost of an economy with a TFP of 0.5. The result would be that on one hand the migration rate increases and on the other hand that the positive self-selection is stronger. The second remark is that not all the households are in the steady state in the South because they are already in the North. This can be considered as a measure of the Brain Drain. So far the comparison has been of steady states but in an hypothetical exercise of computing the transition I would expect that in the first periods immigrants have either high average of schooling or high asset level.

2.4.3 The Effect of a Time Migration Cost on Immigrants' Self-Selection

In this section I focus on the time migration cost. To this end, θ_f is set to zero ($\theta_f = 0$). The calibration strategy is the same as in the previous section. For each South economy the time migration cost that implies 1% of immigrants from the South to the North is found.

As figure 4.2 points out, the effect of the time migration cost in the migration policy functions is substantially different to that of the pecuniary migration cost. In this case the migration cost is higher for higher initial human capital values. The lines in figure 4.2 move to the right since as initial years of schooling increase the migration cost also increases. Additionally, this cost is also higher as the initial ability shock is higher explaining the movement across lines for different initial shocks.

Results are presented in table 2.5. Now, at the steady state the distribution is truncated less than in the previous section and it is truncated from the bottom of years of schooling. For the households with very low years of schooling and a low initial ability shock the time migration cost is relatively less important. So, at the steady state the South distribution is truncated but in this case from the bottom of the distribution. Since households with very low years of schooling are not at the steady state in South when migration is possible, compared to the South benchmark economies, the average years of schooling in the South are higher. This effect is more important for countries with lower TFP levels since these countries accumulate more households in the bottom of the distribution in the benchmark economy of the South.

Note that to keep the migration rate constant, it is necessary to decrease the time migration cost as TFP increases. As previously explained, keeping all values constant asides TFP, the time migration cost is relatively higher for higher TFP values.

Table 2.5: *Results in an open economy with time migration cost for different TFP values.*

TFP	0.7	0.5	0.3
r	5,4%	5.5%	5.8%
South non-immigrants average years of schooling	10.2	7.6	5.5
Immigrants av. years of schooling	11.4	2.5	0.3
θ_t	0.5	0.85	0.94

Similar to the outcome of pecuniary migration costs, immigrants are negatively self-selected for low TFP values and positively self-selected for high TFP levels. The rational behind this result is that economies with low TFP invest less in human capital, as showed in the South benchmark economies. Since migration is costlier for households with higher initial years of schooling, households for which the optimal decision is to migration are those with less average years of schooling and consequently less human capital. In the case that the South economy presents a higher TFP, on the one hand the economy invest more in human capital so the time migration cost is higher but the time migration cost affects the optimal investment between human capital and physical capital. In this case households invest a little bit more in human capital to compensate the migration cost. So, immigrants are positively self-selected and moreover they migrate with physical capital, this is a particularity with respect to the previous cases.

If the economy is run with a TFP of 0.7 but with the time migration cost of an economy with a TFP of 0.5 the results are that the migration rate decreases but the positive self-selection increases. Note that in this case the time migration cost is relatively higher so to compensate that cost households invest more in human capital.

The values for the time migration costs, although there are no previous studies available for comparison, seem to be rather high. Nevertheless, once considering two migration costs together, the time migration cost decreases dramatically for pecuniary migration cost in the interval previously shown.

For instance, consider the following exercise. Let the pecuniary migration cost to be one year of average annual earnings in the North benchmark economy. This pecuniary migration cost is in the interval of estimated migration costs in the previous section. The time cost is then calibrated to get a migration rate of 1%, In this case, the calibrated time migration cost is 0.5 for an economy with TFP of 0.5 and 0.18 for an economy with TFP of 0.7. Average years of schooling for immigrants is 5.47 in the first case and 6.2 in the second and average years of schooling for non-immigrants is 7.21 and 4.7 respectively. First, note that the time migration cost decreases when considering both cost simultaneously. Second, immigrants are still negatively self-selected for a TFP of 0.5 and positively self-selected for a TFP of 0.7. Lastly,, the average years of schooling of non-immigrants is consistent with the previous result. For a higher TFP, consider 0.7, if the pecuniary migration cost, which is relatively less important, is kept constant, the distribution is truncated from the top. Consequently, the average years of schooling for non-immigrants is lower than for an economy with a lower TFP, in this example, a TFP of 0.5.

2.5 The Mexican Case

As showed in the previous section, migration costs affect the immigrants' self-selection. Unfortunately, the data on migration costs is scarce, and when it exists, is very limited. Accepting the estimated migration cost across U.S. states can be used as a lower bound for the pecuniary migration cost across countries, the variation of pecuniary migration cost across different source countries is not obvious. It is possible to use the distance between the U.S. and the sending country as a proxy, however it is not necessarily the case that the pecuniary migration cost is exactly proportional to the distance between locations.[14] Time migration costs also present some difficulties. For example, one interpretation is that that distance also affects the time migration cost since two countries that are closer may have closer cultures making the preparations needed to leave the native country easier and less time consuming. Another interpretation stems from the theory of networks. Once there is a sizeable community from your native country in the host country, migration is easier. Furthermore, as migration starts the risk and cost for new immigrants from the same native country (such as friends and relatives) decreases. Gradual accumulation of network connections and migratory knowledge creates spill-over effects which make migration less selective. This argument is established in Durand, Parrado, and Massey (1996). So the size of the immigrants' communities in the host country may be a proxy to estimate the time migration cost.

This section tries to solve these date limitations in an original way. The migration costs that reproduce a specific self-selection pattern will be found by using data on average years of schooling for immigrants and non-immigrants. The section will focus on the Mexican case. Chiquiar and Hanson (2005) estimates that "Mexican immigrants, while much less educated than U.S. natives, are on average more educated than residents of Mexico" . Hendricks (2002) reports 7.5 average years of schooling for immigrants from Mexico to the U.S while the average years of schooling of Mexican natives is 6.3. This implies a weak positive self-selection.

The TFP ratio for Mexico to U.S. is set 0.77 from Ferreira, Pessoa, and Veloso (2008) and the pecuniary migration cost is set to 2.5 times the average annual earnings of an old agent in the U.S. which is in the interval of estimated migration costs by the literature. The time migration cost is then calibrated to reproduce the immigrants' average years of schooling for immigrants from Mexico to the U.S. Results are presented in table 2.6.

The time migration cost that matches the immigrants' average years of schooling is $\theta_t = 0.035$. This cost seems quite low. As pointed out in the previous section when both migration costs are introduced together, the time migration cost decreases. Moreover, this result supports the thesis behind the network theory since the Mexican community is very large in the U.S. Average

[14] In the closest work to mine Urrutia (2007) uses rather arbitrary numbers for the fixed migration cost in his model.

years of schooling for non-immigrants are lower in the model because the distribution in the South (Mexico in this case) is truncated from the top of average years of schooling due to the pecuniary migration cost. Finally, the result found for the migration rate from Mexico to the U.S. is 1.2% and the interest rate is 5.7%.

Table 2.6: *Results for the Mexican case.*

	Mexico	
	data	model
θ	-	2.5
θ_t	-	0.035
Immigrants av. years of schooling	7.5	7.5
Non-immigrants av. years of schooling	6.3	5.1

This model is able to replicate the evidence for Mexico. Additionally, since data on migration costs is not available, one possibility is to use data on average years of schooling for both immigrants and non-immigrants to estimate the migration costs. This model can be used for that purpose. Another approach could be to estimate the time migration cost using information about immigrants' networks in the host country. Since this data is again limited one can check if the estimated migration cost in this model are in line with observation on immigrants' networks and some measure for the pecuniary migration cost, which could be based on distance.

2.6 The Induced Education Effect

This section studies the induced education hypothesis. This hypothesis states that investment in human capital may increase in the source country due to the possibility of future migration. While this hypothesis is simple, it is very hard to test with data since it is not possible to observe at the same time a scenario where migration is possible and one where it is not. This has presented a big limitation in econometric studies on this hypothesis. Furthermore, though it is possible with my model to compare average years of schooling in the South benchmark economy (note that it was a closed economy) with the average years of schooling of non-immigrants in the open economy, this would be answering a differing question. It would be testing if average years of schooling increases or decreases in the source country when migration is possible. An increase in the average years of schooling in the sending country when there is migration does not imply an induced education effect because the distribution in the source country is different from the distribution in the closed economy. This is due to a difference in the households found at the steady state in the South without migration to those found in the South when there is migration. In order to test the induced education hypothesis it is necessary to compared the investment in human capital by the same households which are located in two different economies, one with migration and another without. Remember that the previous section showed how each migration cost truncates the South distribution at the steady state. Although it is impossible to solve this limitation with data it is possible to solve it in this chapter.

In order to deal with this problem the following approach is taken: Up to now an open economy where one can observe the average years of schooling for the immigrants and for the non-immigrants has been computed. This section will be focus on non-immigrants in order to test the induced education hypothesis. As previously mentioned, it is necessary to compare average years of schooling of non-immigrants with average years of schooling in the South without migration. So, The first, is to calibrate the discount factor in the South economy without migration to match the interest rate in the open economy in order to keep the same returns in physical capital and human capital in the two cases. The second step is to have a closed economy that is exactly the same to the open economy but without migration. In this closed economy it is possible to identify the same households that are found at the steady state distribution in an open economy in the South. More specifically, the same households refers to households with the same initial values of human capital, assets and shocks.

Results are presented in table 2.7. The induced education effect is tested for the cases in sections (4.2) and (4.3), which include different TFP levels and migration costs supported. The South non-immigrant's average years of schooling is the average years of schooling for those in the open economy who do not migrate. This data comes from previous section. The South average years of schooling in a closed economy is the average years of schooling in the South taking into account all of the South distribution. Note that these households do not have to coincide with the households at the steady state distribution in the South with migration. Moreover, the South closed economy has the same interest rate as its equivalent version in an open economy in order to keep constant the same returns in physical capital and human capital.[15] Finally, the adjusted average years of schooling in the South is the average years of schooling of households in the the South in a closed economy that are found at the steady state in the both different scenarios (with and without migration). I identify the households that I find at the steady state in the South when there is migration and I take the average years of schooling of these households but in a closed economy that preserves the same interest rate than the open economy. This average gives an exact measure of the induced education effect since it is found by comparing investment in human capital for exactly the same households in two different frameworks, one where there is migration and another where there is no migration.

The results indicate that there exist an induced education effect. The same households invest more in schooling in an open economy where migration is possible than in an closed economy. This effect is quite important, especially for the time migration cost where the average years of schooling increases approximately 60% for a country with TFP of 0.7 and 0.3. To compensate the time migration cost the households invest more in human capital until returns from human capital investment equalize returns from physical capital investment and, then, they invest in assets. Note that the induced education effect is independent of the self-selection pattern. Even when immigrants are negatively self-selected, the households that do not migrate decide to invest more in human

[15] The difference between the average years of schooling and its equivalent in table (4) is the discount factor. In this section the discount factor has been calibrated to mach the interest rate in the open economy for each case.

capital.

Moreover note that the average years of schooling in the South in a closed economy are consistent with the effect of migration on the steady state distribution depending on the migration costs. If there is a pecuniary migration cost, the average years of schooling in the South in a closed economy are higher than non-immigrants average years of schooling. This is because the South distribution in the open economy in truncated at the upper end of the human capital distribution. If there is a time migration cost, the average years of schooling in the South in a closed economy are lower than non-immigrants average years of schooling. This is because the South distribution in the open economy is truncated at the bottom of human capital distribution.

2.7 The Effect of Migration costs in Cross - Country Output Differences

The brain drain theory defends the thesis that the migration of relatively high human capital has a negative effect for the sending country. More recently, the new brain drain theory highlights the induced education hypothesis. This hypothesis supports the idea that if the induced education effect exists, then under different assumptions it is possible that the sending country benefits from the brain drain. One of these assumptions is that if the households invest more in human capital due to the possibility of future migration then if migration does not occurs, the stock of human capital in the source country increases and this can be positive for the sending country. In this section the effect of migration will be analyzed from a different point of view. It will focus on differences in output per capita across countries by quantifying the effect of migration costs on cross country output per capita differences. To avoid the constraint that the relative size of the population involves, the strategy in this section is the following. In order to avoid the relative size of each economy affecting the results the relative size of each economy is fixed to 0.5 ($\phi_0 = \phi_1 = 1$). Then, a steady state equilibrium implies a natural population growth rate in the South of 1.22% (previously it was 0.95%) and a migration rate of 8.5%.

TABLE 2.7: *Induced education effect for different TFP values and migration costs.*

	Pecuniary migration cost			Time migration cost		
TFP	0.7	0.5	0.3	0.7	0.5	0.3
South non-immigrants average years of schooling	2.9	1.8	1.7	10.2	7.6	5.5
South av. years of schooling in a closed economy	3.8	2.6	1.7	6.6	4.2	1.4
Adjusted South av. years of schooling in a closed economy	2.3	1.7	1.4	6.3	4	3.4
% of variation	26.1	5.9	21.4	61.9	90	61.8

Table 2.8 shows the South to North output per capita ratios for different TFP levels and depending on the migration cost faced. The closed economy results report the output per capita ratios South to North when there is no migration. The South economies without migration have been recalculated for the new South natural population growth rate. Then I provide the same ratios between the South and the North but in an open economy for each type of migration cost. So the open economy with a pecuniary migration cost presents the ratio of output per capita South to North in an open economy when the migration cost is a pecuniary cost. θ is the calibrated cost in this case. Table 2.8 also presents the variation between the South to North ratio of output per capita in an open economy (with a pecuniary migration cost) with respect to a closed economy. A negative number signifies that output per capita differences increase when there is migration and a positive number signifies the opposite, that output per capita differences are lower in an open economy than in a closed economy. Finally, the exercise is repeated for the case of a time migration cost.

TABLE 2.8: *South to North output per capita ratios.*

TFP	0.7	0.5	0.3
Closed economy	0.45	0.21	0.08
Open economy with a pecuniary migration cost	0.28	0.12	-
% of variation	-0.37	-0.44	-
θ	1.7	0.8	-
Open economy with a time migration cost	0.57	0.29	0.1
% of variation	0.28	0.35	0.29
θ_t	0.27	0.44	0.64

When there is a pecuniary migration cost migration increases output per capita differences while with a time migration cost output per capita differences decrease. This effect is quite large. Migration may increase output per capita differences by approximately 40% when there is a pecuniary migration cost. On the other hand the effect of a time migration cost is a reduction of output per capita by roughly 30%.[16]

Since the migration costs affect the difference in output per capita differently, the overall effect will depend on which migration cost dominates the migration decision. This will depend on the TFP ratio South to North.

2.8 Conclusions

The possibility of migration is introduced in a human capital growth model to address three questions. First, what is the pattern of self-selection of immigrants? Second, is investment in human capital affected by the possibility of future migration? And third, how are differences in output per capita affected by mobility of human capital? Results show that immigrants are negatively

[16]It was impossible to compute the pecuniary cost which implies the migration target together with the population parameters of this section for the economy with a TFP ratio of 0.3. The problem problem is that the migration rate is too high.

self-selected when the differences in TFP between the source country and the host country are large. When the TFP in the source country is close to that in the host country then immigrants are positively self-selected. This result is independent of the migration cost faced by immigrants although the mechanism behind the self-selection pattern differs depending on the migration cost supported. This chapter supports the induced education hypothesis. Investment in human capital is higher in an open economy where it is possible to migrate than in a closed economy and this effect is higher when the migration cost is a time migration cost. The average years of schooling increases by 4, 3.6 and 2 years for TFP levels of 0.7, 0.5 and 0.3 respectively. Although less important, migration with a pecuniary migration cost also results in the same households investing more in human capital in an open economy. The induced education effect does not depend on the self-selection pattern. Even when immigrants are negatively self-selected average years of schooling of non-immigrants are higher than in a closed economy. When there is a pecuniary migration cost, migration increases output per capita differences between the South and the North by 40%. The opposite happens if there is a time migration cost. In this case migration decreases output per capita differences by 30%. Finally, when comparing the model with evidence from Mexico. The model is able to reproduce the self-selection pattern for Mexican immigrants for valid values of migration costs.

A limitation in migration literature is the availability of data on migration cost. Usually an accepted proxy for the pecuniary migration cost is the distance between the source country and the sending country. The time migration cost presents more serious complications. This model seems to support the idea that immigrants' networks can be a good proxy for the time migration cost. But data on immigrants' networks also is too heterogeneous. While waiting for precise estimations of migration costs in order to calibrate the model properly, it is nonetheless possible to calibrate the model (and the migration costs) to match the self-selection pattern. This probably needs a case by case calibration. This chapter provides a first attempt at dealing with these problems.

The natural progression is the computation of the transitions. This could solve some of the limitations in this chapter and permit analysis that cannot be performed solely by considering steady states. For example, one could use the model to test different migration policies. Moreover, the study of the transitions is in itself interesting. Finally, it would be interesting to add human capital externalities and complementarity and substitutivity of skills in the model

2.9 Appendix

2.9.1 Population Dynamics

I define N as total world population and the fraction of people living in country i as $\phi_i = \frac{N_i}{N}$ for $i = \{0, 1\}$. Finally, I use the normalization $\phi_0 + \phi_1 = 1$. Using these definitions and equations (2.4) and (2.3) I can write population dynamics in the following way for both economies:

$$\phi_1^{'} = \frac{(1+n_1)\phi_1 + (1+n_0)m\phi_0}{(1+n_1)\phi_1 + (1+n_0)\phi_0} \tag{2.27}$$

$$\phi_0^{'} = \frac{(1+n_0)(1-m)\phi_0}{(1+n_1)\phi_1 + (1+n_0)\phi_0} \tag{2.28}$$

Equilibrium at the steady state implies that $\phi_i^{'} = \phi_i$ for $i = \{0, 1\}$. It means that the size of the population relative to the world population must be constant in each economy. Equivalently, it means that population growth rates are equal in both economies at the steady state. Using this I obtain a necessary condition for the steady state:

$$m = \phi_1 \left(\frac{n_0 - n_1}{1 + n_0} \right) \tag{2.29}$$

2.9.2 Figures

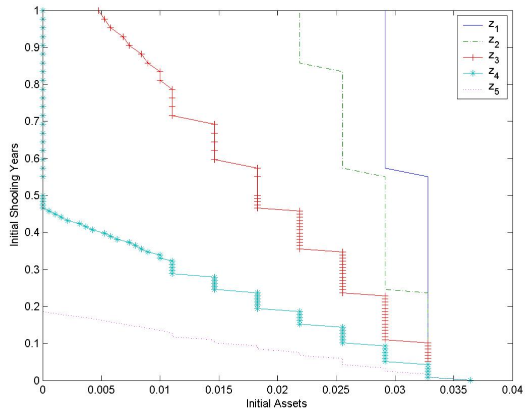

FIGURE 2.1: *Migration policy functions for each initial z for a country with TFP ratio of 0.5 and a pecuniary migration cost.*

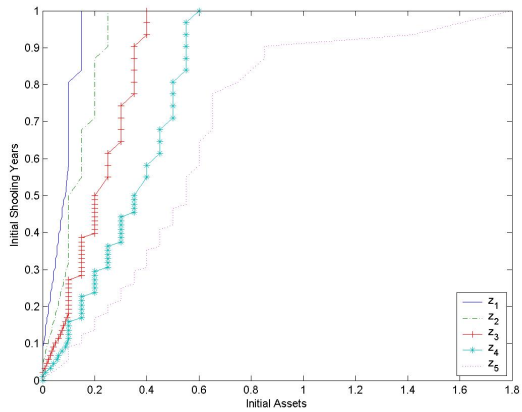

FIGURE 2.2: *Migration policy functions for each initial z for a country with TFP ratio of 0.5 and a time migration cost.*

Chapter 3

Migration and Inequality

3.1 Introduction

What is the effect of differences in inequality across countries on migration? What is the effect of migration on inequality? This chapter addresses these two questions. The relation between migration and inequality is interesting since there is both an ex ante and an ex post relationship. In the first case I am interested in how differences in inequality between two economies affect the migration flows between them.[1] Once this question has been addressed, a second question naturally appears. How does migration affect inequality? This is what makes this topic so controversial since inequality between countries may affect migration but migration may, in turn, affect inequality. Surprisingly, this relation has not been extensively studied. To know the channels through which migration and inequality are linked remains a challenge and is attracting more research. Understanding this mechanism is crucial for several relevant questions in literature on migration, development economics and inequality. This chapter presents a model that represents a first attempt to provide a framework in this topic.

The model economy consists of two locations, a large economy and a small economy. There are OG of dynasties composed by households that are heterogeneous in their ability to accumulate human capital and which decide consumption, physical capital investment, human capital investment and migration. Migration is costly and has two associated costs, a pecuniary migration cost and a time migration cost which affects the effective units of labor. Fundamentally, I consider three different TFP levels for the small economy and, moreover, different inequality degrees between the large economy and the small economy are evaluated.

