The Case for International Cooperation in Migration Policies

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Abstract

Unilateral migration policies impose externalities on other countries. In order to try to internalize these externalities, countries sign bilateral migration agreements. One element of these agreements is the emphasis on enforcing migration policies: immigrant-receiving countries agree to allow more immigrants from their emigrant sending partner if they cooperate in enforcing their migration policy at the border. I present a simple theoretical model that justifies this behavior by combining a two country, two-good classical Ricardian model with welfare maximizing governments. These governments establish migration quotas that need to be enforced at a cost, modeled according to Ethier (1986b). I prove that unilateral migration policies are inefficient. Both countries can improve welfare by exchanging a more "generous" migration quota or terms of trade advantages for expenditure on enforcement policy. Contrary to what could be expected, this result does not depend on the enforcement technology that both countries employ. The Ricardian assumption is not crucial either and a generalization of the model is introduced.

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1 Introduction

Why do countries cooperate in establishing migration policies? In particular, why do immigrant-receiving and emigrant-sending countries sign migration agreements?[1] Clearly, these countries could have opposing interests: immigrant-receiving countries could want to restrict immigration, while emigrant-sending countries could want to relieve their excess labor supply as much as possible. In this paper, we show that cooperation among countries with conflicting interests can be Pareto-improving since unilateral migration policies impose externalities on other countries which can be partly internalized by migration agreements despite a priori conflicting interests. This migration externality takes place because the immigrant-receiving country does not take into account the welfare of its emigrant-sending counterpart when deciding about its optimal migration policy. The result is that this optimal migration policy tends to be inefficiently over-restrictive, thus harming the emigrant-sending country's welfare. There is also an externality on the other side: since restricting migration is costly, the emigrant-sending country has no incentives to do so and therefore imposes inefficiently high enforcement costs on the immigrant-receiving country. Bilateral migration agreements allow to internalize this externality: one element of these agreements is the emphasis on enforcing migration policies by which immigrant-receiving countries agree to allow more immigrants from their emigrant-sending partner if they cooperate in enforcing their migration policy at the border and thereby share the costs. I present a simple theoretical model that justifies this behavior by combining a two country, two-good classical Ricardian model with welfare maximizing governments. These governments establish migration quotas that need to be enforced at a cost. The costly enforcement technology is modeled following Ethier (1986b) original paper original paper. I prove that unilateral migration policies are inefficient whereas both countries can improve welfare by exchanging a more "generous" migration quota or terms of trade advantages for expenditure on enforcement policy. Contrary to what could be expected, this result does not depend on the enforcement technology that both countries employ. The Ricardian assumption is not crucial either and a generalization of the model is introduced.

[1] The case for cooperation between immigrant-receiving countries who would unilaterally like to divert undesired immigrant inflows to their neighbors has been studied elsewhere. For example, see Barbou des Places and Deffains (2004) for an application of the Sandler and Hartley (2001) joint product theory to the case of refugee distribution.

The World Trade Organization (WTO) is an institution where countries can get together and negotiate mutually beneficial trade agreements. When countries set their tariffs unilaterally, they hurt other countries because they improve their own terms of trade at the expense of others' terms of trade. This creates a Prisoner's Dilemma where countries would be better off if they all lowered their tariffs but in fact they do not have the incentive to do so unilaterally. In order to remove this inefficiency, international cooperation is required and this is obtained through the WTO.[2] A key element why international cooperation enhances efficiency is the assumption that freer trade increases world output. This paper shows that a similar reasoning can be applied to migration policy. However, an important difference must also be highlighted: whereas the theory of trade agreements is based on the assumption that all participating countries benefit from higher volumes of trade, this paper shows that migration agreements can be signed even when the immigrant-receiving country welfare is decreasing in the magnitude of the migration flow at the same time that the emigrant-sending country welfare is increasing in the magnitude of the migration flow.

Most theoretical models of migration coincide in concluding that the free movement of factors contributes to a better allocation of resources at the world level, even when one abstracts from fairness considerations (Findlay (1982)). In most cases, the upper estimate of these efficiency gains is notably superior to the efficiency gains that can be expected from, for example, free trade. For example, Hamilton and Whalley (1984) crudely estimated (using data from 1977) that the efficiency gains from totally removing immigration controls could get to double world GNP. In a more recent paper, Rodrik (2002) argues that "...liberalizing cross-border labor movements can be expected to yield benefits that are roughly 25 times larger than those that would accrue from the traditional agenda focusing on goods and capital flows[3]!" Why are these immense efficiency gains not obtained through international cooperation? The typical explanation (Hatton (2007)) is that the movement of people has opposing effects on immigrant-receiving and emigrant-sending countries. Immigrant-receiving countries tend to ask for lower migration whereas emigrant-sending countries tend to ask for freer migration, at least in terms of low-skill migrants.

As a result, the economics literature has typically studied migration policies as a unilat-

[2] Bagwell and Staiger (2003) provide a detailed discussion.

[3] A more modest estimate by the World Bank (2006) finds that "a rise in migration from developing countries sufficient to raise the labor force of high-income countries by 3 percent" would yield gains 13 per cent higher than the gains to be obtained from global trade reforms as proposed in the Doha round.

eral phenomenon. For example, Ethier (1986b) and Ethier (1986a) use the crime-theoretic analysis of Becker (1968) to analyze the effects of different policies aimed at reducing illegal immigration. Bond and Chen (1987) extend Ethier's analysis to a two-country model with capital mobility but they do not allow a policy response of the emigrant-sending country to the migration policy of the immigrant-receiving country[4]. The same can be said about Woodland and Yoshida (2006) contribution, who add emigrants risk preferences to the model. Finally, Schiff (2007) analyzes the relative merits of common migration policy options and proposals, such as permanent migration programs, guest-worker programs and Mode IV in the GATS (General Agreement on Tariffs and Services).

On the contrary, Bandyopadhyay and Bandyopadhyay (1998) extension of Bond and Chen (1987) model is more similar to the one in this paper since they consider a policy response of the emigrant sending country. In their case, this policy consists of imposing restrictions on capital inflows and it can render the border enforcement policy of the immigrant-receiving country partly ineffective. Dula, Kahana, and Lecker (2006) also take the policy options of emigrant-sending countries into account. They advance an original proposal to address the migration externality. They claim that immigrant-receiving countries could save in border enforcement by financing relatively more those emigrant-sending governments who would make a bigger effort in avoiding the exit of illegal emigrants from their country, thereby creating competition among emigrant-sending countries for the funds of the immigrant-receiving country. This kind of auction for development aid has not been formally established yet. A third framework that also considers both the emigrant-sending and the immigrant-receiving country policies is proposed by Stark, Casarico, Devillanova, and Uebelmesser (2007). In the presence of a human capital externality in the emigrant-sending country that makes a certain level of emigration welfare improving by generating a brain gain but additional levels welfare inferior by creating a brain drain, they show that there is scope for migration agreements. There is an important difference with my paper since these migration agreements are only beneficial when both countries' welfare levels are decreasing in the

[4]The issue of the relationship between labor and capital mobility and optimal policies to maximize welfare under different scenarios has a longer tradition in the literature. The classical reference in this area is Ramaswami (1968). He used MacDougall (1960) framework to show how allowing for migration and taxing migrants is preferred to exporting and taxing capital in a neoclassical model with two factors of production. Calvo and Wellisz (1983) showed how the institutional restrictions (inability to discriminate labor) were key in Ramaswami (1968) result so that there was no need to import labor in order to obtain the same outcome.

magnitude of the migration flow, that is, when the preferences of both countries are aligned, as Hatton (2007) suggests. In this paper, it will be shown that the scope for migration agreements remains in the absence of human capital externalities and even when one of the countries would favor larger migration flows whereas the other benefits from smaller migration flows.