To understand the mechanism in the model and the results, consider the following features of the model. In this model migration is unidirectional, from the small economy to the large economy (the small economy has lower TFP than the large economy). The pecuniary migration cost is less important the higher is the TFP in the source country. For the time migration cost the opposite holds, it becomes more important the higher is the TFP in the source country. If there is a pecuniary migration cost then there exist a physical capital level beyond

[1] For within country inequality this chapter considers the Gini index of earnings.

which the optimal decision is migration. It is impossible to find households at the steady state with physical capital above this level, implying that the pecuniary migration cost truncates the distribution at the steady state in the small economy. The time migration cost also truncates the distribution but this effect is less important compared to the previous one. In contrast to the pecuniary migration cost, the time migration cost affects the bottom of the distribution since for households with low initial levels of human capital the time migration cost is relatively lower. Taking this into account the main results are:(i) The migration rates are higher when both economies, the source economy and the host economy, present similar inequality levels.[2] The migration rates decrease when inequality differs between the two locations, independently of which has higher inequality within the country. (ii) Migration decreases inequality in the source country. The effect of migration on inequality depends on the trade-off between the two migration costs and the TFP level of the source country. In an economy with a TFP level of 0.7 the time migration cost is relatively more important and therefore is prevents the distribution of the small open economy from differing much from the distribution when migration is not feasible. In this case the pecuniary migration cost has a stronger effect in reducing inequality. The opposite is true if the TFP of the source country is 0.3. In this case inequality decreases more when considering both migration costs together. (iii) This result is not sensitive to different degrees of inequality between the two locations. (iv) Migration reduces inequality relatively more in countries with lower TFP. For lower TFP levels the accumulation of assets is lower for immigrants and for non-immigrants. So higher a accumulation of assets at the steady state implies a higher Gini index and this happens for higher TFP values.

The model used in this chapter is based on my previous work López-Real (2009) which is focus on immigrants' self-selection. The paper concludes that immigrants are negatively self-selected when the differences in TFP between the source country and the host country are large. When the TFP in the source country is close to that in the host country then immigrants are positively self-selected. Finally the chapter supports the induced education hypothesis and analyzes the effect of migration on output differences across countries. The model presented here differs in two main features. On one hand I simplify the international economy considering a large economy and a small economy that by definition does not affect the former. The motivation for this assumption is to avoid the limitations originated by population dynamics. On the other hand this version introduces a government that gets revenues from income taxes which are used to fund expenditure in education. Compared to my previous work this new environment is able to match the earnings Gini coefficient and the expenditure to GDP ratio.

Probably the pioneering papers in this migration literature are Borjas (1987) and Borjas (1994). He answers the immigrants' self-selection question using a partial static model derived from the Roy's model. Borjas defines positive self-selection as having above average earnings in both the source and the host country and in an equivalent way for negative self-selection. He finds that immigrants are positively self-selected when the correlation of skills is sufficiently high and distribution of earnings is higher in the host country. But if the source

[2]Note that since migration is unidirectional in this model the source economy corresponds to the small economy and the host economy corresponds to the large economy.

country has a higher earnings dispersion than the host country then immigrants are negative self-selected. I find that when inequality in the large economy is lower than inequality in the small economy immigrants are positively self-selected on years of schooling for any TFP value. But if the large economy is more unequal than the small economy then immigrants are negatively self-selected for TFP values of 0.3 and 0.5 and positively self-selected for an economy with TFP of 0.7.

One of the first to study the effect of migration in inequality was Lipton (1980) but his work is about rural-urban migration. He finds that migration enhances inequality but the migration that he is considering is from the most productive groups. He also finds that immigrants from wealthier backgrounds do better.

Durand, Parrado, and Massey (1996) focus their analysis in Mexico. They find that immigrants are from the lower-middle distribution of human capital. Moreover they introduce remittances in the discussion. They find that remittances tend to open up a wealth gap between the middle-income groups, who become wealthier, and the poor who do not have access to migration. Another variable that is usually considered when discussing the effect of migration on inequality is returned migration. The idea behind returned migration is that once someone has migrated and returned, the risk and the cost for new immigrants (such as friends and relatives)decrease. This increases inequality in the first step but gradual accumulation of network connections and migratory knowledge creates spill-over effects which makes migration less selective and finally implies a decrease in inequality . This chapter does not consider remittances and returned migration but finds that migration reduces inequality.

More recent works are Liebig and Sousa-Poza (2004) and Stark (2005), The former finds that highly skilled people are more inclined to migrate, though a higher income inequality attenuates the positive self-selection. The latter gets a positive relationship between income inequality, as measured by the Gini index, and the incentive to migrate. In my model the results also depend on the TFP ratio between the small economy and the large economy.

In a very recent paper Card (2009) studies the relationship between migration and inequality focusing on evidence from cross-city comparisons in the U.S. and he concludes that the impact of recent immigrants on the relative wages of the U.S. natives are small, although the effects on overall wage inequality are larger, which reflects the concentration of immigrants in the tails of the skill distribution and higher residual inequality among immigrants than natives. Finally he estimates that immigration accounts for a 5% of the increase in the U.S. wage inequality between 1980 and 2000. This chapter is not considering the effect of migration in the host country since it is focus on the source country.

The chapter is organized as follows: in section 3.2 the model economy and equilibrium are defined. Section 3.3 shows the calibration, the targets and the benchmark economy for the large economy and for the small economies. Section 3.4 studies the effect of migration on inequality for three small economies that differ in their TFP value. Section 3.5 analyzes to what extend the previous results are sensitive to differences in inequality across countries. Section 3.6 investigates the effect of inequality on migration looking to calibrated migration costs. Finally, section 3.7 concludes.

3.2 The Model Economy

3.2.1 Locations

This chapter considers an international economy with two locations identified by the index $i = \{0, 1\}$. Location or country 1 is a large open economy while the index 0 remains for a small open economy. Economies differ in their TFP level and physical capital is perfectly mobile in the world economy.

3.2.2 Technologies

The production function for aggregate output Y_i uses aggregate physical capital K_i and aggregate human capital H_i and takes the form:

$$Y_i \quad = \quad A_i K_i^{\alpha} H_i^{1-\alpha} \quad for \quad i \in \{0, 1\}, \tag{3.1}$$

TFP differs across countries. I assume that $A_1 > A_0$. The per capita human capital production function has two inputs, time $s \in [0, 1]$ and expenditure in goods allocated to education e and is given by:

$$h^{'} \quad = \quad z^{'}(s^{\eta} e^{1-\eta})^{\xi} \quad \eta, \xi \in (0, 1), \tag{3.2}$$

where $z^{'}$ is a stochastic shock that refers to the individual ability to accumulate human capital.

3.2.3 Government

The households must pay an income tax τ that the government uses to finance a fraction p of the expenditure in education.

3.2.4 Demographic Structure

I model the economies as an overlapping generation of dynasties that are altruistic toward the dynasty. Dynasties are formed by households. Agents live for two periods. In the first period they are young and in the second period they are old. Inside a household there is always one old agent with (1+n) young agents, where n is the natural population growth rate. I assume that natural population growth rates are the same across countries. When an agent becomes old a new household begins.

3.2.5 Preferences and Endowments

Young agents receive an idiosyncratic shock to their ability to accumulate human capital. This shock is unobservable for old agents but it is correlated with their own ability. So investment in human capital by the old agents is made before the realization of the shock. $z \in \mathcal{Z} = \{z_1, ..., z_n\}$ stands for the ability shock which follows a markov process with transition matrix $\pi_{z,z'}$. I assume that all young agents in the same household receive the same shock. This assumption does not affect the results qualitatively.

Finally, the instant utility function is:

$$u(c) \quad = \quad \frac{c^{1-\gamma}}{1-\gamma}. \tag{3.3}$$

where c stands for the household's consumption.

3.2.6 The Household's Problem

There are two types of agents in a household, the old and the young agent. Old agents make all the decisions. They choose consumption c and assets for the next period $a^{'}$. Note that these assets are a bequest for the descendants. Moreover the old agents make an investment in the human capital of their descendants. They decide expenditure in education e and schooling time s. Households pay an income tax τ and receive a fund from the government to finance a fraction p of education expenditures.

Finally, the old agents make the migration decision. They decide where their descendants will start the new household when they become old. i denotes the current location and $i^{'}$ denotes the location in the next period. It can take two possible values $i^{'} = 0, 1$. If future location $i^{'}$ differs from the current location i it means migration has occurred. Migration is costly. One of the costs is a pecuniary migration cost θ_f. The migration literature interprets this cost as travel expenditures between the two locations and, usually, as the cost of keeping in contact with the native country. A proxy for this parameter is the distance between the source country and the host country. The second cost that migration involves is θ_t which refers to the time that the household needs in order to make all the preparations for migration. This cost presumes a loss in the effective labor hours of the old agent. The next sections will show the implications of considering these two migration costs.

The household's income comes from old agent earnings, from young agents earnings and from assets (bequest). Note that young agents earnings depend on the remaining time after investment in human capital $(1-s)$ and also depends on ψ. I assume that young agents have a lower labor market productivity relative to old agents $\psi < 1$.

The state of a household is fully characterized by its initial assets a, the old agent's human capital h, the current value of the stochastic shock z and the current location i. So $V(a, h, z, i)$. In this international economy migration is from location 0 to location 1 at the steady state. Equivalently, migration is from the small economy (with lower TFP) to the large economy (with higher TFP). Using this result the problem faced by a household in country 1 is given by:

$$V(a, h, z, 1) = \max_{c,e,s,a^{'}} \{u(c) + \beta(1+n) \sum_{z^{'}} \pi_{z,z^{'}} V(a^{'}, h^{'}, z^{'}, 1)\} \tag{3.4}$$

s.t.

$$c + (1+n)e(1-p) + (1+n)a^{'} \leq$$

$$(1-\tau)[w_1 h \quad + \quad (1+n_1)(1-s)w_1\psi + ra] + a, \tag{3.5}$$

$$h^{'} \quad = \quad z^{'}(s^{\eta} e^{1-\eta})^{\xi}, \tag{3.6}$$

$$a^{'}, e \geq 0 \qquad and \qquad s \in [0, 1]. \tag{3.7}$$

The problem for households in location 0 is quite similar. The difference with respect the previous one is that the location in the next period is also a decision.

The current location is $i = 0$. If the decision made by the household is $i^{'} = 1$ then the young agents migrate and the household suffers the migration costs. The problem for a household in location 0 becomes:

$$V(a,h,z,0) = \max\{V^M(a,h,z,0), V^S(a,h,z,0)\} \tag{3.8}$$

where

$$V^M(a,h,z,0) = \max_{c,e,s,a^{'}}\{u(c) + \beta(1+n)\sum_{z^{'}}\pi_{z,z^{'}}V(a^{'},h^{'},z^{'},1)\} \tag{3.9}$$

s.t.

$$c + (1+n)e + (1+n)a^{'} \leq$$

$$(1-\tau)[w_0 h + (1+n)(1-s)w_0\psi + ra] + a - [\theta_f + \theta_t(1-\tau)w_0 h], \tag{3.10}$$

$$h^{'} = z^{'}(s^{\eta}e^{1-\eta})^{\xi}, \tag{3.11}$$

$$a^{'}, e \geq 0 \quad and \quad s \in [0,1], \tag{3.12}$$

$$V^S(a,h,z,0) = \max_{c,e,s,a^{'}}\{u(c) + \beta(1+n)\sum_{z^{'}}\pi_{z,z^{'}}V(a^{'},h^{'},z^{'},0)\} \tag{3.13}$$

s.t.

$$c + (1+n)e + (1+n)a^{'} \leq$$

$$(1-\tau)[w_0 h \quad + \quad (1+n)(1-s)w_0\psi + ra] + a, \tag{3.14}$$

$$h^{'} = z^{'}(s^{\eta}e^{1-\eta})^{\xi}, \tag{3.15}$$

$$a^{'}, e \geq 0 \quad and \quad s \in [0,1], \tag{3.16}$$

and the policy function for migration is defined as:

$$i^{'} = \begin{cases} 1 & \text{if } V^M(a,h,z,0) \geq V^S(a,h,z,0), \\ 0 & otherwise. \end{cases} \tag{3.17}$$

3.2.7 Stationary Equilibrium

For notation purposes I set $x = \{a,h,z,i\}$ and $X = \{[0,\infty]\times[0,\infty]\times\mathcal{Z}\times\{0,1\}\}$. Let $\mathcal{B}$ be the $\sigma - algebra$ generated in X by the Borel subsets. A probability measure μ over $\mathcal{B}$ describes the economy by stating how many households there are of each type. Let $P(x,B)$ denote the transition function. The function P describes the conditional probability for a type x household to have a type in the set $B \subset \mathcal{B}$ tomorrow and describes how the economy moves over time by generating a probability measure for tomorrow, $\mu^{'}$, given a probability measure, μ today. So, $\mu^{'}(B) = \int_X P(x,B)d\mu$ is tomorrow distribution of households $\mu^{'}$ as a function of today's distribution μ and the Markov chain. Let X_0 be $X\mid_{i=0}$

and X_1 be $X\mid_{i=1}$ and equivalently for x_i. I set $g^j(x)$ as the policy function for $j=\{c,a^{'},h^{'},e,s,i^{'}\}$.
The steady state equilibrium for this international economy where location 1 is a large open economy and location 0 is a small open economy is a set of functions for the household's problem $\{V(x),\ g^c(x),\ g^{a^{'}}(x),\ g^{h^{'}}(x),\ g^e(x),\ g^s(x),\ g^{i^{'}}(x)\}$, prices w_i and r, income tax rate τ and a measure of households, μ, such that:

1. Markets are competitive and there are no arbitrage opportunities. Note that since location 1 is the large open economy and capital is perfectly mobile the international capital rental price must be that of location 1. Then, factors prices are:

$$r = \alpha A_1\left(\frac{K_1}{H_1}\right)^{\alpha-1} \tag{3.18}$$

and

$$w_i = (1-\alpha)A_i\left(\frac{K_i}{H_i}\right)^{\alpha} \quad for \quad i=\{0,1\}. \tag{3.19}$$

2. Given τ and prices, the functions $\{v(x),\ g^c(x),\ g^{a^{'}}(x),\ g^{h^{'}}(x),\ g^e(x),\ g^s(x),\ g^{i^{'}}(x)\}$ solve the household's problem.

3. The government budget constraint is balanced.

$$\tau Y_i = p\int_{X_i} g^e(x_i) \quad d\mu(x_i) \quad for \quad i=\{1,0\} \tag{3.20}$$

4. Markets clear:

$$H_1 = \int_{X_1} h \quad d\mu(x_1) + \int_{X_1}(1-g^s(x_1))\psi \quad d\mu(x_1), \tag{3.21}$$

$$H_0 = \int_{X_0} h \quad d\mu(x_0) + \int_{X_0}(1-g^s(x_0))\psi - \int_{X_0} g^i(x_0)\theta_t h, \tag{3.22}$$

$$K_0 + K_1 = \int_X a \quad d\mu(x), \tag{3.23}$$

and

$$I = \int_X [g^a(x)-(1-\delta)a] \quad d\mu(x). \tag{3.24}$$

5. The world resource constraint is satisfied:

$$Y_0+Y_1 = \int_X [g^c(x)+g^e(x)] \quad d\mu(x)+I+\int_{X_0} g^i(x_0)\theta_f \quad d\mu(x_0). \tag{3.25}$$

6. The measure of households is stationary $\mu(B) = \int_X P(x, B) \quad d\mu$.[3]

3.3 Calibration

3.3.1 Parameters and Targets

The large open economy is calibrated with data from the U.S. Once the large open economy matches the targets the parameters values are fixed and the program is run for three different TFP levels. These will be the three examples of small economies. These three cases only differ with respect to the large economy in their level of TFP and will be used as benchmark economies for the small economies.

The length of a period is 30 years. The life cycle of an agent is from age 6 to 66. Starting to model from age 6 reproduces better the human capital investment. Age 66 is roughly retirement age. TFP of country 1 is normalize to 1 ($A_1 = 1$). The natural population growth rate, n_1, in the U.S. is 0.59% (from U.S. Census Bureau, International Data Base, year 2005). $\delta = 0.0668$ and $\alpha = 0.33$ are set following Cooley and Prescott (1995). The coefficient of the CRRA utility function σ is equal to 2, which is in the range of usually accepted values in this literature[4]. β is calibrated to match an annual interest rate of 5%. Parameters and their values are summarized in table 3.1. All the values are in annual terms.

TABLE 3.1: *Parameters and their values in the Benchmark Economy.*

Parameter		Value
TFP	A_1	1
US natural population growth rate	n_1	0.59%
Discount Factor	β	0.945
CRRA	σ	2
Physical capital share	α	0.33
Physical capital depreciation	δ	0.0668

Values yet to be chosen are the income tax rate τ and the parameters related to the human capital investment η, ξ, ψ and the ability shock z. Ability follows in logs an AR(1) process:

$$log(z^{'}) \quad = \quad \rho_z log(z) + \epsilon_z, \quad \text{where} \quad \epsilon_z \sim N(0, \sigma_z^2).$$

I use 8 shocks and the procedure in Tauchen (1986) to approximate this process with a Markov chain. This procedure involves 2 additional parameters ρ_z and σ_z^2. In overall still there are 6 parameters to be calibrated using the following

[3]The function $P(x, B)$ is determined by the optimal decisions on assets, human capital and migration and by the exogenous transition probabilities on the ability shock z. So $P(x, B) = Prob[\{z^{'} \in \mathcal{Z} : (g^{a^{'}}(x), g^{h^{'}}(x), g^{i^{'}}(x), z^{'}) \in B\} \mid z]$, where the relevant probability is the conditional probability that describes the behavior of the Markov process z.

[4]See for instance Keane and Wolpin (2001), Klein and Ventura (2007) or Erosa, Koreshkova, and Restuccia (2007)

U.S. cross-sectional data: (i) The average years of schooling is 12.9 from the U.S. Department of Education (2004). (ii) The ratio expenditure in education to GDP is 3.77% from the U.S. National Center for Education Statistics, (2006). (iii) The percentage of the U.S. population 25 years and older with some college, associate's degree or bachelor's degree equal to 43.5% from the U.S. Census Bureau (Current population survey, march 2005).[5] (iv) An intergenerational correlation of log-earnings of 0.5 from Mulligan (1997).[6]. (v) Mincer returns to schooling of 10% from Psacharopoulos (1994) for the U.S. for the period (1990-1995). (vi) Earnings Gini index for households with positive earnings is 0.49 from Díaz and Luengo-Prado (2006).[7]

3.3.2 The Benchmark Economy

Targets, parameters (P) and values (V) are summarized in table 3.2. Also data from the benchmark economy (B.E.) is presented.

TABLE 3.2: *Targets, U.S. data, benchmark economy data, parameters and parameters' values.*

Target	U.S. data	B.E.	P	V
Av. years of schooling	12.9	12.7	ψ	0.108
People with college education or higher	43.5%	42.6%	η	0.7
Intergenerational corr. of log-earnings	0.5	0.5	ρ_z	0.48
Mincer returns to schooling	10%	10%	ξ	0.7
Gini index	0.49	0.489	σ_z	0.75
Expenditure in schooling to GDP	3.77%	3.9%	τ	0.04

The target of the Gini index is the main difference between these results and its equivalents in López-Real (2009) where the Gini index of earnings in the North benchmark economy is 0.27 while here it is 0.49. To achieve the correct target σ_z must be higher implying a higher dispersion of the ability shocks and a higher concentration of shocks in the tails. To improve this concentration in the tails this chapter approximates the markov process with 8 shocks instead of 5 as is the case in López-Real (2009). So by increasing the number of points in the grid for the ability shock, the potential problem originated by shocks being highly concentrated in the extremes of the grid is avoided. The disadvantage is that the log-earnings' variance is higher compared to the data. Finally, compared to the previous work, the government and public funds for expenditure in education increase the expenditure in education as a ratio to GDP. In this chapter the benchmark economy matches the ratio expenditure in schooling to GDP while López-Real (2009) underestimates it. The rest of the parameters' values coincide quite well with those in the previously mentioned work and with those of Erosa, Koreshkova, and Restuccia (2007).

[5] In López-Real (2009) this target is 0.54%. This chapter does not consider the percentage of people with Master's degree, doctoral degree and professional degree which is 9.15%. These degrees are excluded in order that this target is in line with the expenditure in education.

[6] See Mulligan (1997), table 7.5, page 202.

[7] They use the SCF-98 as data source for the earnings and wealth Gini coefficient.

Once the parameters' values are calibrated the program is run for three different TFP levels providing three cases as benchmark economies for three small economies without migration. The three TFP levels are: 0.7, 0.5 and 0.3. Note that TFP of the large economy is normalized to 1. Results are shown in table 3.3

This simple model based on differences in TFP is quite succesful in explaining differences in average years of schooling and Mincer returns. For instance, examples of countries with estimated TFP ratio to the U.S. broadly equal to 0.7 are Finland, where average years of schooling is 9.47, or Taiwan with 7 average years of schooling. With a TFP ratio of 0.5 there is Morocco, where average years of schooling is 5.07, and examples of ratios around 0.3 are Nicaragua, Jamaica and India with average years of schooling of 3.78, 4.16 and 3.05 respectively. Results are also in line with data on Mincer returns.[8]. Note that at this point the objective is to provide three benchmark economies as small economies without migration in order to compere the results in following sections where migration is feasible.

TABLE 3.3: *Results in the small closed economies for different TFP values.*

TFP	1	0.7	0.5	0.3
Output ratio	1	0.58	0.34	0.16
Gini	0.49	0.52	0.52	0.49
Av. years of schooling	12.3	8.79	6.6	4.2
Mincer returns to schooling	10%	11.81%	13.46%	17.82%

It is very hard to perfectly match the Gini index, average years of schooling and Mincer returns for all the possible observations just by differences in TFP. A more carefully comparison with data needs a case by case study. But this is not the aim of this chapter since the intent here is to study the relationship among TFP, migration and inequality.

3.4 The effect of migration on inequality

In this section the mobility of agents from the small economy to the large economy is permitted. The percentage of people for which optimal decision is migration depends on differences in TFP and migration costs. Case (1) assumes that there is only a pecuniary migration cost and case (2) considers both costs together. In the first case the pecuniary migration cost is calibrated to get a percentage of immigrants that is exactly the same (1%) across different TFP levels. The second case considers a pecuniary migration cost that is 1/4 of that in case (1) and calibrates the time migration cost for the target migration rate. Note that the pecuniary migration cost must be lower when considering both costs in order to achieve the target of 1% of immigrants. The aim to isolate the effect of migration on inequality for different TFP levels justifies this procedure. Note that the alternative of fixing the migration cost and then vary the TFP

[8]Data from Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Bils and Klenow (2000) and Hendricks (2002)

across countries for the same migration cost presents two complications. First, a decision for which TFP value to calibrate the migration costs has to be made and second, when moving across TFP levels for the same migration costs the percentage of immigrants changes, affecting the results. Although interesting this is not the effect that this chapter wants to quantify. Results are presented in table 3.4. This table shows the Gini index for each TFP value and for each case, a pecuniary migration cost (1) and both migration costs (2). Moreover average years of schooling for non-immigrants are computed. B.E. stands for the benchmark economy without migration as was calculated in the previous section and it is used for comparisons.

I find that migration decreases inequality in the source country. The quantitative strength of this effect depends on the TFP ratio between the source country and the host country and depends also on the migration costs faced. López-Real (2009) shows that when there is only a pecuniary migration cost the average years of schooling decreases in the source country since the distribution is truncated from the top of years of schooling and assets. The opposite happens for the time migration cost since the distribution is truncated from the bottom of years of schooling increasing average years of schooling in the source country. This effect is significatively lower with respect to the the distribution at the steady state, than that which the pecuniary migration cost involves.

TABLE 3.4: *Results in the small open economies for different TFP values and migration costs.*

TFP	0.7			0.5			0.3		
Case	B.E.	1	2	B.E.	1	2	B.E.	1	2
Gini	0.52	0.47	0.49	0.52	0.43	0.42	0.48	0.40	0.34
Average years of schooling	8.79	6.77	7.19	6.6	4.73	4.53	4.2	2.51	2.66

The pecuniary migration cost is relatively more important for lower TFP levels while the time migration cost is relatively more important for higher TFP levels. This mechanism explains the effect of migration on inequality. Analyzing the small open economy with a TFP level of 0.7 one observes that the pecuniary migration cost reduces inequality more compared to the situation where both migration costs coexist. This is because the time migration cost that, as I mentioned previously, is relatively more important for higher TFP values, is preventing the migration of some households with assets which in the absence of this time migration cost would migrate. So at the steady state the distribution in the small open economy is closer to the distribution in the small closed economy when there are both migration costs than when there is exclusively a pecuniary migration cost. The situation is different for a small open economy with a low TFP of (0.3). Note that inequality decreases more for both migration costs than for the pecuniary migration cost. Investment in human capital for this TFP value is quite low so at the steady state of this economy without migration households are concentrated at the bottom of the distribution of human capital. These households, for whom the migration cost is relatively less important, migrate and so are not at the steady state of the small open economy. On one hand the distribution in the source country is truncated from the top of years of schooling and assets due to the pecuniary migration cost. On the other hand the time migration cost affects the steady state distribution from the bottom where there are the households with lower human capital and physical capital. The result is that the distribution at the steady state is truncated due to both costs. It is truncated from the bottom and from the top ending in a more equal distribution which translates to a Gini of 0.34, compared to 0.48 when there is no migration or 0.40 for the pecuniary migration cost.

Analyzing the results across TFP levels one sees in case (1) that migration reduces inequality relatively more in countries with lower TFP. For lower TFP levels the accumulation of assets is also lower for non-immigrants and for immigrants. So a higher accumulation of assets at the steady state implies a higher Gini index and this happens for higher TFP values.

The last two remarks. Firstly, in order to get a constant migration rate of 1% across TFP levels, the pecuniary migration cost has to be increased for higher TFP levels and the time migration cost has to be decreased for higher TFP levels, corroborating that the pecuniary migration cost is relatively more important for lower TFP values while the time migration cost is relatively more important for higher TFP values.[9] Secondly, the same experiment but calibrating for a higher, although reasonable, migration rates does not affect results significatively.

3.5 The effect of differences in inequality across countries on inequality within the country

The previous section showed the effect of migration on inequality within the country. This section compares the previous results with a scenario where inequality in the source country strongly differs from inequality in the host country. The objective is to test whether the previous results are consistent with higher differences in inequality within the country across countries. To this end, in the first exercise the large economy will present lower inequality than the small economy while in the second exercise inequality in the large economy will be higher than in the small economy.

TABLE 3.5: *Results in the small open economies for different TFP values when Gini index in the large economy is 0.25.*

TFP	0.7			0.5			0.3		
Case	B.E.	1	2	B.E.	1	2	B.E.	1	2
Gini	0.52	0.51	0.52	0.52	0.41	0.44	0.48	0.34	0.34
Average years of schooling	8.79	7.7	8	6.6	4	4.97	4.2	2.69	2.85

In the first exercise the large open economy is calibrated to match the same targets than before except for the Gini index.[10] The target for the Gini index

[9] An exhaustive analysis of calibrated migration costs is done in the last section of this chapter.
[10] New calibration is shown in the appendix.

in this new version of the large economy is 0.25, broadly half of the Gini index used in the previous section. The small economies remain unchanged but now when households decide between migration or staying in the native country they compare next period value functions in the native country with those in the large economy, and the latest are calculated with the new inequality's target. Results in this new scenario are presented in table 3.5. The procedure is analogous to the one in the last section. For each TFP level and case the migration cost is calibrated for a target of 1% of immigrants. Case (1) stands for the pecuniary migration cost and case (2) for both migration costs together.

Lower inequality in the large economy with respect to the small economy does not vary significantly to previous results. Compared to the previous section, inequality in a country with a TFP level of 0.7 remains more unaffected. In the first case, this is because lower inequality in the host country decreases the number of immigrants for the same migration cost. It means that the pecuniary migration cost truncates the distribution less at the steady state which implies that inequality does not change significantly. Equivalently, the higher the TFP, the higher the time migration cost compared to the pecuniary migration cost. So in case (2) the pecuniary migration cost is less important than the time migration cost explaining the Gini index 0.52 for a TFP of 0.7. Inequality decreases more for a pecuniary migration cost in a small open economy with TFP of 0.3 than in the previous section. Note that with migration and the pecuniary migration cost the Gini index is 0.34 while it was 0.40.

In the second part of the experiment the source countries present lower inequality than the host country. The large economy is the same as in the first section, with a Gini of 49% but each small closed economy is calibrated to have a Gini of 25% and to reproduce the same data for the rest of the targets as in the previous section.[11] So, these benchmark economies only differ with respect to the previous benchmark economies in the degree of inequality. Results are presented in table 3.6.

TABLE 3.6: *Results in the small open economies for different TFP values when Gini index in the large economy is 0.49 and Gini index for each small economy in the benchmark economy is 0.25.*

TFP	0.7			0.5			0.3		
Case	B.E.	1	2	B.E.	1	2	B.E.	1	2
Gini	0.25	0.19	0.19	0.25	0.20	0.20	0.25	0.18	0.16
Average years of schooling	8.79	6.4	6.3	6.6	4.6	4.5	4.2	2.8	2.62

As in the previous exercise results do not differ from the first section. Obviously Gini indexes are different because the small closed benchmark economies are calibrated for a lower Gini index but the variations in inequality due to migration are equivalent to the previous ones. The conclusion that we extract from this exercise is that the effect of migration on inequality in the source county does not depend significantly on the difference between inequality in the source country and inequality in the host country. One explanation is that maybe this model is too simple to explain differences in inequality across countries. Another

[11] See appendix for the values of this calibration.

possible explanation is that this chapter considers the that source economy has no effect on the host country since the former is defined as a small economy. This has some implications compared to López-Real (2009) where there is an international economy and immigrants affect the distribution in the host country at the steady state equilibrium. The main limitation compared to the previous work is that this model presents values for the immigrants' self-selection on average years of schooling that are too extreme. But the big advantage is that the results do not depend on the relative size of the countries with respect the world population which is advantageous when studying inequality.

3.6 The effect of inequality on migration

Up to now all the analysis has been focused on two questions: (i) what is the effect of migration on inequality within a country? and (2), How does this effect depend on differences in inequality across countries?. This section studies the effect of inequality on migration considering information from the previous sections to answer this relationship.

All the migration costs have been calibrated to reproduce a migration rate of 1% with respect the small open economy since data on migration costs is quite controversial, when available. This section follows the idea that the calibrated migration costs permit us to gain further insight as they give valuable information about the model. Table 3.7 presents the calibrated values for the migration costs for each scenario in this chapter. S.1 stands for the first scenario, so that in section 3.4 where the large economy has a Gini of 0.49 and each of the small economies only differ in TFP values. S.2 stands for the first case presented in section 3.5, when the large economy has a Gini index of 0.25 and S.3 is for the second case in the section 3.5 where the small economies have a Gini index of 0.25. In the first row the values for the pecuniary migration cost are reported (case 1). The second row shows the values of the time migration cost when it coexist with the pecuniary migration cost (case 2). Remember that in this case the pecuniary migration cost would be 1/4 of the pecuniary migration cost. To interpret the number of the pecuniary migration cost take into account that the actual pecuniary migration cost is that number multiplied by the annual average earnings of an old agent in the large economy.[12]

TABLE 3.7: *Calibrated migration costs for each scenario and for different TFP values.*

TFP	0.7			0.5			0.3		
	S.1	S.2	S.3	S.1	S.2	S.3	S.1	S.2	S.3
Pecuniary migration cost	9.7	6.65	3.6	7.7	5.5	2.2	2.19	2.4	0.85
Time migration cost considering both costs	0.12	0.11	0.18	0.2	0.22	0.21	0.26	0.25	0.23

Note that all these costs have been calibrated for the target of migration rate of 1%. Considering the first scenario in order to get the target of the migration,

[12]This means that the pecuniary migration cost θ_f is defined as $\theta\bar{w}_1$ where $\bar{w}_1$ is per year average earnings of an old agent in the large benchmark economy.

the pecuniary migration cost has to be increased for higher TFP values. This is expected since for the same pecuniary migration cost, for higher TFP values it is easier to afford the pecuniary migration cost and more households would migrate. Analyzing the second scenario, where inequality in the large economy is lower than inequality in the small economies, to keep 1% of immigrants the pecuniary migration cost for a TFP value of 0.7 and 0.5 has to decrease, but it does not significantly affect the small economy with a TFP of 0.3. Moreover in the third scenario (inequality is lower in the small economies than in the large economy) the pecuniary migration cost has to decrease also, even for the TFP of 0.3. Since the first scenario is for two countries that do not differ too much in terms of inequality with respect to the other two scenarios it indicates that higher differences in inequality across countries reduces migration. This is independent of which country, the source or the host country, presents higher inequality within the country. Expressed in a different way, keeping everything constant except inequality across countries, the migration rates are higher when inequality in the source and the host country is similar.

The opposite happens with the time migration cost when considering both migration costs. The time migration cost is relatively more important for higher TFP values. To keep constant the migration rate, one would expect that this cost must decrease as TFP increases. This is precisely what happens. The calibrated time migration cost does not change significantly across different scenarios. Since the pecuniary migration cost is 1/4 of the previously calibrated pecuniary migration cost it indicates that it is this cost which is adjusting to differences in inequality across countries.

To have an idea about the calibrated pecuniary migration cost, Davies, Greenwood, and Li (2001) and Kennan and Walker (2003) estimate that migration costs are between 4 and 6 times the U.S. average annual household income and Bayer and Juessen (2008) estimate a lower number that it is less than one-half of the U.S. average annual household income. But these works are for migration between U.S. states. So in the best of the cases we can expect migration costs across countries to be at least as high as these estimations. Note that taking 1/4 of the calibrated pecuniary migration cost the results are in line with these estimations.

Relating these results with Borjas (1994), he finds that immigrants are positively self-selected when correlation of skills is sufficiently high and distribution of earnings is higher in the hosting country. But if the source country has a higher earnings dispersion than the host country then immigrants are negatively self-selected. In this model when inequality in the large economy is lower than inequality in the small economy immigrants are positively self-selected on years of schooling for any TFP value. However, if the large economy is more unequal than the small economy then immigrants are negatively self-selected for TFP values of 0.3 and 0.5 and positively self-selected for an economy with TFP of 0.7.

3.7 Conclusions

Inequality has been extensively studied in previous works and migration is a topic that is becoming day by day more requested due to the importance and challenges that migration involves in the present economies. It is therefore surprising that the relation between migration and inequality yet remains to be seriously investigated. This chapter is a first attempt in this direction, studying how inequality affects migration and how migration affects inequality.

The main results are:(i) Migration rates are higher when both economies, the source economy and the host economy, present similar inequality levels. Migration rates decrease when inequality differs between both locations independently of which has higher inequality within the country. (ii) Migration decreases inequality in the source country. The effect of migration on inequality depends on the trade-off between both migration costs and the TFP level of the source country. (iii) The previous results are not sensitive to different degrees of inequality between both locations. (iv) Migration reduces inequality relatively more in countries with lower TFP because of lower accumulation of assets for immigrants and for non-immigrants.

In this chapter it is assumed that the income tax rate is the same across economies. A good starting point to extend this chapter is to remove this assumption. Moreover future work should take into account two variables very common in this topic. These variables are remittances and returned migration. In order to do that the study of the transitions of this model is fundamental. Moreover, the computation of the transitions allows the study of two relations. First, the "migration hump", this is that migration increases when wealth increases but that after some point migration starts to decrease for higher levels of wealth. The overall result is an inverted u-curve for migration to wealth. Second, as migration increases, inequality increases too, but after inequality reaches a maximum point, higher migration rates decrease inequality resulting again in an inverted u-curve for inequality to migration rate.

3.8 Appendix

3.8.1 Parameter's Values for Alternative Calibrations

This section presents the values for the calibration in section 3.5 on page 44.

Calibration for the large economy with a Gini index of 0.25 takes the following values presented in table 3.8.

Table 3.8: *Parameters' values for the large economy with a Gini of 0.25.*

Parameters	ψ	η	ρ_z	ξ	σ_z	τ	β
Values	0.139	0.73	0.44	0.73	0.25	0.04	0.95

Calibration for each small economy with a Gini index of 0.25 is showed in table 3.9.

Table 3.9: *Parameters' values for the small economies with a Gini of 0.25.*

Parameters	Values for a TFP 0.7	Values for a TFP 0.5	Values for a TFP 0.3
ψ	0.1	0.1	0.1
η	0.79	0.78	0.77
ρ_z	0.5	0.5	0.48
ξ	0.7	0.7	0.7
σ_z	0.28	0.33	0.38
τ	0.4	0.4	0.4

Chapter 4

The Effect of International Trade Barriers on Migration Flows

4.1 Introduction

A well-known result in international trade theory is that if trade takes place between a large economy and a small economy, the former can improve its terms of trade by imposing trade barriers without any cost since international prices are those of the large economy. This chapter analyzes the effects of trade barriers on international trade considering labor mobility across countries and finds that trade barriers foster migration from South to North. So this chapter shows a mechanism through which the North is hit by its own trade policy. The main implication is that one has not to be worried about migration flows but must be concerned about trade barriers.

Simultaneously with the tariff reduction alternatives policy instruments (quotas, regulations, etc.) have been developed affecting the final trade cost.Anderson and van Wincoop (2004) report a tariff equivalent trade barrier of around 170% in a representative rich country. As these authors pointed out, trade costs are closely linked to economic policy through policy instruments (tariffs, quotas, exchanges rates) and other policies (transport infrastructure, informational institutions, regulations, languages, etc). Moreover, developed countries concentrate trade barriers in a few sectors, in which many developing countries have comparative advantage, such as agricultural or textile products. In fact, protectionism is very strong in these sectors (see Messerlin (2002)).

Obviously, this protectionism from the developed towards the developing countries has important negative consequences for the development and convergence of developing countries. However, the main contribution of this chapter is the negative consequences that this protectionism policy implies for the developed countries.

This chapter presents a dynamic model of international trade with two countries, the North and the South. The North is assumed to be a large economy and has technological advantage in the production of capital goods and the South is a small economy. The comparative advantage allows the North to decide the international prices through its trade policy. Households decide whether to migrate or to stay in their native country. The key elements of the model are: First, immigrants earn less than natives due to the fact that migration is costly with households suffering a productivity loss when they migrate. Second, there is a publicly provided good that is financed with income taxes, which means that the fiscal system is progressive. Households with less income pay less than households with more income but they receive the same. These two assumptions in the model correspond to the stylized facts that: (i) immigrants' earnings are lower than natives' earnings (see Borjas (1994)) and, (ii) the fiscal system in developed countries is progressive.

If migration flows across countries are not considered, the result in this chapter is in line with traditional international trade theory. The North can use trade barriers to improve its terms of trade and, consequently, worsen the South's terms of trade without any cost. The idea is that a large economy (the North) improves its terms of trade if the other country is a small economy (the South) since the international prices are those of the large economy. We find that trade barriers increase the relative capital price in the South and this discourages capital accumulation and decreases wages in the South. But, since trade barriers increase wage differences across both economies we also allow for labor mobility across countries and find that trade barriers foster migration from South to North. This migration flow represents an significant extra effect that has to be considered. The result is that labor per capita decreases in the North due to migration and, therefore, per capita income and the per capita publicly provided good decrease too. It is assumed that immigrants are less productive when they move to the foreign country, as data stresses, although the intuition of the result does not depend on whether we assume the productivity loss to be permanent or transitory. In the case of immigrants' transitory productivity loss the previous result is even stronger since migration flows affect North factor prices because of the higher immigrants propensity to consume since their labor income profile is increasing. Finally, we do an optimal tariff exercise and find that the optimal tariff when we allow for labor mobility is always smaller than the optimal tariff when there is no labor mobility. The policy implication of the model is very clear. If one is concerned about migration the best one can do is to revise its trade policy.

The international trade theory has emphasized the benefits of international trade and the negative consequences that trade barriers have. This chapter belongs to the literature that explains the inconvenient effects of protectionism. The difference with previous literature is that we do not focus on the inefficiency that protectionism generates in the allocation of resources inside each country but in the inefficiency that protectionism generates in the allocation of resources at the world level due to migration flows. The standard result in the former literature is that countries with protectionist policies devote too many resources to the production of goods in which these countries do not have a comparative advantage. In this chapter the focus is on the inefficiency that protectionism generates due to the migration flows that it induces. Such inefficiency comes from the fact that migration is costly and protectionism involves more migration costs.

This chapter considers a Ricardian trade model and treat migration and international trade as imperfect substitutes. In a Ricardian trade model migration and trade are substitutes if the production function does not present increasing returns to scale. In the standard Heckscher-Ohlin trade model they are also substitutes although if one considers differences in technologies then migration and trade may be complements. So the relation depends on the settings of the model. One of the most classical papers in this literature is Mundell (1957) where it is shown that substitution between trade and migration holds in the Heckscher-Ohlin model. On the other hand Markusen (1983) finds that they are complementary in five different models under free trade and identical factor endowments.[1] Schiff (2006) generalizes in a nice exercise the Markusen's paper to allow for different degrees of protectionism and finds that substitution holds under high protectionism and complementarity holds under low protectionism. Once considering trade and costly migration Schiff (2004) finds that the effect of trade is superior to the effect of labor movements if trading costs are no higher than private migration costs. Ethier (1985) also analyzes the relation between international trade and migration but he is interested in the following contradiction. In order to be possible to preserve jobs for the native workers in the situation of an economic downturn by sending migrants to their native country one needs immigrants labor and native labor to be substitutes but in order to preserve domestic jobs by hiring immigrants one needs immigrants labor and native labor to be complementaries. He finds that this can be explained by combinations of commodity dumping and migrants dumping to smooth the native labor employment fluctuations. He uses a theoretical static model which main assumptions are immigrants workers as imperfect substitutes of native workers and temporal migration is temporal. In our model there is not returned migration. However, the papers so far mentioned, do not take into account the well documented empirical fact that migration is costly and that labor earnings of immigrants are lower than the labor earning of natives (see Borjas (1994) and Hendricks (2002)). Furthermore, this trade literature and migration is mainly static. The approach used in this chapter has the advantage that it uses a dynamic model that allows the analyzes of capital accumulation and the long-run effect that protectionism has, considering labor mobility.