The public finance literature has also addressed the issue of cooperation in migration policies in the context of regional migration. From this literature, the most relevant result for the purposes of this paper is that of Myers (1990), who shows that, under free migration, decentralized policies are enough to achieve efficiency because countries (regions in his case) internalize the consequences of their policies on their neighbors through their effect on migration flows. The immediate consequence is that the establishment of migration controls may preclude an efficient solution since decentralized policies will then create externalities on other countries (regions). For example, Casella (2005) shows how there are situations in which countries (regions) can individually choose to set migration barriers optimally, thus preventing externalities from being internalized through the effect of other policies (redistribution policies in her model) on migration flows. In those situations, both migratory policies and internal policies must be coordinated in order to achieve efficiency. The difference with my approach is that the source of the externality in Casella (2005) is not the migratory policy itself but the existence of technological spillovers.

As of 2004, there were at least 176 bilateral agreements on migration issues.[5] What is the economic justification behind all of these? One useful starting point to address this question is to incorporate the arguments that are actually given for signing bilateral migration agreements. According to the background paper for the joint IOM/World Bank/WTO Trade and Migration Seminar, IOM/World Bank/WTO (2004), the reasons why migrant-receiving countries sign these agreements are:

- Combatting irregular migration.
- Responding to labor market needs of temporary or permanent nature.
- Promoting economic links with sending countries.

[5] The number refers only to agreements in which at least one OECD member is involved (OECD (2004)).

On the other hand, the reasons why sending states agree to sign these bilateral agreements are:

- Relieving labor surpluses.
- Protecting the rights of their nationals abroad.
- Limiting the effects of brain drain by ensuring the return of their nationals.

The models presented in this paper concentrate on the first point of both set of objectives, that is, the reason for immigrant-receiving countries to sign an agreement will be the will to combat irregular migration. For some reason, they will consider that additional immigration is welfare-reducing. On the contrary, emigrant sending countries will want to relieve their labor market surplus, that is, they will consider that additional emigration is welfare-improving for them.

In the next sections, I start by concentrating on a Ricardian example of the model, which is then generalized in the following section. Some conclusions finish the paper.

2 Ricardian Model with Migration Quotas and Costly Enforcement

2.1 Ricardian Model

Suppose there are two countries (A and B) and two goods (X and Y). Country A is assumed to have a comparative and absolute advantage in the production of X whereas country B is assumed to have an absolute and comparative advantage in the production of good Y (the objective is to ensure complete specialization[6]). Labor requirements follow thus:

$$\begin{aligned} a_{LX}^{A} &< a_{LX}^{B} \\ a_{LY}^{A} &> a_{LY}^{B} \end{aligned}$$

so that the comparative advantage is:

[6] These assumptions will be relaxed in the general model.

$$\frac{a_{LX}^A}{a_{LY}^A} < \frac{a_{LX}^B}{a_{LY}^B}$$

Autarky prices are then:

$$\begin{aligned}
p_a^A &\equiv \frac{P_X^A}{P_Y^A} = \frac{a_{LX}^A}{a_{LY}^A} \\
p_a^B &\equiv \frac{P_X^B}{P_Y^B} = \frac{a_{LX}^B}{a_{LY}^B}
\end{aligned}$$

Consumers' utilities are assumed to be identical in both countries (this is why country superscripts are dropped for a moment) and they are given by the following Cobb-Douglas function:

$$U = X^\alpha Y^{1-\alpha}$$

Consumers maximize utility subject to their budget constraint:

$$P_X X + P_Y Y = M$$

The resulting indirect utility function can be written as:

$$U = M\left(\frac{\alpha}{P_X}\right)^\alpha \left(\frac{1-\alpha}{P_Y}\right)^{1-\alpha} = \alpha^\alpha \left(1-\alpha\right)^{1-\alpha} M' p^{-\alpha}$$

where M is nominal consumer income, $M' \equiv \frac{M}{P_Y}$ and relative prices are defined as $p \equiv \frac{P_X}{P_Y}$.