As Markusen and Zahniser (1997) states, one of the motivations for the U.S. to support the NAFTA was to reduce the incentives for Mexican migration into the U.S. So the subjacent argument was that trade and migration are substitutes. This argument is line with our result since we find that trade barriers foster migration. Markusen et al. give reasons why NAFTA may not has raise the wages of Mexican workers but their study is focus on unskilled workers while in our model we do not deal with the skill premium. We assume that in the native country all the agents are identical and it is when they migrate that they have different adaptability levels. Also related to the Mexican case one finds Hanson and Harrison (1995), but they study the fact that during the 1980s, the wages of more-educated, more-experienced workers rose relative to those of less-educated, less-experienced workers together with Mexico's trade reform. Their results suggest that the rising wage gap is associated with changes internal to industries and even internal to plants that cannot be explained by Stolper-Samuelson-type effects.

Davis and Weinstein (2002) present a model with migration and international

[1] Then he changes one of the other assumptions in the traditional Heckscher-Ohlin model to perform the exercise.

trade in which migration harms host countries (the U.S.) by deteriorating their terms of trade. This mechanism is not present in our model where the terms of trade are not affected by migration.

This chapter is also related in some sense with the literature about the fiscal consequences of migration. Matsuyama (2000) claims that a migration policy that would imply immigrant with high skills would have fiscal benefits for natives in the host country. This result does not contradict ours. If in our model immigrant would have more skills than natives, migration would benefit also natives in the host country through the fiscal channel. We assumed the opposite, immigrants are less skilled (have less efficiency units of labor) than native, simply because there is strong empirical evidence in favor of such hypothesis. In any case our focus is on the consequences of protectionism which is completely different from this literature.

Klein and Ventura (2007) present a growth model in which migration is costly and vanishes in the long run. Obviously such model is not suitable for our goal which is studying long run effects of trade barriers and its relation with migration in the long run.

The chapter is organized as follows. In section 4.2, we lay out the model environment. Section 4.3 analyzes the decisions made by the agents. In section **??**equilibrium and steady state is defined and international prices are studied. In section 4.5 we set the results for the steady state without migration. Section 4.6 investigates the steady state under migration in a tractable special case: when the immigrants productivity loss is permanent. Section 4.7 presents a more general model. Optimal tariff is analyzed in section 4.8 and section 4.9 concludes. All the proofs and some technical details are showed in the Appendix 4.10.

4.2 The Model

This chapter considers an infinite horizon model with discrete time where periods are indexed by the subscript $t \in \{0, 1, 2, ...\}$. There are two countries or locations denoted by the superscript $x \in \{N, S\}$ meaning the North (N) and (S) denoting the South or a developed country and a developing country respectively. These indexes will be removed when it does not create confusion.

4.2.1 Technology

There is a continuum of goods indexed by $z \in \{c, g\} \cup [0, 1]$. Where c stands for a private consumption good and g denotes a publicly provided good. Finally, there is a continuum of capital goods indexed in $[0, 1]$. The consumption good and the capital goods are tradable but the publicly provided good is not. Abusing the notation we also denote by c per capita consumption of the private consumption good and by g per capita consumption of the publicly provided good and capital letters C and G are used for their respective aggregates. $Q(z)$ stands for the aggregate capital good $z \in [0, 1]$ used by firms in the economy ($q(z)$ in per capita terms). $Y(z)$ is the aggregate production of the good z in the economy ($y(z)$ in per capita terms). Goods are produced with labor L (l in per capita terms) and capital goods according to the following production function:

$$Y^x(z) = \phi^x(z) \left(\int_0^1 \left(Q^x(\widetilde{z}, z)\right)^{\varepsilon} d\widetilde{z} \right)^{\frac{\alpha}{\varepsilon}} \left(L^x(z)\right)^{1-\alpha} \quad \text{for} \quad x \in \{N, S\} \qquad (4.1)$$

where $Q(\widetilde{z}, z)$ is the amount of capital good $\widetilde{z}$ used in the production of the good z and $L(z)$ is the amount of labor used in the production of the good z. This model is not of a "Heckscher-Ohlin" type since all the sectors have the same factor intensities and there is trade because the productivity of different sectors varies across countries ($\phi^x(z)$). In this sense, the model is a "Ricardian" trade model. The law of motion for the accumulation of the capital goods is the following:

$$Q^x_{t+1}(z) = I^x_t(z) + Q^x_t(z) \quad \text{for} \quad x \in \{N, S\} \qquad (4.2)$$

where $I^x_t(z)$ is the investment in the capital good z in the country x at time t. The depreciation rate is assumed to be zero which helps find an analytical solution and does not affect the intuition of the results. We also assume that the stock of capital is not mobile across countries, only new capital goods (investment goods) are mobile which is a standard assumption in trade theory.

Productivity in the North is constant across sectors:

$$\phi^N(z) = A \quad \forall z \in \{c, g\} \cup [0, 1] \qquad (4.3)$$

where $A \in \Re_{++}$. The productivity in the South is equal to the productivity in the North for the sectors $\{c, g\} \cup [0, \underline{z}]$:

$$\phi^S(z) = A \text{ if } z \in \{c, g\} \cup [0, \underline{z}] \qquad (4.4)$$

where $\underline{z} \in [0, 1)$. $\phi^S(z)$ is a continuous twice differentiable strictly decreasing function in the interval $[\underline{z}, 1]$, such that $\phi^S(\underline{z}) = A$ and $\phi^S(1) = 0$. An example of such a function would be $A\left(\frac{1-z}{1-\underline{z}}\right)$.

4.2.2 Demography and Migration Arrangements

Economies are habited by a continuum of infinite-life households indexed by $j \in \Omega_t = \Omega^N_t \cup \Omega^S_t$, where Ω_t is the set of all the agents in the world in period t and it is a measurable subset of $\Re$. Ω^x_t is the set of households residing in country x in period t (immigrants included). Over these sets we define the Lebesgue measure μ and denote by $\wp_t = \mu(\Omega_t)$ the world population and by $\wp^x_t = \mu(\Omega^x_t)$ the country's population x. World population grows at a constant rate n ($\wp_{t+1} = (1+n)\wp_t$) and half of the births of the world take place in each country. This assumption is consistent with a stationary distribution of the population across countries in a world with migration and in a world without migration, while the assumption of constant natality rates in each country it is not.[2] This chapter compares a world with migration with a word without

[2] Assume that the countries have constant natality rates. Then, without migration, the population grows at a constant rate $\wp^x_{t+1} = \wp^x_t(1+n^x)$ for $x \in \{N, S\}$. Obviously, a stationary distribution of population across countries exists (with $\wp^N_t/\wp^S_t$ constant), if and only if natality rates are the same $n^N = n^S$. Now consider the case in which there is migration from the South to the North (the migration pattern considered in this chapter): $m^N > 0$,

migration (which is the benchmark economy) which justifies the assumption that half of the births in the world take place in each country. Assuming that countries have constant natality rates, which are different across countries, the weight of the population of the country with lower natality rate would tend to zero in a world without migration. The assumption that countries have constant and common natality rates implies that the weight of the population of the source country in a world with migration tends to zero.

The households make the migration decision at their birth period. This assumption simplifies the exposition but it is not restrictive since this chapter is focus on the study of the steady state equilibrium and at the steady state equilibrium if a household does not have incentives to migrate at its birth period, it is not going to have incentives to migrate in any other period (see subsequent analysis). The proportion of households that are born in country $\overline{x}$ at time t and decide to migrate in period t to country x is defined as m_t^x (where the country $\overline{x}$ denotes the country which is different from x):

$$m_t^x = \frac{\mu\left(\{j \in \Omega_t^x \text{ s.th.} t_b(j) = t \text{ and } x_b(j) = \overline{x}\}\right)}{\mu\left(\{j \in \Omega_t \text{ s.th. } t_b(j) = t \text{ and } x_b(j) = \overline{x}\}\right)} \quad \text{for} \quad x \in \{N, S\} \tag{4.5}$$

where $t_b(j)$ and $x_b(j)$ are respectively the period and the country in which household j is born. Taking into account the previous two assumptions, migration takes place only at birth and half of births in the world occurs in each country, the population dynamics for each country can be written as:

$$\wp_{t+1}^x = \wp_t^x + \frac{\wp_t n}{2}\left(1 + m_{t+1}^x - m_{t+1}^{\overline{x}}\right) \quad \text{for} \quad x \in \{N, S\} \tag{4.6}$$

$$\wp_{t+1} = (1+n)\wp_t \tag{4.7}$$

The population in the next period for any country is the sum of three terms: the country's population in the present period $\wp_t^x$, the newborn agents in the country $\frac{\wp_t n}{2}$ and the net migration $\frac{\wp_t n}{2}\left(m_{t+1}^x - m_{t+1}^{\overline{x}}\right)$.

4.2.3 Preferences and Endowments

Dynasties live infinite periods. They are endowed with one efficiency unit of labor when they stay in their native country. If a household migrates, its endowment of efficiency units of labor $h_t(j)$ depends on the time it has been living in the host country and on its adaptability to the host country, which is indexed by $\theta \in [0,1]$ where higher θ means less adaptability. More precisely:

$$h_t(j) = \begin{cases} 1 & \text{if } x_b(j) = x_r(j) \\ h(\theta(j), t - t_b(j)) & \text{if } x_b(j) \neq x_r(j) \end{cases} \tag{4.8}$$

where $x_r(j)$ is the country of residency of the household j and $h(.)$ is a continuous twice differentiable function, bounded bellow by 0 and above by 1, it is

$m^S = 0$. In this case, the population law of motion is: $\wp_{t+1}^N = (1+n^N)\wp_t^N + m^N n^S \wp_t^S$; $\wp_{t+1}^S = \left(1 + n^S(1-m^N)\right)\wp_t^S$. These equations imply the following stationary distribution of population: $\frac{\wp_t^N}{\wp_t^S} = \frac{m^S n^S}{n^S(1-m^N)-n^N}$. Obviously, in order to have a stationary distribution of population n^S should be larger than n^N: $n^S > n^S(1-m^N) > n^N$. Thus, under the assumption of constant natality rates in each country, it is impossible to obtain a stationary population distribution simultaneously in a world with migration and in a world without migration.

strictly decreasing in the first argument (θ) and strictly increasing in the second argument ($t-t_b$), such that $h(0,t-t_b)=1$, $h(1,0)=0$ and $\frac{\partial^2 h}{\partial\theta\partial t}\geq 0$[3]. Households which decide to migrate suffer a productivity loss that depends on their adaptability to the host country and decreases over time. An example of such function would be $h(\theta,t-t_b)=1-\frac{\theta}{1+t-t_b}$. The productivity loss that the workers suffer when they decide to migrate is a stylized empirical fact (see Borjas (1994)) which has different interpretations, for instance, immigrants find cultural and idiomatic problems or difficulties with the recognition of their qualifications or degrees. This chapter does not try to explain why immigrants are less productive in the host country but simply takes into account this stylized fact since, in order for the results to hold, the existence of some migration costs in the host country is needed. It is assumed that θ is uniformly distributed in $[0,1]$ among each new generation[4].

The Dynasties' utility is a function of private consumption and the publicly provided good:

$$V_{t_0}(j)=\sum_{t=t_0}^{\infty}\left[ln\left(c_t(j)\right)+\eta ln\left(g_t^{x_r(j)}\right)\right]\beta^{t-t_0} \tag{4.9}$$

where $V_{t_0}(j)$ is the expected utility of household j at period t_0, $c_t(j)$ is the consumption of household j at period t and $g_t^{x_r(j)}$ is the per capita publicly provided good at period t in the household's country of residency $x_r(j)$.

4.2.4 Institutional Arrangements

Trade barriers are *ad valorem* with rate τ^x. For simplicity the next sections of this chapter assumes that trade barriers do not produce government revenues, so trade barriers are exogenous. Later on, in section 4.8, trade barriers will be tariffs which generate government revenues and the optimal tariff will be studied. It will be shown that in case that migration is not considered, the optimal tariff is always positive in the North since the North may improve its terms of trade by imposing a tariff over the South's imports. But this discussion is postponed until section 4.8 and for the moment it is assumed exogenous non-tariffs trade barriers which do not generate government revenues.

Since trade barriers are not tariffs, the government finances the public good G with income taxes with tax rate τ_y, which is constant and equal across countries (optimal income tax rate is also analyzed in section 4.8):

$$\tau_y y_t = w_t l_t(g)+\int_0^1 r_t(z)q_t(z,g) \tag{4.10}$$

where w_t is the wage per efficiency units of labor, $r_t(z)$ is the renting price of capital of type z. Moreover, $q_t(z,g)$ and $l_t(g)$ are respectively the per capita capital of type z and the the per capita amounts of labor (in efficiency units) used in the production of the publicly provided good g. Finally,

$$y\equiv\int_{\{c,g\}\cup[0,1]}\left[w_t l_t(z)+\left[\int_0^1 r_t(\widetilde{z})q_t(\widetilde{z},z)d\widetilde{z}\right]\right]dz \tag{4.11}$$

[3]The assumption that $\frac{\partial^2 h}{\partial\theta\partial t}\geq 0$ is used in lemma 11.

[4]That is, $\frac{\mu(\{j \text{ s.th } x_b(j)=x,\ t_b(j)=j \text{ and } \theta(j)\leq\theta\})}{\mu(\{j \text{ s.th } x_b(j)=x,\ t_b(j)=j\})}=\theta \quad \forall\theta\in[0,1]$.

is the per capita income. The right hand side of the equation (4.10) is per capita public expenditure which is devoted to pay factors in order to produce the public good. The left hand side is per capita public revenue obtained from income taxes.

4.3 Agents' decisions

4.3.1 Selling and Renting price of capital

The following arbitrage condition says that the return on each capital type must be equal to the interest rate (denoted by r):

$$p_t(z)\,(1+r_{t+1}) = r_{t+1}(z) + p_{t+1}(z) \Leftrightarrow r_{t+1} = \frac{r_{t+1}(z)}{p_t(z)} + \frac{p_{t+1}(z)-p_t(z)}{p_t(z)} \tag{4.12}$$

where $p_t(z)$ and $r_{t+1}(z)$ are respectively the selling and the renting price of capital type z. This equation means that the return on the capital type z must be equal to the return on bonds r_{t+1}. The return on the capital type z is equal to the revenue per unit of investment of the capital type z, which is $\frac{r_{t+1}(z)}{p_t(z)}$, plus the capital gains per unit of investment $\frac{p_{t+1}(z)-p_t(z)}{p_t(z)}$. The above equation implies that:

$$r_{t+1}(z) = r_{t+1}\left[p_t(z) - \frac{\Delta p_{t+1}(z)}{r_{t+1}}\right] \quad \text{where} \quad \Delta p_{t+1}(z) \equiv p_{t+1}(z) - p_t(z). \tag{4.13}$$

4.3.2 Firms

The firms are competitive and maximize profits. The maximization problem of a firm that produces the good type z is the following:

$$\max_{Q(\tilde{z},z),\,L(z)} p(z)\phi(z)\left(\int_0^1 (Q(\tilde{z},z))^{\varepsilon}\,d\tilde{z}\right)^{\frac{\alpha}{\varepsilon}} (L(z))^{1-\alpha} \text{-} wL(z) \text{-} \int_0^1 r(\tilde{z})Q(\tilde{z},z)d\tilde{z} \tag{4.14}$$

It is shown in the appendix that the maximization problem of the firm that produces capital of type z may be rewritten as follows:

$$\max_{K(z),\,L(z)} p(z)\phi(z)\,(K(z))^{\alpha}\,(L(z))^{1-\alpha} - wL(z) - r\,p(k)K(z) \tag{4.15}$$

where

$$K(z) = \left(\int_0^1 (Q^z(\tilde{z},z))^{\varepsilon}\,d\tilde{z}\right)^{\frac{1}{\varepsilon}} \tag{4.16}$$

and

$$p_t(k) = \left(\int_0^1 \left(p_{t-1}(z)\text{-}\frac{\Delta p_t(z)}{r_t}\right)^{-\frac{\varepsilon}{1-\varepsilon}} dz\right)^{-\frac{1-\varepsilon}{\varepsilon}}. \tag{4.17}$$

The first order conditions for the profit maximization problem (4.15) are the well-known equalization of the marginal product of each factor with its renting price:

$$(1-\alpha)p(z)\phi(z)\left(\frac{K(z)}{L(z)}\right)^{\alpha}=w \tag{4.18}$$

and

$$\alpha p(z)\phi(z)\left(\frac{L(z)}{K(z)}\right)^{1-\alpha}=r\,p(k) \tag{4.19}$$

It follows from (4.19) that when a good z is produced, its price should be equal to its marginal cost (MC):

$$p(z)=MC=\frac{1}{\phi(z)}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r\,p(k)}{\alpha}\right)^{\alpha} \tag{4.20}$$

4.3.3 Government

The government maximizes the production of the publicly provided good subject to its budget constraint:

$$g=\max_{l(g),k(g)}\phi(g)\,(k(g))^{\alpha}\,(l(g))^{1-\alpha} \tag{4.21}$$

s.t.

$$\tau y=wl(g)+r\,p(k)k(g) \tag{4.22}$$

The first order condition for the above maximization problem implies that the marginal rate of technical substitution between labor and capital must equalize to the relative price of labor with respect to capital:

$$MRTS_{l,k}=\frac{1-\alpha}{\alpha}\frac{k(g)}{l(g)}=\frac{w}{r\,p(k)} \tag{4.23}$$

4.3.4 Households

The household j faces the following maximization problem:

$$V_{t_0}(j)=\max_{c_t}\sum_{t=t_0}^{\infty}\beta^{(t-t_0)}\left[\ln\left(c_t(j)\right)+\eta ln\left(g_t\right)\right] \tag{4.24}$$

s.t.

$$p_t(c)c_t(j)+B_{t+1}(j)=\left[w_th_t(j)+r_tB_t(j)\right](1\text{-}\tau_y)+B_t(j), \tag{4.25}$$

and

$$B_{t_b(j)}(j)=0 \tag{4.26}$$

A constant consumption price implies the following Euler and transversality conditions for the above maximization problem:

$$\frac{c_{t+1}(j)}{c_t(j)}=\beta\left(1+r_{t+1}\left(1-\tau_y\right)\right) \tag{4.27}$$

$$\lim_{t\to\infty} \frac{1}{c_t(j)} \beta^t B_{t+1}(j) = 0 \tag{4.28}$$

The budget constraint (4.25), the Euler equation (4.27) and the transversality condition (4.28) produce:

$$c_t(j) = (1\text{-}\beta) \left[\sum_{i=0}^{\infty} \frac{(1-\tau_y)\, \frac{w_{t+i}}{p(c)} h_{t+i}(j)}{\prod_{s=1}^{i} \left(1 + r_{t+s}^{at}\right)} + \frac{B_t(j)}{p(c)} \left(1 + r_t^{at}\right) \right] \tag{4.29}$$

$$V_t(j) \quad = \quad \frac{\ln c_t(j)}{1\text{-}\beta} + \frac{\beta \ln \beta}{(1\text{-}\beta)^2} + \sum_{i=1}^{\infty} \beta^i \sum_{s=1}^{i} \ln\left(1 + r_{t+s}^{at}\right) + \sum_{i=0}^{\infty} \beta^i \eta \ln\left(g_{t+i}\right) \tag{4.30}$$

where r_t^{at} is the after tax interest rate ($r_t^{at} \equiv r_t\,(1-\tau_y)$). Consumption is proportional to the households' wealth which consists of its assets and in the present value of its labor income. Note that the relevant measure of labor payment for consumption and for household's welfare is the wage in consumption terms $\frac{w_{t+i}}{p(c)}$ and we will define it as the real wage.

4.3.5 Migration Decision:

A household decides migration comparing the expected life time utility in the host country with in its native country. The lifetime utility of an agent in its native country $x_b(j)$ is according to:

$$V_{t_b}^{x_b}(x_b, t_b, \theta) = \max_{c_t} \sum_{t=t_b}^{\infty} \beta^{(t-t_b(j))} \left[\ln(c_t) + \eta ln\left(g_t^{x_b}\right)\right] \tag{4.31}$$

s.t.

$$p_t^{x_b}(c) c_t + B_{t+1} = \left[w_t^{x_b} + r_t^{x_b} B_t\right](1-\tau_y) + B_t, \tag{4.32}$$

and

$$B_{t_b} = 0 \tag{4.33}$$

where $V_t^x(x_b, t_b, \theta)$ stands for the utility of a household at period t when its country of residency is x, its native country is x_b, its birth period is t_b and its adaptability index is θ. If the household decides to migrate to country $\overline{x}_b$ then its life-time utility is the following:

$$V_{t_b}^{\overline{x}_b}(x_b, t_b, \theta) = \max_{c_t} \sum_{t=t_b}^{\infty} \beta^{(t-t_b)} \left[\ln(c_t) + \eta ln\left(g_t^{\overline{x}_b}\right)\right] \tag{4.34}$$

s.t.

$$p_t^{\overline{x}_b}(c) c_t + B_{t+1} = \left[w_t^{\overline{x}_b} h(\theta, t-t_b) + r_t^{\overline{x}_b} B_t\right](1-\tau_y) + B_t, \tag{4.35}$$

and

$$B_{t_b} = 0 \tag{4.36}$$

Agents migrate if they are better off in the foreign country (if $V_{t_b}^{\overline{x}_b}(x_b, t_b, \theta) \geq V_{t_b}^{x_b}(x_b, t_b, \theta)$). Note that $V_{t_b}^{\overline{x}_b}(x_b, t_b, \theta)$ is a decreasing function in the adaptability index θ. If migration is feasible, the agents that migrate are those which are more adaptable to the host country (those with lower θ). Thus, if there is migration from country $\overline{x}$ to country x, the new immigrants t are those new agents that are born in country $\overline{x}$ which adaptability coefficient in a certain interval $[0, \theta_t^x]$, where θ_t^x is the adaptability such that a household that is born in $\overline{x}$ would be indifferent between living in x or living in $\overline{x}$. Since θ is uniformly distributed, this "marginal" immigrant coincides with the proportion of newborn agents that migrate to country x: $\theta_t^x = m_t^x$. Therefore:

$$\begin{cases} m_t^x = 0 & \text{if } V_t^x(\overline{x}, t, 0) \leq V_t^{\overline{x}}(\overline{x}, t, 0), \\ m_t^x \Leftrightarrow V_t^x(\overline{x}, t, m_t^x) = V_t^{\overline{x}}(\overline{x}, t, m_t^x) & \text{otherwise.} \end{cases} \tag{4.37}$$

The above expression means that if the more adaptable agent born in country $\overline{x}$, is better off staying at his native country than migrating, then, migration from country $\overline{x}$ to county x does not take place ($m_t^x = 0$); otherwise it migrates a proportion of newborn population that coincides with the marginal household that is indifferent between migrating or not.

Lemma 1. *Migration is unidirectional: if* $m_t^x > 0 \Rightarrow m_t^{\overline{x}} = 0$.

The above lemma establishes that migration is just in one direction: from North to South or from South to North. It will be clear in the next sections that the only type of migration that exists at the steady state in this environment is from South to North.

4.4 Equilibrium

4.4.1 Definitions

An equilibrium is a sequence of:

- prices

$$\left\{ \left\{ \{p_t^x(z)\}_{z \in \{c\} \cup [0,1]}, w_t^x, r_t^x \right\}_{x \in \{N,S\}} \right\}_{t=0}^{\infty}, \tag{4.38}$$

- allocations

$$\left\{ \left\{ \{c_t(j), b_t(j), h_t(j)\}_{j \in \Omega_t^x} \right\}_{x \in \{N,S\}} \right\}_{t=0}^{\infty}, \tag{4.39}$$

$$\left\{ \left\{ \{y_t^x(z), k_t^x(z), l_t^x(z)\}_{z \in \{c,g\} \cup [0,1]} \right\}_{x \in \{N,S\}} \right\}_{t=0}^{\infty}, \tag{4.40}$$

$$\left\{ \left\{ \{i_t^x(z)\}_{z \in [0,1]} \right\}_{x \in \{N,S\}} \right\}_{t=0}^{\infty}, \tag{4.41}$$

$$\left\{ \{k_t^x, i_t^x\}_{x \in \{N,S\}} \right\}_{t=0}^{\infty}, \tag{4.42}$$

- and measures

$$\left\{\{\wp_t^x, m_t^x\}_{x\in\{N,S\}}, \wp_t\right\}_{t=0}^{\infty}, \tag{4.43}$$

such that:

1. The households maximize their utility according to the maximization problem (4.24)-(4.25).
2. The firms maximize their profits according to the maximization problem (4.15) and the goods supply is:

$$y_t^x(z) = \phi^x(z)\left(k_t^x(z)\right)^{\alpha}\left(l_t^x(z)\right)^{1-\alpha} \quad \forall z \in \{c\}\cup[0,1] \quad \text{for} \quad x \in \{N,S\}$$

3. The government maximizes the production of the publicly provided good g subject to its budget constraint according to the maximization problem (4.21).
4. The investment in capital goods satisfies equation (4.123) and capital follows its law of motion (4.124) (see Appendix 4.10).
5. The price of goods satisfies the following arbitrage condition:

$$p_t^x(z) \leq p_t^{\overline{x}}(z)(1+\tau^x)\forall z \in \{c\}\cup[0,1] \quad \text{for} \quad x \in \{N,S\}$$

6. The population follows its law of motions (4.6)-(4.7), and migration is determined by the optimal household's decision according to (4.37).
7. The good market clearing conditions are:

$$\frac{\wp_t^N}{\wp_t} i_t^N(z) + \frac{\wp_t^S}{\wp_t} i_t^S(z) = \frac{\wp_t^N}{\wp_t} y_t^N(z) + \frac{\wp_t^S}{\wp_t} y_t^S(z) \quad \forall z \in [0,1]$$

and

$$\frac{\int_{\Omega_t} c(j)dj}{\wp_t} = \frac{\wp_t^N}{\wp_t} y_t^N(c) + \frac{\wp_t^S}{\wp_t} y_t^S(c)$$

8. The labor market clearing condition is:

$$\frac{\int_{\Omega_t^x} h_t(j)dj}{\wp_t^x} = \int_{\{c\}\cup[0,1]} l_t^x(z)dz \quad \text{for} \quad x \in \{N,S\}$$

9. The capital market clearing condition is:

$$\frac{\int_{\Omega_t^x} b_t(j)dj}{\wp_t^x} = \int_{\{c\}\cup[0,1]} p_t^x(k) k_t^x(z)dz \quad \text{for} \quad x \in \{N,S\}$$

A steady state equilibrium is an equilibrium in which prices and allocations are constant over time, and in which m_t^x and the ratios $\frac{\wp_t^x}{\wp_t}$ are also constant for $x \in \{N,S\}$.

4.4.2 International Prices of Goods

Autarky Prices

Equation (4.20) (price equal to marginal cost) implies that when a country produces two goods, z and $\tilde{z}$, the relative price of z with respect to $\tilde{z}$ must be equal to the marginal rate of transformation of z in terms of $\tilde{z}$:

$$\text{If } y(z) > 0 \qquad \text{and} \qquad y(\tilde{z}) > 0 \Rightarrow \frac{p(z)}{p(\tilde{z})} = \frac{\phi(\tilde{z})}{\phi(z)} \tag{4.44}$$

So the relative price of a good in terms of the other must equalize its opportunity cost in term of the other (or marginal rate of transformation). In the case of autarky this equation implies that the relative price of goods with respect to consumption good in the North and in the South are equal to the marginal rate of transformation of these goods with respect to consumption good:

$$\begin{aligned} &\tfrac{p^{Autarky,N}(z)}{p^{Autarky,N}(c)} = MRT^N(z) = \tfrac{\phi(c)}{\phi(z)} = 1, \\ &\tfrac{p^{Autarky,S}(z)}{p^{Autarky,S}(c)} = MRT^S(z) = \tfrac{\phi(c)}{\phi(z)} = \begin{cases} 1 & \text{if } z \in [0, \underline{z}] \\ \frac{A}{\phi(z)} & \text{if } z \in [\underline{z}, 1] \end{cases} \end{aligned} \tag{4.45}$$

where $MRT^x(z)$ is the marginal rate of transformation of good z with respect to the consumption good in country x. So the amount of good z that can be produced in the economy if the production of the consumption good is reduced in one unit. From now on the marginal rate of transformation of a good with respect to the consumption good is defined by MRT.

International Prices

A country that exports a good satisfies the following arbitrage condition:

$$\text{If} \quad y^x(z) > i^x(z)[y^x(c) > c^x \quad \text{if} \quad z = c] \Rightarrow p^x(z) = p(z) \quad \text{for} \quad x \in \{N, S\} \tag{4.46}$$

where $p(z)$ is the international price of good z and $p^x(z)$ is the price of good z in country x. If country x exports the good z, then the international price of z must coincide with the price inside the country ($p^x(z) = p(z)$). If the price of z in x were lower than the international price, then there would be an arbitrage opportunity by buying good z in x and selling it in the international market. If the price of z in x were higher than the international price, no firm in x would have incentives to sell it abroad.

A country that imports a good satisfies the following arbitrage condition:

$$\begin{aligned} \text{If} \quad & y^x(z) < i^x(z)[y^x(c) < c^x \quad \text{if} \quad z = c] \Rightarrow \\ & p^x(z) = p(z)\,(1 + \tau^x) \quad \text{for} \quad x \in \{N, S\} \end{aligned} \tag{4.47}$$

If country x imports a good its price must satisfy the arbitrage condition $p^x(z) = p(z)\,(1 + \tau^x)$. If $p^x(z) > p(z)\,(1 + \tau^x)$, then there is an arbitrage opportunity by buying the good z in the international market and selling it in country x. If $p^x(z) < p(z)\,(1 + \tau^x)$, no one would buy good z in the international market and would sell it in x because the importer would incur in negative profits.

From now on the prices are normalized such that the consumption price in the North is equal to one ($p^N(c) = 1$).

Proposition 2. *If at the steady state* $c^N \geq \frac{1-\frac{z}{1-z}}{2}(1-\tau_y)y^N$ *and* $k^N \geq k^S$*, then at the steady state* $p^N(z) = 1 \;\forall z \in [0,1]$.

Average propensity to consume larger than $\frac{1-\frac{z}{1-z}}{2}$ and higher per capita capital in the North than in the South imply that prices in the North are the same than in the case of autarky ($p^N(z) = 1$). We consider from now on that conditions of proposition 2 hold and the next sections show that this is really the case.

Corollary 3. *If at the steady state* $c^N \geq \frac{1-\frac{z}{1-z}}{2}(1-\tau_y)y^N$ *and* $k^N \geq k^S$*, then at the steady state the international price of the exported goods by the North (imported by the South) is equal to* 1 *and the price of imported goods by the North (exported by the South) is* $\frac{1}{1+\tau^N}$.

This corollary comes from proposition 2 and arbitrage conditions (4.46) and (4.47) and shows that the North can improve its terms of trade using its trade policy. Section 4.8 shows that trade barriers may benefit the North when migration is not considered.

It follows from corollary 3, arbitrage conditions (4.46) and (4.47) that the price in the South of exported goods by the South must be equal to $\frac{1}{1+\tau^N}$ and the price in the South of the imported goods by the South must be $(1+\tau^S)$:

$$\text{If} \quad y^S(z) > i^S(z)[y^S(c) > c^S \quad \text{if} \quad z = c] \Rightarrow p^S(z) = p(z) = \frac{1}{1+\tau^N} \tag{4.48}$$

$$\text{If} \quad y^S(z) < i^S(z)[y^S(c) < c^S \quad \text{if} \quad z = c] \Rightarrow p^S(z) = (1+\tau^s)p(z) = (1+\tau^s) \tag{4.49}$$

The autarky prices (4.45) involve that the South has comparative advantage in the consumption good, which means that the consumption good is one of the goods that the South exports. Thus, the price of the consumption good in the South must satisfy the equation (4.48):

$$p^S(c) = \frac{1}{(1+\tau^N)} = p(c) \tag{4.50}$$

Using (4.48), (4.49) and (4.50) we get that the relative price of the exported and imported goods by the South are:

$$\text{If} \quad y^S(z) > i^S(z) \quad \Rightarrow \quad \frac{p^S(z)}{p^S(c)} = 1 \tag{4.51}$$

$$\text{If} \quad y^S(z) < i^S(z) \quad \Rightarrow \quad \frac{p^S(z)}{p^S(c)} = (1+\tau^s)(1+\tau^N) \tag{4.52}$$

Figure 4.1 on 88 represents the relative price of capital goods with respect to the consumption good in the South (thick line) and the opportunity cost of these goods in terms of the consumption good (the MRT). From this figure one observes that only the goods in the interval $[0, \underline{z}]$, that is those goods that have the same technology and the same cost in the South and in the North, satisfy the equation (4.51) in the South which means that the consumption good and the goods in the interval $[0, \underline{z}]$ are the goods exported by the South. There are also goods that would be more costly to produce by the South than to import them. These goods are those which MRT is larger than the relative price of imported goods in terms of consumption in the South $(1+\tau^s)(1+\tau^N)$ (see (4.52)). Since the MRT increases with z, it follows that there is a certain interval $[z^*, 1]$ of goods that are imported by the South, as figure 4.1 shows. Where z^* is the "marginal" good such that its MRT coincides with the relative price of imported goods in the South $(1+\tau^s)(1+\tau^N)$. So z^* is the "marginal" good because if it is produced in the South it costs exactly the same that if it is imported:

$$z^* \overset{definition}{\Leftrightarrow} MRT^S(z^*) = \frac{A}{\phi^S(z^*)} = (1+\tau^S)(1+\tau^N) \tag{4.53}$$

Finally, figure 4.2 shows that there is an intermediate range of goods, which are in the interval $(\underline{z}, z^*)$, such that its MRT is between the relative price of exported goods in the South "1" and the relative price of imported goods $(1+\tau^S)(1+\tau^N)$. These goods can not compete abroad since its marginal cost is above its international price, but can be sold at its marginal cost in the South due to the fact that trade barriers protect them from the international competition. Then these goods are not exchanged in the international market.

To sum up, there are three types of goods depending on the trade pattern:

1. Those goods that the South exports to the North, which are the consumption good c and the capital goods in the interval $[0, \underline{z}]$.
2. Those goods that are not exchanged in the international market $z \in (\underline{z}, z^*)$.
3. Those goods that the South imports from the North $z \in [z^*, 1]$.

It is showed in figure 4.2 that when trade barriers $(1+\tau^S)(1+\tau^N)$ increase, the price of the imported goods in the South rises, making profitable to produce for the national market certain goods which were not competitive before the increment of the protectionism. So when trade barriers go up, the marginal good imported by the South z^* goes in the same direction[5].

From the above discussion we learn that the relative good prices in the South are:

$$\frac{p^S(z)}{p^S(c)} = \begin{cases} 1 & \text{if } z \in \{c\} \cup [0, \underline{z}] \\ \frac{A}{\phi^S(z)} & \text{if } z \in [\underline{z}, z^*] \\ (1+\tau^S)(1+\tau^N) & \text{if } z \geq z^* \end{cases} \tag{4.54}$$

This equation together with the figure 4.1 implies that the relative price of capital with respect to consumption in the South is larger than one (the relative

[5] This can be proved by applying the Implicit Function Theorem to the definition of z^* in (4.53) which yields:

$$\frac{\partial z^*}{\partial\left((1+\tau^S)(1+\tau^N)\right)} = \left(\frac{A\left(-\frac{\partial \phi^S\left(z^*\left((1+\tau^S)(1+\tau^N)\right)\right)}{\partial z}\right)}{\left[\phi^S\left(z^*\left((1+\tau^S)(1+\tau^N)\right)\right)\right]^2}\right)^{-1} > 0$$

price of capital with respect to consumption in the North) being equal just in the case that there is no trade barriers. Figure 4.2 shows that when trade barriers $(1+\tau^S)(1+\tau^N)$ increase, the price of the capital goods in the interval $[z_0^*, 1]$ in the South goes up as well. This implies that an increment in trade barriers rises the relative price of capital with respect to consumption in the South.

Lemma 4. *The relative price of capital good with respect to consumption good in the South is an increasing function of trade barriers* $(1+\tau^S)(1+\tau^N)$.

The above result will play an important role in this chapter. The introduction of trade barriers by the North improves its terms of trade and worse off the terms of trade of the South, generating a higher relative price of capital in the South and discouraging capital accumulation in the South, which depresses wages in the South and fosters migration.

4.4.3 Per Capita Income

Using (4.19), (4.23) and the capital and labor market clearing conditions it follows that:

$$y_t = \frac{w_t l_t}{1-\alpha} = \frac{r_t p_t(k) k_t}{\alpha} = p_t(z)\phi(z) k_t^\alpha l_t^{1-\alpha} \quad \forall z \quad \text{such that} \quad y_t(z) > 0 \tag{4.55}$$

This implies that:

$$y_t^N = A\left(k_t^N\right)^\alpha \left(l_t^N\right)^{1-\alpha} \tag{4.56}$$

$$y_t^S = \frac{A}{1+\tau^N}\left(k_t^S\right)^\alpha \left(l_t^S\right)^{1-\alpha} \tag{4.57}$$

Considering the per capita income in consumption terms yields:

$$\frac{y_t^N}{p_t^N(c)} = A\left(k_t^N\right)^\alpha \left(l_t^N\right)^{1-\alpha} \tag{4.58}$$

$$\frac{y_t^S}{p_t^S(c)} = A\left(k_t^S\right)^\alpha \left(l_t^S\right)^{1-\alpha} \tag{4.59}$$

Finally, introducing (4.19) and (4.23) in the government budget constraint (4.22) the result is:

$$g = \tau_y A\left(k\right)^\alpha \left(l\right)^{1-\alpha} \tag{4.60}$$

4.5 Steady State without Migration

When there is not the possibility of migration all households have one efficiency unit of labor. It follows from (4.29) that per capita consumption at the steady state is:

$$p(c)c = (1-\beta)\left[w\left(1-\tau_y\right)\frac{1+r^{at}}{r^{at}} + b\left(1+r^{at}\right)\right] \tag{4.61}$$

Adding the households' budget constraint and using the capital market clearing condition it is obtained that:

$$p(c)c_t + np(k)k = \left[wl + rp(k)k\right]\left(1-\tau_y\right) \tag{4.62}$$

Plugging equation (4.55) and (4.61) in (4.62) the following results are got:

$$r^{at} = \xi \equiv \left[\frac{1+\alpha n}{\beta} - 1\right] \tag{4.63}$$

$$\frac{w}{p(c)} = (1-\alpha)\left(\frac{A}{\left(\frac{\xi}{\alpha(1-\tau_y)}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}} \tag{4.64}$$

$$k = \left(\frac{A}{\frac{\xi}{\alpha(1-\tau_y)}\frac{p(k)}{p(c)}}\right)^{\frac{1}{1-\alpha}} \tag{4.65}$$

$$g = \tau_y y = \tau_y\left(\frac{A}{\left(\frac{\xi}{\alpha(1-\tau_y)}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}} \tag{4.66}$$

The real wage (wage in consumption terms), the per capita capital and the per capita public good at the steady state depend on the relative price of capital with respect to consumption. This relative price is equal to one in the North and it is an increasing function of trade barriers in the South (see lemma (3)). The relative price in the South is equal to one just in the case of free trade. Then, the real wage, the per capita capital and the per capita public good in the South decrease with trade barriers.

Lemma 5.

If at the steady state $r^{at,N} \geq 2\alpha n(1-\underline{z})$, *then* $c^N \geq \dfrac{1-\frac{\underline{z}}{1-\underline{z}}}{2}(1-\tau_y)y^N$

Since per capita capital in the North is higher than in the South, just the following assumption is needed in order that the result of proposition 2 applies.

Assumption 1

$$\xi \geq 2\alpha n(1-\underline{z}) \Leftrightarrow \frac{(1+\alpha n)}{1+2\alpha n(1-\underline{z})} \geq \beta \tag{4.67}$$

Proposition 6. *Trade barriers do not affect the interest rate, the real wage and the per capita capital in the North at the steady state. The interest rate is the same in the North and in the South. The South-North ratios of real wage* ($\frac{w^S}{p^S(c)}/\frac{w^N}{p^N(c)}$), *per capita capital* (k^S/k^N) *and per capita public provided good* (g^S/g^N) *are decreasing functions of the trade barriers* $(1+\tau^S)(1+\tau^N)$. *These ratios are equal to one when there is no trade barriers* ($\tau^S = \tau^N = 0$).

Corollary 7. *The life time utility of a newborn household* $V_{t_b(j)}(j)$ *does not depend on trade barriers in the North, but it is a decreasing function of trade barriers in the South being equal just in absence of trade barriers.*

Then migration does not take place if there are not trade barriers since the newborn households enjoy the same welfare in the North and in the South.

When there are trade barriers, the newborn households in the North are better off than households in the South involving that households in the South have incentives to migrate to the North and these incentives increase as trade barriers also increase.

For simplicity it was assumed that trade barriers are not tariffs and therefore do not generate government revenues. So trade barriers do not benefit households in the North. In section 4.8 this assumption is removed and it is showed that trade barriers imposed by the North improve its terms of trade and benefit households in the North.