In autarky, nominal consumer income comes exclusively from wages:

$$M = \frac{P_X}{a_{LX}} = \frac{P_Y}{a_{LY}}$$

If country populations are denoted L^A and L^B respectively, the resulting price if both countries engage in free trade will be:

$$p_{ft} \equiv \frac{\alpha}{1-\alpha}\frac{L^B}{L^A}\frac{a_{LX}^A}{a_{LY}^B}$$

Suppose that there is complete specialization in free trade, that is, country A only produces good X whereas country B only produces good Y. This is equivalent to setting:

$$p_a^A < p_{ft} < p_a^B$$

In addition, it will be assumed that country A citizens attain a higher utility level that country B nationals. The parametric condition that makes this true is:[7]

$$\frac{\alpha}{1-\alpha}\frac{L^B}{L^A} > 1$$

The economic intuition behind this expression is straightforward. Under complete specialization, country A is richer than country as long as the good it specializes in is relatively more liked (the α's determine the demand side) and its production is relatively more scarce (the populations determine the supply capabilities). As a result, there is an incentive for inhabitants of country B to migrate and work in country A as long as migration is costless. If m migrants move to work from country A to country B, the world price will be altered following:

$$p(m) = \frac{\alpha}{1-\alpha}\frac{L^B - m}{L^A + m}\frac{a_{LX}^A}{a_{LY}^B}$$

For completeness, the full definition of $p(m)$ is:

[7]To see this, notice that we can transform the indirect utility function by dividing by $\alpha^\alpha (1-\alpha)^{1-\alpha}$ so that utility can be expressed as:

$$U' = M' p^{-\alpha}$$

Free trade utilities in country A is:

$$\begin{aligned} U_{ft}'^A &= M'^A p_{ft}^{-\alpha} \\ U_{ft}'^B &= M'^B p_{ft}^{-\alpha} \end{aligned}$$

We just need to compare real income levels:

$$M'^A = \frac{p_{ft}}{a_{LX}^A} = \frac{\alpha}{1-\alpha}\frac{L^B}{L^A}\frac{1}{a_{LY}^B} = \frac{\alpha}{1-\alpha}\frac{L^B}{L^A}M'^B$$

It can be seen that $M'^A > M'^B$ if and only if $\frac{\alpha}{1-\alpha}\frac{L^B}{L^A} > 1$.

$$M'^A > M'^B \Leftrightarrow \frac{\alpha}{1-\alpha}\frac{L^B}{L^A} > 1$$

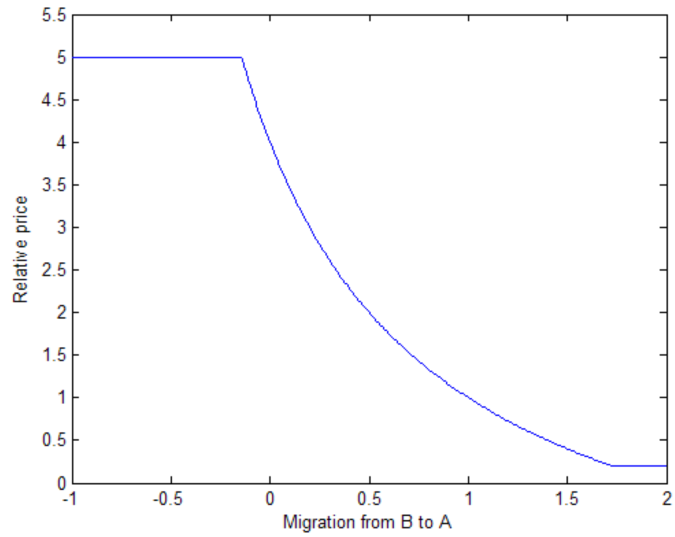

Figure 1: Example of the relative price function

$$p(m) = \left\{ \begin{array}{ll} = p_a^B & \text{if } -L^A \leq m \leq -m^B \\ = \frac{\alpha}{1-\alpha} \frac{L^B - m}{L^A + m} \frac{a_{LX}^A}{a_{LY}^B} & \text{if } -m^B \leq m \leq m^A \\ = p_a^A & \text{if } m^A \leq m \leq L^B \end{array} \right\}$$

The discontinuities arise when one of the countries becomes so big in population terms with respect to the other that it needs to produce again both goods X and Y.[8]

That is, if more than m^B people migrate from A to B, B's autarky price will prevail whereas if more than m^A people migrate from B to A, A's autarky price will prevail. A parametric example of the previous function can be observed in figure 1 with $\alpha = \frac{2}{3}; L^A = 1; L^B = 2; a_{LX}^A = 1; a_{LX}^B = 5; a_{LY}^A = 5$ and $a_{LY}^B = 1$.

There will be migration as long as $M'^A > M'^B$. The migration process is stable since the

[8]The limit points can be calculated as:

$$\begin{aligned} m^B &\equiv -\frac{a_{LX}^A \alpha L^B - a_{LX}^B (1-\alpha) L^A}{a_{LX}^A \alpha + a_{LX}^B (1-\alpha)} \\ m^A &\equiv \frac{a_{LY}^A \alpha L^B - a_{LY}^B (1-\alpha) L^A}{a_{LY}^A \alpha + a_{LY}^B (1-\alpha)} \end{aligned}$$

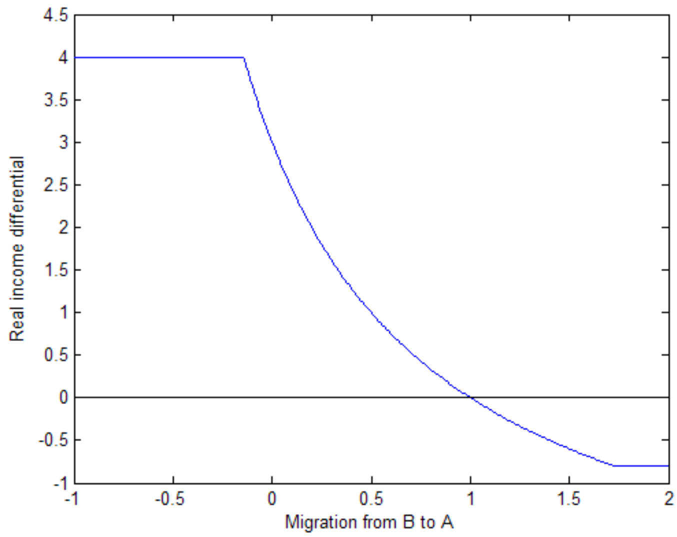

Figure 2: Example of the real income differential function

real income differential $RID(m) \equiv M'^{A} - M'^{B} = \left(\frac{\alpha}{1-\alpha}\frac{L^B - m}{L^A + m} - 1\right)\frac{1}{a_{LY}^B}$ is decreasing in the number of migrants m. The complete characterization of $RID(m)$ is:

$$RID(m) = \left\{ \begin{array}{ll} = \left(\frac{a_{LX}^B}{a_{LX}^A} - 1\right)\frac{1}{a_{LY}^B} & \text{if } -L^A < m \leq -m^B \\ = \left(\frac{\alpha}{1-\alpha}\frac{L^B - m}{L^A + m} - 1\right)\frac{1}{a_{LY}^B} & \text{if } -m^B \leq m \leq m^A \\ = \frac{1}{a_{LY}^A} - \frac{1}{a_{LY}^B} & \text{if } m^A \leq m < L^B \end{array} \right\}$$

Figure 2 shows $RID(m)$ for the previous example.

Migration will only stop when $RID(m^*) = 0$, where m^* is defined as the optimal[9] number of migrants. In this case, m^* can be calculated as:

$$m^* = \alpha L^B - (1-\alpha) L^A > 0$$

The free migration price is:

$$p_{fm} \equiv p(m^*) = \frac{a_{LX}^A}{a_{LY}^B}$$

It is clear that utilities are equalized through free migration. The problem is that the utility level of country A with free trade is reduced under free migration so that country A

[9]Optimal refers to the number of migrants that maximizes world output.