4.6 Migration with a Permanent Loss of Productivity

This section investigates a model with migration in which immigrants suffer a permanent loss of productivity when they migrate. This environment is used as a starting point since it is the simplest one but we will turn to a more realistic, although more complex, model in the next section. The present section assumes that if the household j migrates then its efficiency units of labor is given by $h(j) = h(\theta(j))$, where $h(.)$ is a strictly decreasing function such that $h(0) = 1$ and $h(1) = 0$. This case presents the important analytical advantage that migration does not affect either interest rate or the wage at the steady state.

It follows from lemma 4 and equations (4.64) and (4.66) that the wage and the per capita income are higher in the North than in the South (except when there are not trade barriers). Thus, if there is migration, this will be from the South to the North (see lemma 1).

As we explained in section 4.3, the migration decision consists in a comparison of the life time utility in both countries. Since the adaptability index implies that an agent with lower index has higher productivity abroad, the immigrant will be the agent with an adaptability index in the interval $[0, m]$ where m is the adaptability index such that a household with adaptability index m is indifferent between migration or remain at the native country. Since the adaptability index is uniformly distributed, it coincides with the proportion of newborn agents in the South that migrate to the North. It follows from equations (4.6)-(4.7) that the steady state population is as follows:

$$\frac{\wp_t^N}{\wp_t} = \frac{1+m^N}{2}, \quad \frac{\wp_t^S}{\wp_t} = \frac{1\text{-}m^N}{2}, \tag{4.68}$$

$$\frac{\mu\left(j \in \Omega_t^N / x_b(j) = N\right)}{\wp_t^N} = \frac{1}{1+m^N} \tag{4.69}$$

and

$$\frac{\mu\left(j \in \Omega_t^N / x_b(j) = S\right)}{\wp_t^N} = \frac{m^N}{1+m^N} \tag{4.70}$$

Since there is no migration to the South, the per capita labor supply in the South is one while the per capita labor supply in the North is given by the expression:

$$l^N = l(m^N) = \left[\frac{1}{(1{+}m^N)}1 + \frac{m^N}{(1{+}m^N)}\left(\frac{\int_0^{m^N} h(\theta)d\theta}{m^N}\right)\right] = \frac{1+\int_0^{m^N} h(\theta)d\theta}{1+m^N} \tag{4.71}$$

where $l(m^N)$ is the function that relates per capita labor supply with the migration rate m. The agents that are born in the North, which are the proportion $1/\left(1{+}m^N\right)$ of the North population, have one unit of labor, while the immigrants in the North that are the fraction $m^N/\left(1{+}m^N\right)$ of the North population have on average a amount of labor equal to $\int_0^{m^N} h(\theta)d\theta \Big/ m^N$. The supply of labor in the North is a decreasing function of the proportion of agents that migrate:[6]

$$\frac{\partial l(m)}{\partial m} = -\frac{\left[(1-h(m)) + \left(\int_0^m h(\theta)d\theta - mh(m)\right)\right]}{(1+m)^2} < 0 \qquad \forall m > 0 \tag{4.72}$$

Using equations (4.55) and (4.61) in (4.62) the following results are obtained:

$$r^{at} = \xi \tag{4.73}$$

$$\frac{w}{p(c)} = (1-\alpha)\left(\frac{A}{\left(\frac{\xi}{\alpha(1-\tau_y)}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}} \tag{4.74}$$

$$k = \left(\frac{A}{\frac{\xi}{\alpha(1-\tau_y)}\frac{p(k)}{p(c)}}\right)^{\frac{1}{1-\alpha}} l(m) \tag{4.75}$$

$$g = \tau_y \frac{y}{p(c)} = \tau_y \left(\frac{A}{\left(\frac{\xi}{\alpha(1-\tau_y)}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}} l(m) \tag{4.76}$$

It is easy to check by comparison of equations (4.63)-(4.66) with equations (4.73)-(4.76) that migration does not affect the factor prices (interest rate and real wage) but affects the per capita capital and the per capita public good because these variables depend on the per capita labor supply which depends on the number of immigrants.

The "marginal" immigrant in the North m is indifferent between remain in the South or migrate to the North. Using the fact that at the steady state the interest rate is the same across countries it follows that the marginal immigrant satisfies the following equations (see (4.30)):

$$\begin{aligned} V_t^S(S,t,m) &= V_t^N(S,t,m) \Leftrightarrow \\ \ln\left[\frac{w^N h(m)}{p^N(c)}\right] + \eta \ln\left(g^N\right) &= \ln\left[\frac{w^S}{p^S(c)}\right] + \eta \ln\left(g^S\right) \end{aligned} \tag{4.77}$$

[6]Since $l(m)$ is a strictly decreasing function, it follows that $\int_0^m h(j)dj > \int_0^m h(m)dj = ml(m) \quad \forall m > 0$.

Lemma 8. $k^N \geq k^S$

It follows from lemma 4 and 8 and assumption 4.5 that proposition 2 applies. That is, international prices are as described in section 4.4.

Lemma 9. *The proportion of households from the South that migrate to the North (m) is an increasing function of trade barriers* $(1+\tau^S)(1+\tau^N)$.

Note that the per capita labor supply in the North is a decreasing function of m, which is an increasing function of trade barriers. Thus, the per capita labor supply in the North is a decreasing function of trade barriers. Since per capita capital and per capita public good increase with per capita labor supply (see (4.75) and (4.76)), it follows that these variables decrease with trade barriers.

Corollary 10. *The per capita labor supply* l^N*, the per capita capital* k^N*, the per capita income* y^N *and the per capita public good* g^N *are decreasing functions of trade barriers in the North at the steady state. The wage* w^S*, the per capita capital* k^S*, the per capita income* y^S *and the per capita public good* g^S *are decreasing functions of trade barriers in the South at the steady state.*

To sum up, trade barriers reduce the wage and the per capita public good in the South because trade barriers increase the relative price of capital in the South which discourages capital accumulation in the South. Trade barriers reduce the wage and the per capita public good in the North due to the extra effect that trade barriers involves reducing the wage in the South which stimulates migration to the North and the immigrants imply a drop in the per capita labor supply in the North. Consequently there is a reduction in the per capita capital and public good in the North. The result is that if we consider mobility of labor in this version of an international Ricardian trade model, trade barriers not only reduce the welfare of households in the South but also in the North.

Proposition 11. *The life time utility of any type of household* $(x, t, \theta) \in \{N, S\} \times \{0, 1, 2, ...\} \times [0, 1]$ *at the steady state is a decreasing function of trade barriers.*

Proof. Consider $V(x, t, \theta) = \max\left\{V_t^x(x, t, \theta), V_t^{\overline{x}}(x, t, \theta)\right\}$ as the life time utility of a household that is born in country x at period t with adaptability index θ. It derives from equations (4.30) and (4.73) that the households' utility in the South $V_t^S(x, t, \theta)$ at the steady state is:

$$V_t^S(S, t, \theta) = \frac{\ln\left[\frac{w^S}{p^S(c)}\right] + \eta \ln\left(g^S\right)}{1\text{-}\beta} + \frac{\beta\left[\ln\beta + \ln(1+\xi)\right]}{(1\text{-}\beta)^2} \tag{4.78}$$

It follows from (4.74) and (4.76) that the real wage $\frac{w^S}{p^S(c)}$ and the per capita public good g^S are decreasing function of the capital relative price in the South $\frac{p^S(k)}{p^S(c)}$. But according to lemma 4 the relative price of capital in the South is an increasing function of trade barriers. Therefore $V_t^S(S, t, \theta)$ is a decreasing function of trade barriers at the steady state. Applying the channel rule we get that:

$$\frac{\partial V_t^S(S, t, \theta)}{\partial\left((1+\tau^S)(1+\tau^N)\right)} = \tag{4.79}$$

$$\underbrace{\frac{\partial V_t^S(S,t,\theta)}{\partial\left(\frac{w^S}{p^S(c)}\right)}}_{(+)}\underbrace{\frac{\partial\left(\frac{w^S}{p^S(c)}\right)}{\partial\left((1+\tau^S)(1+\tau^N)\right)}}_{(-)}+\underbrace{\frac{\partial V_t^S(S,t,\theta)}{\partial\left(g^S\right)}}_{(+)}\underbrace{\frac{\partial\left(g^S\right)}{\partial\left((1+\tau^S)(1+\tau^N)\right)}}_{(-)}<0$$

The immigrants' utility is:

$$V_t^S(N,t,\theta)=\frac{\ln\left[\frac{w^N}{p^S(c)}h(\theta)\right]+\eta\ln\left(g^N\right)}{1\text{-}\beta}+\frac{\beta\left[\ln\beta+\ln(1+\xi)\right]}{(1\text{-}\beta)^2} \tag{4.80}$$

Since the per capita public good in the North is a decreasing function of migration, which is an increasing function of trade barriers it follows that the immigrants' utility decreases also with trade barriers:

$$\frac{\partial V_t^S(N,t,\theta)}{\partial\left((1+\tau^S)(1+\tau^N)\right)}= \tag{4.81}$$

$$\left[\underbrace{\frac{\partial V_t^S(N,t,\theta)}{\partial\left(\frac{w^N}{p^N(c)}\right)}}_{(+)}\underbrace{\frac{\partial\left(\frac{w^N}{p^N(c)}\right)}{\partial m}}_{(0)}+\underbrace{\frac{\partial V_t^S(N,t,\theta)}{\partial g^N}}_{(+)}\underbrace{\frac{\partial g^N}{\partial m}}_{(-)}\right]\underbrace{\frac{\partial m}{\partial\left((1+\tau^S)(1+\tau^N)\right)}}_{(+)}<0$$

Note that $V(S,t,\theta)=\max\left\{V_t^S(S,t,\theta),V_t^{\overline{N}}(S,t,\theta)\right\}$ and it was showed that both, the South resident households' utility $V_t^S(S,t,\theta)$ and the immigrants' utility $V_t^S(N,t,\theta)$ are decreasing functions of trade barriers at the steady state, it follows that the life-time utility at the steady state of any type of household that are born in the South is a decreasing function of trade barriers. Equivalently the life-time utility of households that are born in the North is:

$$V^N(N,t,\theta)=V_t^N(N,t,\theta)=\frac{\ln\left[\frac{w^N}{p^S(c)}\right]+\eta\ln\left(g^N\right)}{1-\beta}+\frac{\beta\left[\ln\beta+\ln(1+\xi)\right]}{(1-\beta)^2} \tag{4.82}$$

The per capita public good in the North is a decreasing function of migration which is an increasing function of trade barriers, so the North native households' utility decreases also with trade barriers:

$$\frac{\partial V(N,t,\theta)}{\partial\left((1+\tau^S)(1+\tau^N)\right)}= \tag{4.83}$$

$$\left[\underbrace{\frac{\partial V(N,t,\theta)}{\partial\left(\frac{w^N}{p^N(c)}\right)}}_{(+)}\underbrace{\frac{\partial\left(\frac{w^N}{p^N(c)}\right)}{\partial m}}_{(0)}+\underbrace{\frac{\partial V(N,t,\theta)}{\partial g^N}}_{(+)}\underbrace{\frac{\partial g^N}{\partial m}}_{(-)}\right]\underbrace{\frac{\partial m}{\partial\left((1+\tau^S)(1+\tau^N)\right)}}_{(+)}<0$$

□

4.7 General Model

This section considers the general model in which the immigrant's productivity loss instead of being permanent is transitory. It is assumed that immigrants improve their productivity as they stay in the host country, so $h(\theta, t-t_b)$ is an increasing function in the second argument. An interpretation for this new formulation is that immigrants adapt to the host country over time. We anticipate that the results do not differ much with respect to the previous section. The unique change is that migration does not only affect per capita income and per capita public good, but it also affects the factor prices, wages and interest rate. In this case migration implies that the wages per efficiency unit of labor go down while the interest rate goes up involving a negative effect of migration over the North native households even stronger than in the previous section. The extra effect of trade barriers does not come just from the fiscal channel, now there is an additional mechanism: migration depresses wages of North native households.

It follows from (4.29) that per capita consumption at the steady state is:

$$c = \frac{(1\text{-}\beta)}{p(c)}\left[w\,(1\text{-}\tau_y)\,l(m)\left[\frac{1+r^{at}+\Psi(r^{at},m)}{r^{at}}\right]+b\left(1\text{+}r^{at}\right)\right], \tag{4.84}$$

where

$$\Psi(r^{at},m) = \frac{\frac{n}{1+n}r^{at}\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^{s}\sum_{i=1}^{\infty}\frac{\left[\int_0^m[h(\theta,s+i)-h(\theta,s)]d\theta\right]}{[1+r^{at}]^i}\right]}{(1+m)l(m)}, \tag{4.85}$$

and

$$l(m) = \frac{1+\frac{n}{1+n}\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^{s}\int_0^m h(\theta,s)d\theta\right]}{1+m} \tag{4.86}$$

The difference between these equations and its analogous version of the previous section is the term $\Psi(r^{at},m)$ that appears now. Note that this additional term is zero when there is no migration. $\Psi(r^{at},m)$ means that immigrants have a higher propensity to consume since their labor income profile is increasing. Thus, in order to smooth consumption, the immigrants save less at the beginning of their life than if they would have a constant labor income.

Lemma 12. $\frac{\partial\Psi(r^{at},m)}{\partial m} > 0$ *and* $\frac{\partial\Psi(r^{at},m)}{\partial r^{at}} < 0$.

Adding households' budget constraints and using capital market clearing condition and the equation (4.55) the new expression for after tax interest rate becomes:

$$r^{at} = \xi + \frac{(1-\beta)(1-\alpha)\Psi(r^{at},m)}{\beta} \tag{4.87}$$

Applying the Implicit Function Theorem it is possible to define $r^{at}(m)$ such that:

$$r^{at}(m) = \xi + \frac{(1-\beta)(1-\alpha)\Psi(r^{at}(m),m)}{\beta} \tag{4.88}$$

$$\frac{\partial r^{at}(m)}{\partial m} = \frac{\frac{(1-\beta)(1-\alpha)}{\beta}\frac{\partial\Psi(r^{at},m)}{\partial m}}{1-\frac{(1-\beta)(1-\alpha)}{\beta}\frac{\partial\Psi(r^{at},m)}{\partial r}} > 0 \tag{4.89}$$

Finally, using equations (4.55) and (4.60) it follows that:

$$\frac{w}{p(c)} = (1-\alpha)\left(\frac{A}{\left(\frac{r^{at}(m)}{(1-\tau_y)\alpha}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}} \tag{4.90}$$

$$k = \left(\frac{A}{\frac{r^{at}(m)}{(1-\tau_y)\alpha}\frac{p(k)}{p(c)}}\right)^{\frac{1}{1-\alpha}} l(m) \tag{4.91}$$

$$g = \tau_y\frac{y}{p(c)} = \tau_y\left(\frac{A}{\left(\frac{r^{at}(m)}{(1-\tau_y)\alpha}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}} l(m) \tag{4.92}$$

As previously mentioned the "marginal" immigrant m^N is indifferent between stay in the South or migrate to the North. Using that the interest rate is the same across countries at the steady state it follows that the marginal immigrant satisfies the following equations (see (4.30)):

$$V_t^N(S,t,m^N) = V_t^S(S,t,m^N) \Leftrightarrow \tag{4.93}$$

$$\ln\left[\frac{w^N(1-\tau_y)}{p(c)}\sum_{i=0}^{\infty}\frac{h_{t+i}(m^N,i)}{\left(1+r^{at,N}\right)^i}\right] + \frac{\beta\ln\left(1+r^{at,N}\right)}{1-\beta} + \eta\ln\left(g^N\right) =$$

$$\ln\left[\frac{w^S(1-\tau_y)}{p(c)}\frac{1+r^{at,S}}{r^{at,S}}\right] + \frac{\beta\ln\left(1+r^{at,S}\right)}{1-\beta} + \eta\ln\left(g^S\right)$$

Lemma 13. *If $\Psi(\overline{r}^{at},m) \leq \frac{\beta\left(\overline{r}^{at}-\xi\right)}{(1-\beta)(1-\alpha)}$, the proportion of households from the South that migrate to the North m^N is an increasing function of trade barriers $(1+\tau^S)(1+\tau^N)$, where $\overline{r}^{at} \equiv \frac{1-\beta}{\beta-\alpha}$.*

Assumption 2

$$\Psi\left(\overline{r}^{at},1\right) \leq \frac{\beta\left(\overline{r}^{at}-\xi\right)}{(1-\beta)(1-\alpha)} \tag{4.94}$$

Assumption 4.7 is needed to avoid multiple equilibria. It means that when the per capita capital falls down at the steady state the welfare of agents with zero capital falls down as well (see appendix 4.10). Remember that $\Psi(r,m)$ is equal to zero when the productivity loss is permanent.

It follows from lemma 13 and equations (4.86), (4.89), (4.91) and (4.92) that, as in the previous section, the per capita capital, the per capita income and the public good decrease with trade barriers in the North. Furthermore, from (4.90) wages decrease also with trade barriers. In the South, the results are exactly the same as in the previous section with permanent loss of productivity.

Corollary 14. *The per capita labor supply l^N, the wage w^N, the per capita capital k^N, the per capita income y^N and the per capita public good g^N are* *decreasing functions of trade barriers in the North at the steady state. The wage w^S, the per capita capital k^S, the per capita income y^S and the per capita public good g^S are decreasing functions of trade barriers in the South at the steady state.*

Considering this corollary, not surprisingly, the results in the previous section about welfare hold. Every household, in the North and in the South, are worse off under trade barriers.

Proposition 15. *The life time utility at the steady state of any type of household $(x, t, \theta) \in \{N, S\} \times \{0, 1, 2, ...\} \times [0, 1]$ is a decreasing function of trade barriers.*

The result in this more general model is that the extra effect of trade barriers is more significant than in the previous section. Migration does not only affect welfare of North native households by reducing the public good due to the reduction of the per capita income. Now, there is an additional mechanism to add to this fiscal channel that amplifies the overall effect. Migration reduces wages and therefore the labor income of North native households.

4.8 Optimal Tariff

Until now it was assumed that trade barriers are non-tariff trade barriers. This section considers that trade barriers are tariffs and the optimal tariff is analyzed with and without migration. The government chooses the income tax rate τ_y and the tariff rate τ^x such that it maximizes the life time utility of its native households.

4.8.1 Optimal Tariff without Migration

In the case that trade barriers are tariffs, the government revenues come from the income tax and the tariff to imports. Then, the government budget constraint becomes:

$$g^x = \tau_y^x A (k^x)^\alpha (l^x)^{1-\alpha} + \tau^x \left(\frac{\wp_t^S}{\wp_t^x} \int_{z^*}^1 \frac{p(z)}{p(c)} i^S(z) dz \right) \quad \text{for} \quad x \in \{N, S\} \tag{4.95}$$

where we are using the fact that North exports are equal to North imports due to trade balance equilibrium:

$$\int_{z^*}^1 p(z) i^S(z) dz = p(c) \left[y^S(c) - c^s \right] + \int_{\{c\} \cup [0, \underline{z}]} p(z) \left[y^S(c) - i^S(z) \right] dz \tag{4.96}$$

Since South imports at the steady state are (see (4.125)):

$$\int_{z^*}^1 \frac{p(z)}{p(c)} i^S(z) dz = \left(\frac{p^S(k)}{1 + \tau^S} \right)^{\frac{1}{1-\varepsilon}} (1 - z^*) \left[n k^S \right] \tag{4.97}$$

we can rewrite the government budget constraint as:

$$g^x = \tau_y^x A (k^x)^\alpha (l^x)^{1-\alpha} +$$

$$+\tau^x \left[\frac{\wp_t^S}{\wp_t^x} \left(\frac{p^S(k)}{1+\tau^S} \right)^{\frac{1}{1-\varepsilon}} (1-z^*) \left[nk^S \right] \right] \quad \text{for} \quad x \in \{N, S\} \tag{4.98}$$

The life time of a household at the steady state is (see (4.30)):

$$V = \frac{\ln \left[(1\text{-}\beta) \left[(1-\tau_y) \frac{w}{p(c)} \frac{1+r^{at}}{r^{at}} \right] \right] + \frac{\beta \ln \left[\beta \left(1+r^{at} \right) \right]}{(1\text{-}\beta)} + \eta \ln(g)}{1-\beta} \tag{4.99}$$

It follows from (4.63) that the after tax interest rate at the steady state does not depend on the fiscal policy. Therefore, the objective function of the government may be simplified to:

$$\arg \max_{\tau, \tau_y} V = \arg \max_{\tau, \tau_y} \ln \left((1-\tau_y) \frac{w}{p(c)} \right) + \eta \ln(g) \tag{4.100}$$

Thus, the maximization problem of the government in the North is as follows (see equations (4.64) and (4.66)):

$$\max_{\tau^N, \tau_y^N} \ln \left(\left(1-\tau_y^N \right) \frac{w}{p(c)} \right) + \eta \ln(g) \tag{4.101}$$

s.t.

$$\frac{w}{p(c)} = (1-\alpha) \left(A \left(\frac{(1-\tau_y^N)\alpha}{\xi} \right)^{\alpha} \right)^{\frac{1}{1-\alpha}}, \tag{4.102}$$

$$g = \tau_y^N \left(A \left(\frac{(1-\tau_y^N)\alpha}{\xi} \right)^{\alpha} \right)^{\frac{1}{1-\alpha}} + \tau^N \int_{z^*}^{1} i^S(z) dz, \tag{4.103}$$

and

$$\int_{z^*}^{1} i^S(z) dz = \left(\frac{p^S(k)}{1+\tau^S} \right)^{\frac{1}{1-\varepsilon}} (1-z^*)\, n \left(\frac{A \left(1-\tau_y^S \right)}{\frac{\xi}{\alpha} \frac{p^S(k)}{p^S(c)}} \right)^{\frac{1}{1-\alpha}} \tag{4.104}$$

The first order condition for this government's maximization problem with respect to the income tax rate is:

$$\frac{1}{1-\alpha} \frac{1}{1-\tau_y} = \eta \frac{y}{g} \left[1 - \frac{\alpha}{1-\alpha} \frac{\tau_y}{1-\tau_y} \right] \tag{4.105}$$

This first order condition with respect to income tax rate means that the marginal utility of consumption multiplied by the reduction of wage due to income tax (which discourage capital accumulation) must equalize the marginal utility of the public good multiplied by the marginal revenues due to the increase of the income tax rate. This marginal revenue is not 1 since when income tax rate is increased, capital accumulation is discouraged and this reduces per capita income at the steady state.