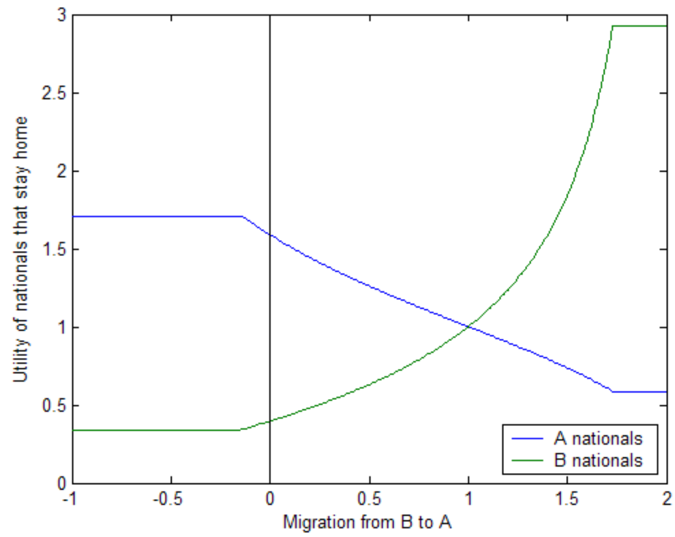

Figure 3: Example of utility of nationals for different migration levels

would have an incentive to restrict the entry of migrants. On the contrary, country B has an incentive to ease emigration since the utility level of its inhabitants is increasing in m. This can be observed in figure 3.

2.2 Migration quotas and Costly Enforcement

Suppose now that both countries can choose their migration policy and do so in order to maximize the utility of their nationals. The most extended form of migration policy we observe in the world is a system of migration quotas. On the other hand, emigrant-producing countries tend to have passive migration policies (at least towards their unskilled labor force) unless they are asked to cooperate by immigrant-receiving countries. A very simple model can capture this incentive for cooperation. Suppose that the only migration policy tool available for countries is to set a migration quota and suppose that this quota cannot be negative. If the migration quota can be costlessly enforced, country A will choose a zero quota and there will be no migration. However, assume that migrants will try to come into the rich country as long as there is a real income level differential and that the entrance of immigrants can only be stopped by spending resources in the enforcement of the migration quota. These resources are collected by imposing a uniform per capita tax on country A's residents. Country B will also be allowed to set a tax that could help enforce country A's migration quota so as to analyze later the possibility of migration agreements.

The government budget constraints will then be:

$$\begin{aligned} E^A &= T^A \left(L^A + m\right) \\ E^B &= T^B \left(L^B - m\right) \end{aligned}$$

where E^i is the nominal expenditure in enforcement of country i whereas T^i is the nominal tax per head in country i used to finance the enforcement expenditure. This can be expressed in Y terms as:

$$\begin{aligned} e^A &= t^A \left(L^A + m\right) \\ e^B &= t^B \left(L^B - m\right) \end{aligned}$$

Clarifying the timing of the model becomes relevant again at this point. First, governments choose migration policies so as to maximize national residents' welfare. The institutional assumption is that migrants cannot be discriminated once they cross the border and receive the same treatment as nationals. The migration policy must be feasible in the sense of respecting the budget constraint stated above. As a result, the enforcement expenditure depends on the expectation over the number of individuals that will move from one country to the other and this expectation is assumed to be correct in equilibrium. The second step is that, given fiscal policies and the expectation over enforcement expenditure, individuals decide where to locate in order to maximize expected utility. Again, these expectations turn out to be correct. Finally, production and consumption take place so that all agents' plans carry out as expected. This formulation might seem artificial but it is required as long as the model is static. Different assumptions about timing do not have any effect on the basic intuition of the model.

The relative price will now depend on the tax and enforcement levels. Using market clearing in the X good, we will have:

$$p\frac{L^A + m}{a^A_{LX}} = \alpha\left(\left(L^A + m\right) M'^A + \left(L^B - m\right) M'^B\right)$$

where $M'^A = \frac{p}{a^A_{LX}} - t^A$ and $M'^B = \frac{1}{a^B_{LY}} - t^B$. Solving for p in the previous equation, the complete schedule $p\left(m; t^A, t^B\right)$ can be written as:

$$p\left(m; t^A, t^B\right) = \left\{ \begin{array}{ll} = p^B_a & \text{if } -L^A < m \leq -m^B \\ = \frac{\alpha}{1-\alpha}\frac{a^A_{LX}}{a^B_{LY}}\frac{L^B - m}{L^A + m} & \text{if } -m^B \leq m \leq m^A \\ -\frac{\alpha}{1-\alpha} a^A_{LX} t^A - \frac{\alpha}{1-\alpha}\frac{L^B - m}{L^A + m} a^A_{LX} t^B & \\ = p^A_a & \text{if } m^A \leq m < L^B \end{array} \right\}$$

The thresholds are now different from the previous section.[10]

The real income differential will now depend on the tax level as well so that migration flows could even be reversed depending on the fiscal policy adopted by both countries:

$RID\left(m; t^A, t^B\right) = \frac{p\left(m; t^A, t^B\right)}{a^A_{LX}} - \frac{1}{a^B_{LY}} - \left(t^A - t^B\right)$

$$RID\left(m; t^A, t^B\right) = \left\{ \begin{array}{ll} = \left(\frac{a^B_{LX}}{a^A_{LX}} - 1\right)\frac{1}{a^B_{LY}} - \left(t^A - t^B\right) & \text{if } -L^A < m \leq -m^B \\ = \left(\frac{\alpha}{1-\alpha}\frac{L^B - m}{L^A + m} - 1\right)\left(\frac{1}{a^B_{LY}} - t^B\right) & \text{if } -m^B \leq m \leq m^A \\ -\frac{1}{1-\alpha} t^A & \\ = \frac{1}{a^A_{LY}} - \frac{1}{a^B_{LY}} - \left(t^A - t^B\right) & \text{if } m^A \leq m < L^B \end{array} \right\}$$

Notice, however, that the real income differential is still a weakly decreasing function in m.

2.2.1 Costly Enforcement

What happens if countries spend resources on enforcing their migration policies? Following Ethier (1986b), define $g(e)$ as the probability of an immigrant being denied entry, where $e = e^A + e^B$ is the joint enforcement effort. As in Ethier (1986b), it is assumed that $g(0) = 0$, $g' > 0$ and $g < 1$. Hanson and Spilimbergo (1999) implicitly test whether

[10] The new thresholds are:

$$m^B\left(t^A, t^B\right) \equiv \frac{L^A\left(p^B_a + \frac{\alpha}{1-\alpha} a^A_{LX} t^A\right) - L^B \frac{\alpha}{1-\alpha} a^A_{LX}\left(\frac{1}{a^B_{LY}} - t^B\right)}{p^B_a + \frac{\alpha}{1-\alpha} a^A_{LX}\left(\frac{1}{a^B_{LY}} + t^A - t^B\right)}$$

$$m^A\left(t^A, t^B\right) \equiv \frac{L^B \frac{\alpha}{1-\alpha} a^A_{LX}\left(\frac{1}{a^B_{LY}} - t^B\right) - L^A\left(p^A_a + \frac{\alpha}{1-\alpha} a^A_{LX} t^A\right)}{p^A_a + \frac{\alpha}{1-\alpha} a^A_{LX}\left(\frac{1}{a^B_{LY}} + t^A - t^B\right)}$$

$g' > 0$ by regressing the number of apprehensions of illegal immigrants at the Mexico-US border on the enforcement effort of the US Border Patrol. They find that an increase in the number of hours patrolling the border in the period 1968-1996 results in an increase in the number of apprehensions, controlling for other variables that affect attempts of entry and also instrumenting for the endogeneity of the enforcement effort. This would translate into $g' > 0$ as long as the the elasticity of migrant attempts with respect to enforcement is negative and the elasticity of the probability of detection with respect to the number of attempts is less than one in absolute value.[11]