The first order condition for this government's maximization problem with respect to the tariff is:

$$\int_{z^*}^{1} i^S(z)dz = \tau^N \int_{z^*}^{1} i^S(z)dz \left[\underbrace{\frac{1}{1-\varepsilon}\frac{-\frac{\partial p^S(k)}{\partial \tau^N}}{p^s(k)}}_{(1)} + \underbrace{\frac{\frac{\partial z^*}{\partial \tau^N}}{1-z^*}}_{(2)} + \underbrace{\frac{1}{1-\alpha}\frac{\frac{\partial\left(\frac{p^S(k)}{p^S(c)}\right)}{\partial \tau^N}}{\frac{p^S(k)}{p^S(c)}}}_{(3)} \right] \tag{4.106}$$

The tariff enter in the households' utility simply as a source of government revenues, therefore the optimal tariff is the one that maximizes the government revenues due to tariff. An increase in the tariff imposed by the North produces a trade off. Since North imports are equal to South imports, when there is a marginal increment of the tariff the revenues of the North rise in the amount of the North imports. Note that by trade balance North imports are equal to North exports, that is $\int_{z^*}^{1} i^S(z)dz$. But the increment of the tariff reduces the relative price of South exports and then reduces North exports. This reduction is represented in the term (1). Secondly, an increment of the tariff reduces the quantity of goods that the North exports as z^* increases (term (2)). Finally the increment of the tariff in the North has a long run negative effect over the capital of the South. Such reduction of the capital of the South has a negative effect on the demand for North capital goods by the South represented by the term (3). If the tariff in the North is zero, the left hand side of this equation is zero, implying that the optimal tariff in the North is always positive.

The reason why the tariff improves welfare in the North has been explored in the static trade theory. Since the North has a monopoly in certain goods, it can improve its terms of trade by introducing a tariff. Note that the international price of goods imported by the North is $\frac{1}{1+\tau^N}$, while the international price of goods exported by the North is 1. Therefore the tariff improves the terms of trade of the North, improving the North welfare. In this particular model, these improvements in the terms of trade lead to an increment in the revenues of the government, which in turns rises the public good and welfare of the North native households.

4.8.2 Optimal Tariff with Migration

When migration is considered the main difference with respect to the previous section is that, as it was previously mentioned, the interest rate is a function of immigrants. Then, the maximization problem of the government in the North becomes (see equations (4.90) and (4.92)):

$$\max_{\tau^N,\tau_y^N} \ln\left[\frac{w\,(1\text{-}\tau_y)}{p(c)}\frac{1+r^{at}(m)}{r^{at}(m)}\right] + \frac{\beta \ln\left(1+r^{at}(m)\right)}{1-\beta} + \eta \ln\left(g^N\right) \tag{4.107}$$

s.t.

$$\frac{w}{p(c)} = (1-\alpha)\left(A\left(\frac{\alpha(1-\tau_y)}{r^{at}(m)}\right)^{\alpha}\right)^{\frac{1}{1-\alpha}}, \tag{4.108}$$

$$g = \tau_y^N \left(A \left(\frac{\alpha(1-\tau_y)}{r^{at}(m)} \right)^{\alpha} \right)^{\frac{1}{1-\alpha}} l(m) + \tau^N \int_{z^*}^{1} i^S(z)dz, \tag{4.109}$$

and

$$\int_{z^*}^{1} i^S(z)dz = \left(\frac{p^S(k)}{1+\tau^S} \right)^{\frac{1}{1-\varepsilon}} (1\text{-}z^*)\, n \left(\frac{A\left(1\text{-}\tau_y^S\right)}{\frac{\xi}{\alpha}\frac{p^S(k)}{p^S(c)}} \right)^{\frac{1}{1-\alpha}} \tag{4.110}$$

The first order condition with respect to the income tax rate is similar to its equivalent in the previous section but now appears an additional positive term because higher income tax rate reduces migration:

$$\frac{1}{1-\alpha}\frac{1}{1-\tau_y^N} = \eta\frac{y}{g}\left[1 - \frac{\alpha}{1-\alpha}\frac{\tau_y^N}{1-\tau_y^N}\right] +$$

$$+ \left[\underbrace{\left[-\frac{1}{1-\alpha}\frac{1}{r^{at}(m)} + \frac{1}{1-\beta}\frac{1}{1+r^{at}(m)} \right]}_{(-)} \underbrace{\frac{\partial r^{at}(m)}{\partial m}}_{(+)} + \underbrace{\eta\frac{\tau_y^N \frac{\partial y}{\partial m}}{g}}_{(-)} \right] \underbrace{\frac{\partial m}{\partial \tau_y^N}}_{(-)} \tag{4.111}$$

The first order condition with respect to the tariff is as follows:

$$\int_{z^*}^{1} i^S(z)dz = \tau^N \int_{z^*}^{1} i^S(z)dz \left[\frac{1}{1-\varepsilon}\frac{-\frac{\partial p^S(k)}{\partial \tau^N}}{p^s(k)} + \frac{\frac{\partial z^*}{\partial \tau^N}}{1-z^*} + \frac{1}{1-\alpha}\frac{\frac{\partial\left(\frac{p^S(k)}{p^S(c)}\right)}{\partial \tau^N}}{\frac{p^S(k)}{p^S(c)}} \right] -$$

$$- \underbrace{\tau_y^N \frac{\partial y}{\partial m}\frac{\partial m}{\partial \tau^N}}_{(1)} - \underbrace{\left[-\frac{1}{1-\alpha}\frac{1}{r^{at}(m)} + \frac{1}{1-\beta}\frac{1}{1+r^{at}(m)} \right] \frac{\partial r^{at}(m)}{\partial m}\frac{\partial m}{\partial \tau^N}}_{(2)} \tag{4.112}$$

There are two extra negative terms in this first order condition with respect to its analogous version in the previous section. First, there is a reduction of income tax revenues due to the reduction of per capita income that migration generates (term (1)). Furthermore, there is another effect not related with government revenues: the increment of the tariff encourages migration, which reduces wages and therefore the life time utility of the households. This reduction is represented by the term (2) which is negative (see assumption 4.7 and appendix 4.10).

Thus, the optimal tariff when there is migration is always smaller than the optimal tariff when there is no migration and in fact may be zero when the following condition is satisfied:

$$\eta\frac{\int_{z^*}^{1} i^S(z)dz + \tau_y^N \frac{\partial y}{\partial m}}{g} - \left[\frac{1}{1-\alpha}\frac{1}{r^{at}(m)} + \frac{1}{1-\beta}\frac{1}{1+r^{at}(m)} \right] \frac{\partial r^{at}(m)}{\partial m} \leq 0 \tag{4.113}$$

4.9 Conclusions

This chapter analyzes the effects of trade barriers in international trade considering labor mobility across countries. A well-known result in international trade theory is that if trade takes place between a large economy and a small economy, the former can improve its terms of trade by imposing trade barriers without any cost since international prices are those of the large economy. In this model this result holds when the possibility of migration flows is not considered. We find that the introduction of trade barriers by the North improves its terms of trade and, consequently, worse off the South's terms of trade. The relative capital price increases in the South and this discourages capital accumulation and decreases wages in the South. Since trade barriers increases wage differences across both economies we allow for labor mobility and find that trade barriers foster migration from South to North. This migration flow represents an extra effect that has not been considered previously. The result is that labor per capita decreases in the North due to migration and, therefore, per capita income and the per capita public good also decrease. Then the North is hit by its own trade policy.

This chapter assumes that immigrants are less productive when they move to the foreign country as data stresses. The intuition of the result does not depend on if the productivity loss is permanent or transitory. In the case of immigrants' transitory productivity loss the previous result is even stronger since migration flows affects North factor prices because of the higher propensity to consume of the immigrants since their labor income profile is increasing. Finally, we perform an optimal tariff exercise and find that the optimal tariff when allowing for labor mobility is always smaller than the optimal tariff when there is not labor mobility.

The main implication of this chapter is that one does not have to be worried about migration flows but be concerned about trade barriers. So, this model can be used to study the enlargement of the European Union and can be extended introducing complementarity and substitutability of skills and studying the transitions to do most sophisticated optimal policy.

4.10 Appendix

4.10.1 Firms' Maximization Profits

Taking into account the equation (4.12), the first order conditions for the profit maximization problem (4.14) may be written as follows:

$$w_t = (1-\alpha)p_t(\tilde{z})\phi(\tilde{z})\left(\int_0^1 (Q_t(z,\tilde{z}))^{\varepsilon}\,dz\right)^{\frac{\alpha}{\varepsilon}} (L_t(\tilde{z}))^{-\alpha} \tag{4.114}$$

$$p_{t-1}(z)r_t - \Delta p_t(z) = \frac{\alpha p_t(\tilde{z})\phi(\tilde{z})\,(L_t(\tilde{z}))^{1-\alpha}\,(Q_t(z,\tilde{z}))^{\varepsilon-1}}{\left(\int_0^1 (Q_t(z,\tilde{z}))^{\varepsilon}\,dz\right)^{1-\frac{\alpha}{\varepsilon}}} \tag{4.115}$$

where $\Delta p_{t+1}(z) = p_{t+1}(z) - p_t(z)$. These conditions imply that the marginal rate of technical substitution across different types of capital must be equal to their relative price:

$$\frac{(Q_t(z,\tilde{z}))^{\varepsilon-1}}{(Q_t(z_1,\tilde{z}))^{\varepsilon-1}}=\frac{p_{t-1}(z)-\frac{\Delta p_t(z)}{r_t}}{p_{t-1}(z_1)-\frac{\Delta p_t(z_1)}{r_t}}\Rightarrow$$

$$Q_t(z,\tilde{z})=\left(\frac{p_{t-1}(z_1)-\frac{\Delta p_t(z_1)}{r_t}}{p_t(z)-\frac{\Delta p_t(z)}{r_t}}\right)^{\frac{1}{1-\varepsilon}}Q_t(z_1,\tilde{z}) \tag{4.116}$$

We define

$$K_t(\tilde{z})=\left(\int_0^1 (Q_t(z,\tilde{z}))^{\varepsilon}\,dz\right)^{\frac{1}{\varepsilon}} \tag{4.117}$$

and

$$p_t(k)=\left(\int_0^1\left(p_{t-1}(z)-\frac{\Delta p_t(z)}{r_t}\right)^{-\frac{\varepsilon}{1-\varepsilon}}dz\right)^{-\frac{1-\varepsilon}{\varepsilon}} \tag{4.118}$$

Introducing the equation (4.116) in the definition of capital it produces:

$$Q_t(z,\tilde{z})=\left(\frac{p_t(k)}{p_{t-1}(z)-\frac{\Delta p_t(z)}{r_t}}\right)^{\frac{1}{1-\varepsilon}}K_t(\tilde{z}) \tag{4.119}$$

It follows from (4.13) and (4.119) that:

$$\int_0^1 r_t(z)Q_t(z,\tilde{z})dz=r_{t+1}p_t(k)K(\tilde{z}) \tag{4.120}$$

Thus, the maximization problem of the firm that produces capital of type $\tilde{z}$ may be written as in the main text (equation (4.15)).

4.10.2 Capital Law of Motion

To equalize the return of every capital type among them, equation (4.116) must hold at the aggregated level. It follows from (4.119) and capital markets clearing conditions that:

$$\left.\begin{aligned}Q_t(z)&=\left(\frac{p_{t-1}(k)}{p_{t-1}(z)-\frac{\Delta p_t(z)}{r_t}}\right)^{\frac{1}{1-\varepsilon}}K_t\\ Q_{t+1}(z)&=I_t(z)+Q_t(z)\end{aligned}\right\}\Rightarrow \tag{4.121}$$

$$I_t(z)=\left(\frac{p_t(k)}{p_t(z)-\frac{\Delta p_{t+1}(z)}{r_{t+1}}}\right)^{\frac{1}{1-\varepsilon}}K_{t+1}-\left(\frac{p_{t-1}(k)}{p_{t-1}(z)-\frac{\Delta p_t(z)}{r_t}}\right)^{\frac{1}{1-\varepsilon}}K_t \tag{4.122}$$

$$i_t(z)=\left(\frac{p_t(k)}{p_t(z)-\frac{\Delta p_{t+1}(z)}{r_{t+1}}}\right)^{\frac{1}{1-\varepsilon}}k_{t+1}(1+n_{t+1})-\left(\frac{p_{t-1}(k)}{p_{t-1}(z)-\frac{\Delta p_t(z)}{r_t}}\right)^{\frac{1}{1-\varepsilon}}k_t$$

(4.123)

$$i_t = \left[\int_0^1 \left(\frac{p_t(k)p_t(z)^{1-\varepsilon}}{p_t(z) - \frac{\Delta p_{t+1}(z)}{r_{t+1}}}\right)^{\frac{1}{1-\varepsilon}} dz\right] k_{t+1}(1+n_{t+1}) -$$

$$-\left[\int_0^1 \left(\frac{p_{t-1}(k)p_t(z)^{1-\varepsilon}}{p_{t-1}(z) - \frac{\Delta p_t(z)}{r_t}}\right)^{\frac{1}{1-\varepsilon}} dz\right] k_t \tag{4.124}$$

where $I_t = \int_0^1 p(z)I_t(z)dz$ is the investment and i_t is the per capita investment. It follows from the definition of $p(k)$, equations (4.123) and (4.124) that when the prices are constant the following equations hold:

$$i_t(z) = \left(\frac{p(k)}{p(z)}\right)^{\frac{1}{1-\varepsilon}} [k_{t+1}(1+n_{t+1}) - k_t] \tag{4.125}$$

$$i_t = p(k)\left[k_{t+1}(1+n_{t+1}) - k_t\right] \tag{4.126}$$

4.10.3 Proof Lemma 1

Proof. Using the definition of $V_t^x(x_b, t_b, \theta)$ it follows that if $m_t^x > 0 \Rightarrow$

$$V_t^x(x, t, 0) > V_t^x(\overline{x}, t, m_t^x) = V_t^{\overline{x}}(\overline{x}, t, m_t^x) = V_t^{\overline{x}}(x, t, 0) \Rightarrow m_t^{\overline{x}} = 0.$$

□

4.10.4 Proof Proposition 2

Proof. Note that all sectors have constant returns to scale and that the supply of goods is perfectly elastic. The goods that the South exports to the North are in the set $\{c\}\cup[0, \underline{z}]$, but the North may also produce them at the same cost than importing them from the South. The goods in the interval $[\underline{z}, z^*]$ are not going to be traded in the international market and each country are going to produce them by itself. The key feature is that the goods in the interval $[z^*, 1]$ are going to be produced only by the North. Thus, the condition needed in order that the market of goods is in equilibrium is that the North has enough resources to be able to attend the World Demand of these goods $[z^*, 1]$. It follows from (4.125) that the demand of these goods at the steady state is as follows $\forall z \in [z^*, 1]$:

$$\frac{\wp^S}{\wp} i^S(z) + \frac{\wp^N}{\wp} i^N(z) = \tag{4.127}$$

$$\frac{\wp^S}{\wp}\left(\frac{p^S(k)}{p^S(z)}\right)^{\frac{1}{1-\varepsilon}} nk^S + \frac{\wp^N}{\wp} nk^N < \frac{\wp^S}{\wp} nk^S + \frac{\wp^N}{\wp} nk^N \leq 2nk^N$$

In the first inequality the definition of z^* is used.[7] In the second inequality we use the fact that migration is unidirectional from South to North and therefore $\wp^N > \wp^S$ together with the condition of the proposition 2 ($k^N \geq k^S$). In order that the North may be able to satisfy the international demand of these goods, it has to have enough resources. Let´s consider the following factor allocation:

$$\begin{aligned}
\tilde{l}(z) &= \begin{cases} \frac{(1-\tau_y)}{1-\underline{z}} l^N & \text{If } z \in [\underline{z}, 1] \\ 0 & \text{If } z \in \{c\} \cup [0, \underline{z}] \\ \tau_y l^N & \text{If } z = g \end{cases} \\
\tilde{k}(z) &= \left(\frac{k^N}{l^N}\right) l^N(z)
\end{aligned}$$

This allocation is feasible in the North. If with this allocation the North produces more than the world demand for the goods $z \in [\underline{z}, 1]$, then there is an allocation such that $l^N(z) \leq \tilde{l}(z) \quad \forall z \in [\underline{z}, 1]$ in which the World goods market is in equilibrium. The following is the sufficient condition to ensure this (see equations (4.55), (4.126) and (4.128)):

$$A\left(\tilde{k}(z)\right)^{\alpha}\left(\tilde{l}(z)\right)^{1-\alpha} = \frac{(1-\tau_y)}{(1-\underline{z})} A\left(k^N\right)^{\alpha}\left(l^N\right)^{1-\alpha} \geq$$

$$2nk^N = 2\left[(1-\tau_y)A\left(k^N\right)^{\alpha}\left(l^N\right)^{1-\alpha} - c^N\right] \Leftrightarrow$$

$$c^N \geq \frac{1}{2}\frac{1-2\underline{z}}{1-\underline{z}}(1-\tau_y)y^N$$

□

4.10.5 Proof lemma 3

Proof. The relative price of capital with respect to consumption in the South is:

$$\frac{p^S(k)}{p^S(c)} = \left(\underline{z} + \int_{\underline{z}}^{z^*}\left(\frac{A}{\phi^S(z)}\right)^{-\frac{\varepsilon}{1-\varepsilon}} dz + (1\text{-}z^*)\left((1+\tau^S)(1+\tau^N)\right)^{-\frac{\varepsilon}{1-\varepsilon}}\right)^{-\frac{1-\varepsilon}{\varepsilon}} \tag{4.128}$$

It follows from this equation that:

$$\frac{\partial\left(\frac{p^S(k)}{p^S(c)}\right)}{\partial\Upsilon} = \tag{4.129}$$

$$-\frac{1-\varepsilon}{\varepsilon}\left(\frac{p^S(k)}{p^S(c)}\right)^{\frac{1}{1-\varepsilon}}\left[\frac{\partial(z*)}{\partial\Upsilon}\left[\left(\frac{A}{\phi^S(z^*)}\right)^{-\frac{\varepsilon}{1-\varepsilon}} - \Upsilon^{-\frac{\varepsilon}{1-\varepsilon}}\right] - \right.$$

$$\left. -\frac{\varepsilon}{1-\varepsilon}(1\text{-}z^*)\Upsilon^{-\frac{1}{1-\varepsilon}}\right] = \left(\frac{p^S(k)}{p^S(c)}\right)^{1+\varepsilon}(1\text{-}z^*)\Upsilon^{-\frac{1}{1-\varepsilon}} > 0$$

Where $\Upsilon = \left((1+\tau^S(c))(1+\tau^N)\right)$ and the last equality uses the definition of z^*. □

[7] If $z \in [z^*, 1] \Rightarrow \forall\tilde{z} \in [0, z^*)\ p^S(z) > p^S(\tilde{z}) \Rightarrow p^S(z) > p^S(k)$

4.10.6 Proof lemma 4

Proof. If $r^{at,N} \geq 2\alpha n(1-\underline{z})$, it follows from (4.55) and (4.126) that

$$A\left(k^N\right)^{\alpha}\left(l^N\right)^{1-\alpha}(1-\tau_y) \geq 2(1-\underline{z})nk^N \Leftrightarrow \tag{4.130}$$

$$y^N(1-\tau_y) \geq 2(1-\underline{z})\left[y^N(1-\tau_y)-c^N\right] \Leftrightarrow$$

$$c^N \geq \frac{1-\frac{\underline{z}}{1-\underline{z}}}{2}(1-\tau_y)y^N$$

□

4.10.7 Proof lemma 8

Proof. Introducing (4.74) and (4.76) in (4.77) we get:

$$V_t^S(S,t,m^N) = V_t^N(S,t,m^N) \Rightarrow \left(\frac{p^S(k)}{p^S(c)}\right)^{-\frac{\alpha}{1-\alpha}} = \tag{4.131}$$

$$h(m^N)^{\frac{1}{1+\eta}} l(m^N)^{\frac{\eta}{1+\eta}} \leq l(m^N) \Rightarrow$$

$$k^S = \left(\frac{A}{\frac{\xi}{\alpha(1-\tau_y)}\left(\frac{p^S(k)}{p^S(c)}\right)^{1-\alpha}}\right)^{\frac{1}{1-\alpha}}\left(\frac{p^S(k)}{p^S(c)}\right)^{-\frac{\alpha}{1-\alpha}} \leq$$

$$\left(\frac{A}{\frac{\xi}{\alpha(1-\tau_y)}}\right)^{\frac{1}{1-\alpha}} l(m^N) = k^N$$

□

4.10.8 Proof lemma 9

Proof. Equations (4.74) and (4.76) in (4.77) produce:

$$V_t^S(S,t,m^N) = V_t^N(S,t,m^N) \Leftrightarrow \left(\frac{p^S(k)}{p^S(c)}\right)^{-\frac{\alpha}{1-\alpha}} = h(m^N)^{\frac{1}{1+\eta}} l(m^N)^{\frac{\eta}{1+\eta}} \tag{4.132}$$

Applying the Implicit function Theorem we find that exists an increasing function:

$$m^N\left((1+\tau^S)(1+\tau^N)\right) \tag{4.133}$$

that satisfies the above equation.

$$m^N\left((1+\tau^S)(1+\tau^N)\right) \overset{def}{\Leftrightarrow} \left(\frac{p^S(k)}{p^S(c)}\right)^{-\frac{\alpha}{1-\alpha}} = \tag{4.134}$$

$$h\left(m^N((1+\tau^S)(1+\tau^N))\right)^{\frac{1}{1+\eta}} l\left(m^N((1+\tau^S)(1+\tau^N))\right)^{\frac{\eta}{1+\eta}}$$

$$\frac{\partial m^N\left((1+\tau^S)(1+\tau^N)\right)}{\partial\left((1+\tau^S)(1+\tau^N)\right)} =$$

$$-\frac{\frac{\alpha}{1-\alpha}\left(\frac{p^S(k)}{p^S(c)}\right)^{-\frac{\alpha}{1-\alpha}}\frac{\partial\frac{p^S(k)}{p^S(c)}}{\partial((1+\tau^S)(1+\tau^N))}}{h(m^N)^{\frac{1}{1+\eta}}l(m^N)^{\frac{\eta}{1+\eta}}\left[\frac{1}{1+\eta}h'(m^N)+\frac{\eta}{1+\eta}l'(m^N)\right]} > 0 \tag{4.135}$$

To get this result is used lemma 4, equation (4.72) and the fact that $h(.)$ is a decreasing function. □

4.10.9 Proof lemma 12

Proof. First we prove that $h(\theta, s+i) - h(\theta, s)$ is an increasing function of θ. Using the assumption $\frac{\partial^2 h}{\partial\theta\partial t} \geq 0$ and the Taylor Theorem, it follows that:

$$\frac{\partial h(\theta, s+i)}{\partial\theta} = \frac{\partial h(\theta, s)}{\partial\theta} + \frac{\partial h(\theta, \lambda(s+i)+(1-\lambda)s)}{\partial\theta\partial t} i \geq$$

$$\frac{\partial h(\theta, s)}{\partial\theta} \Rightarrow \frac{\partial\left(h(\theta, s+i) - \partial h(\theta, s)\right)}{\partial\theta} = \frac{\partial h(\theta, s+i)}{\partial\theta} - \frac{\partial h(\theta, s)}{\partial\theta} \geq 0$$

Thus, $h(\theta, s+i) - h(\theta, s)$ is an increasing function of θ.

$$\frac{\partial\Psi(r^{at}, m)}{\partial m} = \tag{4.136}$$

$$\frac{\frac{n}{1+n}\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^s\sum_{i=0}^{\infty}\frac{[h(m,s+i)-h(m,s)]}{[1+r^{at}]^i}\Xi\right]}{\Xi^2} -$$

$$-\frac{\frac{n}{1+n}\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^s\sum_{i=0}^{\infty}\frac{\left[\int_0^m[h(\theta,s+i)-h(\theta,s)]d\theta\right]}{[1+r^{at}]^i}\right]}{\left[\frac{n}{1+n}\sum_{s=0}^{\infty}\left(\left(\frac{1}{1+n}\right)^s h(m,s)\right)\right]^{-1}\Xi^2} >$$

$$\frac{\left(\frac{n}{1+n}\right)^2\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^s\sum_{i=0}^{\infty}\frac{\left[\int_0^m[h(\theta,s+i)-h(\theta,s)]d\theta\right]}{[1+r^{at}]^i}\right]}{\Xi^2} -$$

$$-\frac{\left(\frac{n}{1+n}\right)^2\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^s\sum_{i=0}^{\infty}\frac{\left[\int_0^m[h(\theta,s+i)-h(\theta,s)]d\theta\right]}{[1+r^{at}]^i}\right]}{\Xi^2} = 0$$

where

$$\Xi = \left[1 + \frac{n}{1+n}\sum_{s=0}^{\infty}\left(\left(\frac{1}{1+n}\right)^s\int_0^m h(\theta, s)d\theta\right)\right]$$

To obtain this result we have used these two results:
i) $[h(\theta, s{+}i) - h(\theta, s)]$ is an increasing function in θ, which implies that:

$$\begin{aligned}\int_0^m [h(\theta, s{+}i) - h(\theta, s)]\, d\theta &\leq \int_0^m [h(m, s{+}i) - h(m, s)]\, d\theta = \\ [h(m, s{+}i) - h(m, s)]\, m &< [h(m, s{+}i) - h(m, s)]\end{aligned}$$

ii) $\frac{n}{1+n} \sum_{s=0}^{\infty} \left(\left(\frac{1}{1+n}\right)^s h(m, s)\right) \leq \frac{n}{1+n} \sum_{s=0}^{\infty} \left(\left(\frac{1}{1+n}\right)^s 1\right) = 1.$
To finish the proof it is necessary to establish the sign of $\frac{\partial \Psi(r^{at}, m)}{\partial m}$:

$$\frac{\frac{\partial \Psi(r^{at}, m)}{\partial r^{at}}}{\frac{\frac{n}{1+n}}{(1+m)l(m)}} = \tag{4.137}$$

$$-\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^s \sum_{i=1}^{\infty} \frac{\left[\int_0^m [h(\theta, s{+}i) - h(\theta, s)]\, d\theta\right] i}{(1 + r^{at})^i}\right] \frac{r^{at}}{1 + r^{at}} +$$

$$+\sum_{s=0}^{\infty}\left[\left(\frac{1}{1+n}\right)^s \sum_{i=1}^{\infty} \frac{\left[\int_0^m [h(\theta, s{+}i) - h(\theta, s)]\, d\theta\right]}{[1 + r^{at}]^i}\right] =$$

$$-\sum_{s=0}^{\infty}\left(\frac{1}{1+n}\right)^s \frac{r^{at}}{1 + r^{at}} \frac{\left[\sum_{i=1}^{\infty} \frac{\left[\int_0^m [h(\theta,s+i)-h(\theta,s)]d\theta\right]}{[1+r^{at}]^i}\right]}{1 - \frac{1}{1+r^{at}}} -$$

$$-\left[\sum_{s=0}^{\infty}\left(\frac{1}{1+n}\right)^s \frac{r^{at}}{1 + r^{at}}\right]$$

$$\left[\frac{\sum_{i=2}^{\infty} \frac{\left[\int_0^m [h(\theta,s+i)-h(\theta,s)]d\theta - \int_0^m [h(\theta,s+i-1)-h(\theta,s)]d\theta\right](i-1)}{[1+r^{at}]^i}}{1 - \frac{1}{1+r^{at}}}\right] +$$

$$+\sum_{s=0}^{\infty}\left(\frac{1}{1+n}\right)^s \sum_{i=1}^{\infty} \frac{\left[\int_0^m [h(\theta, s{+}i) - h(\theta, s)]\, d\theta\right]}{[1 + r^{at}]^i} <$$

$$-\sum_{s=0}^{\infty}\left(\frac{1}{1+n}\right)^s \sum_{i=1}^{\infty} \frac{\left[\int_0^m [h(\theta, s{+}i) - h(\theta, s)]\, d\theta\right]}{[1 + r^{at}]^i} +$$

$$+\sum_{s=0}^{\infty}\left(\frac{1}{1+n}\right)^s \sum_{i=1}^{\infty} \frac{\left[\int_0^m [h(\theta, s{+}i) - h(\theta, s)]\, d\theta\right]}{[1 + r^{at}]^i} = 0$$

□

4.10.10 Proof lemma 13

Proof. It follows from (4.88), lemma 12 and assumption 2 that $r^{at} < \overline{r}^{at} \equiv \frac{1-\beta}{\beta-\alpha}$. Thus,

$$V_t^N(S, t, m^N) = \tag{4.138}$$

$$ln\left[(1\text{-}\alpha)\left(\frac{A}{\left(\frac{r^{at}(m)}{\alpha}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}}(1\text{-}\tau_y)\left[h_t(m^N,0)\frac{(1+r^{at}(m))}{r^{at}(m)}+\Gamma\right]\right]+$$

$$+\frac{\beta\ln\left(1+r^{at,N}\right)}{1-\beta}+\eta\ln\left(\tau_y\left(\frac{A}{\left(\frac{r^{at}(m)}{\alpha}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}}l(m)\right)$$

$$\frac{\partial V_t^N(S, t, m^N)}{\partial m^N} = \tag{4.139}$$

$$\left[\underbrace{-\frac{1+\alpha\eta}{1\text{-}\alpha}\frac{1}{r^{at}(m)}+\frac{1}{1\text{-}\beta}\frac{1}{1+r^{at}(m)}}_{(-)}\underbrace{\frac{\partial\ln\left[r^{at}(m)^{-\frac{1}{1-\alpha}}\Gamma\right]}{\partial r^{at}(m)}}_{(-)}\right]\underbrace{\frac{\partial r^{at}(m)}{\partial m}}_{(+)}+$$

$$+\underbrace{\sum_{i=0}^{\infty}\frac{\frac{\partial h_{t+i}(m^N,i)}{\partial m}}{\left(1+r^{at}(m)\right)^i}}_{(-)}+\eta\underbrace{\frac{\frac{\partial l(m^N)}{\partial m}}{l(m)}}_{(-)}<0$$

where

$$\Gamma = \sum_{i=0}^{\infty}\frac{h_{t+i}(m^N,i)\text{-}h_t(m^N,0)}{\left(1+r^{at}(m)\right)^i}$$

We have used the result $r < \frac{(1-\beta)}{\beta-\alpha}$ to know that $-\frac{1}{1-\alpha}\frac{1}{r^{at}(m)}+\frac{1}{1-\beta}\frac{1}{1+r^{at}(m)} < 0$. Since $V_t^S(S, t, m^N)$ does not depend on m^N we apply the Implicit Function Theorem to equation (4.94) to define the function $m\left((1+\tau^N)(1+\tau^S)\right)$ such that:

$$m\left((1+\tau^N)(1+\tau^S)\right) \overset{Def}{\Leftrightarrow} V_t^S(S, t, m^N) = V_t^N(S, t, m^N) \tag{4.140}$$

$$\frac{\partial m\left((1+\tau^N)(1+\tau^S)\right)}{\partial\left((1+\tau^N)(1+\tau^S)\right)} = \frac{\frac{\partial V_t^S(S,t,m^N)}{\partial((1+\tau^N)(1+\tau^S))}}{\frac{\partial V_t^S(S,t,m^N)}{\partial m^N}} > 0 \tag{4.141}$$

□

4.10.11 Proof Proposition 15

Proof. $V_t^S(S,t,\theta)$ is exactly as in the case of permanent productivity loss. We already proved that it is a decreasing function of trade barriers (see proof proposition 11). It follows from (4.30), (4.90) and (4.92) that the immigrants' utility is:

$$V_t^S(N,t,\theta) = \tag{4.142}$$

$$\frac{\ln(1\text{-}\beta) + \ln\left[\frac{(1-\tau_y)}{(1-\alpha)^{-1}}\left(\frac{A}{\left(\frac{r^{at}(m)}{\alpha}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}}\right] + \ln\left[\sum_{i=0}^{\infty}\frac{h(\theta,i)}{(1+r^{at}(m^N))^t}\right]}{1\text{-}\beta}$$

$$+\frac{\beta\ln\beta}{(1\text{-}\beta)^2}+\frac{\beta\ln[1+r^{at}]}{(1-\beta)^2}+\frac{\eta\ln\left(\tau_y\left(\frac{A}{\left(\frac{r^{at}(m)}{\alpha}\frac{p(k)}{p(c)}\right)^{\alpha}}\right)^{\frac{1}{1-\alpha}}\right)}{1-\beta}+\frac{\eta\ln l(m)}{1-\beta} =$$

$$\frac{-\frac{\alpha(1+\eta)}{1-\alpha}\ln[r^{at}] + \ln\left[h(\theta,0)\frac{1+r^{at}}{r^{at}} + \sum_{i=0}^{\infty}\frac{h(\theta,i)-h(\theta,0)}{(1+r^{at}(m^N))^t}\right]}{1\text{-}\beta} +$$

$$+\frac{\beta\ln[1+r^{at}]}{(1-\beta)^2}+\frac{\eta\ln l(m)}{1-\beta}+\Delta$$

where Δ is an unimportant constant term.

$$\frac{\partial V_t^S(N,t,\theta)}{\partial r^{at}}(1-\beta) = \tag{4.143}$$

$$-\frac{\alpha(1+\eta)}{1-\alpha}\frac{1}{r^{at}} - \frac{\frac{1}{1+r^{at}}\sum_{i=0}^{\infty}\frac{h(\theta,i)i}{(1+r^{at})^i}}{\sum_{i=0}^{\infty}\frac{h(\theta,i)}{(1+r^{at})^i}} + \frac{\beta}{1\text{-}\beta}\frac{1}{1+r^{at}} =$$

$$-\frac{\frac{1}{1+r^{at}}\frac{1}{1-\frac{1}{1+r^{at}}}\left[\sum_{i=0}^{\infty}\frac{h(\theta,i)}{(1+r^{at}))^i} + \sum_{i=1}^{\infty}\frac{[h(\theta,i)-h(\theta,i-1)](i-1)}{(1+r^{at}))^i}\right]}{\sum_{i=0}^{\infty}\frac{h(\theta,i)}{(1+r^{at})^i}} -$$

$$-\frac{\alpha(1+\eta)}{1-\alpha}\frac{1}{r^{at}} + \frac{1}{1\text{-}\beta}\frac{1}{1+r^{at}} < -\frac{1+\alpha\eta}{1-\alpha}\frac{1}{r^{at}} + \frac{\beta}{1\text{-}\beta}\frac{1}{1+r^{at}} < 0$$

In the last inequality we use assumption 4.7. Then:

$$\frac{\partial V_t^S(N,t,\theta)}{\partial\left((1+\tau^S)(1+\tau^N)\right)} = \tag{4.144}$$

$$\left[\underbrace{\frac{\partial V_t^S(N,t,\theta)}{\partial r^{at}}}_{(-)}\underbrace{\frac{\partial r^{at}}{\partial m}}_{((+))}+\underbrace{\frac{\partial V_t^S(N,t,\theta)}{\partial l(m)}}_{(+)}\underbrace{\frac{\partial l(m)}{\partial m}}_{(-)}\right]\underbrace{\frac{\partial m}{\partial\left((1+\tau^S)(1+\tau^N)\right)}}_{(+)}<0$$

It follows from (4.30), (4.90) and (4.92) that North native household's utility is:

$$V_t^N(N,t,\theta)= \tag{4.145}$$

$$\Gamma+\frac{1}{1-\beta}\left[-\frac{1+\alpha\eta}{1-\alpha}\ln\left[r^{at}\right]+\frac{1}{(1-\beta)}\ln\left[1+r^{at}\right]\right]+\frac{\eta\ln l(m)}{1-\beta}$$

It follows from assumption 4.7 that $\frac{\partial V_t^N(N,t,\theta)}{\partial r^{at}}<0$. Thus:

$$\frac{\partial V_t^N(N,t,\theta)}{\partial\left((1+\tau^S)(1+\tau^N)\right)}= \tag{4.146}$$

$$\left[\underbrace{\frac{\partial V_t^N(N,t,\theta)}{\partial r^{at}}}_{(-)}\underbrace{\frac{\partial r^{at}}{\partial m}}_{(+)}+\underbrace{\frac{\partial V_t^N(N,t,\theta)}{\partial l(m)}}_{(+)}\underbrace{\frac{\partial l(m)}{\partial m}}_{(-)}\right]\underbrace{\frac{\partial m}{\partial\left((1+\tau^S)(1+\tau^N)\right)}}_{(+)}<0$$

□

4.10.12 Figures

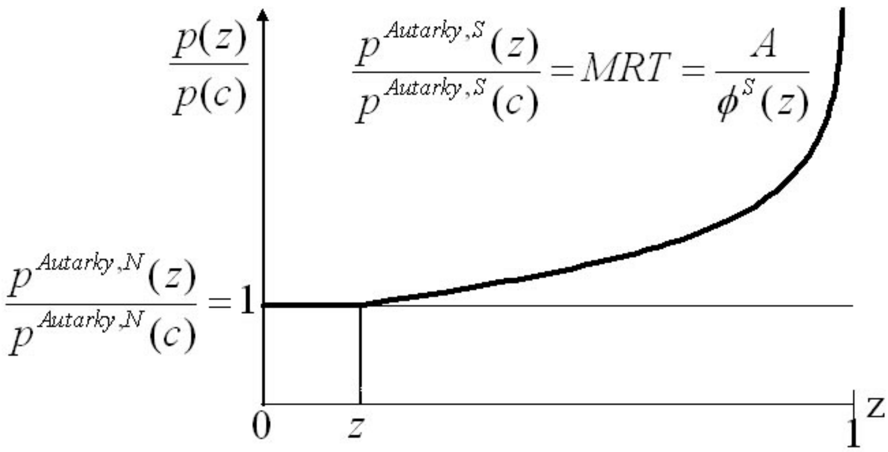

FIGURE 4.1: *Relative price of the capital goods with respect to the consumption good in autarky.*

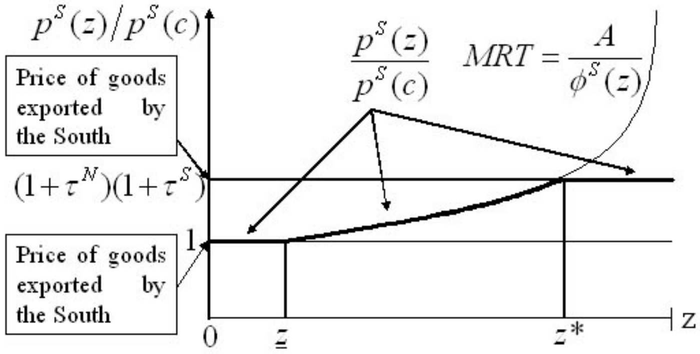

FIGURE 4.2: *Relative price of the capital goods with respect to the consumption good in the South in international trade.*

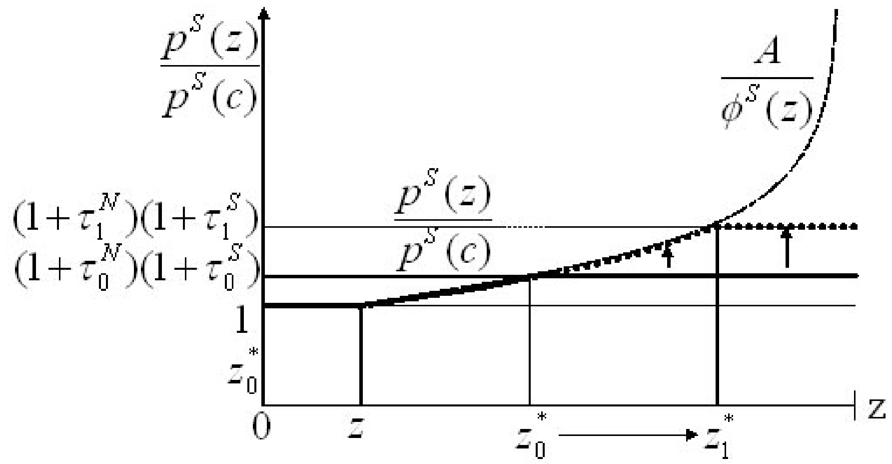

FIGURE 4.3: *The effect of trade barriers on the marginal tradable good z^*.*

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