Let k be the penalty (wage equivalent in terms of good Y) imposed on an immigrant who is denied entry. Following Ethier (1986b), the penalty k is assumed to be exogenous[12]. Assuming that individuals are risk neutral, the inhabitants of the poor country will equalize the expected return from migration to the return they obtain when staying home. In this case, whenever $M'^A - M'^B > 0$, this will mean:

$$\left(M'^B - k\right) g\left(e\right) + M'^A \left(1 - g\left(e\right)\right) = M'^B$$

As a result, the real income differential is not equated to 0 any more but:

$$M'^A - M'^B = k \frac{g\left(e\right)}{1 - g\left(e\right)} \equiv \kappa\left(e\right)$$

It must be noticed that the effectiveness of the migration policy depends crucially on the values that define the enforcement technology: the functional form of g and the constant k.

Without loss of generality, the case where fiscal policy can overturn migration from the rich to the poor country will be disregarded by assuming that the penalty for migrating into the poor country is very large (some k' tending to infinity, for example). Since $e = e^A + e^B = t^A\left(L^A + m\right) + t^B\left(L^B - m\right) = t^A L^A + t^B L^B + m\left(t^A - t^B\right)$, m can be written as a function of the tax levels. If k is relatively big, migration will always be 0 unless the tax effort is also 0. The condition for m=0 is:

$$RID\left(0; t^A, t^B\right) - \kappa\left(t^A L^A + t^B L^B\right) \leq 0$$

[11]Under the same conditions and given the size of some of their estimates, they claim that, contrary to Ethier's assumption that $g'' < 0$, it could be the case that the elasticity of the probability of detection with respect to border enforcement is increasing in the enforcement effort.

[12]The qualitative conclusions of the model do not change if k is endogenous as long as it is not costless.

Define $MRID\left(m;t^A,t^B\right) \equiv RID\left(m;t^A,t^B\right) - \kappa\left(t^A L^A + t^B L^B + m\left(t^A - t^B\right)\right)$. The above condition can be rewritten in terms of this modified real income differential:

$$MRID\left(0;t^A,t^B\right) \leq 0$$

Suppose $MRID\left(0;t^A,t^B\right) > 0$. Then, there will be migration from B to A. Will the migration process be stable? That will depend on the sign of:

$$\frac{\partial MRID\left(m;t^A,t^B\right)}{\partial m} = \frac{\partial RID\left(m;t^A,t^B\right)}{\partial m} - \kappa'(e)\left(t^A - t^B\right)$$

It is clear that $\frac{\partial RID\left(m;t^A,t^B\right)}{\partial m} \leq 0$ but the sign of $\frac{\partial MRID\left(m;t^A,t^B\right)}{\partial m}$ could be positive for high values of t^B (greater than t^A).

If $\frac{\partial MRID\left(m;t^A,t^B\right)}{\partial m} < 0$, migration will continue until $MRID\left(m;t^A,t^B\right) = 0$ or else until country B will be unpopulated ($m = L^B$). The condition for country B to lose all of its population is:

$$MRID\left(L^B;t^A,t^B\right) > 0$$

If $\frac{\partial MRID\left(m;t^A,t^B\right)}{\partial m} \geq 0$, then the migration process will increase the real income differential and this will also lead to country B becoming unpopulated, for which the above condition will again be satisfied. It can be expected that country B will never set a policy that will cause all of its population to leave.

As a result, the complete specification of $m\left(t^A,t^B\right)$ is the following:

$$m\left(t^A,t^B\right) = \left\{\begin{array}{ll} = 0 & \text{if } MRID\left(0;t^A,t^B\right) \leq 0 \\ = L^B & \text{if } MRID\left(L^B;t^A,t^B\right) > 0 \\ \text{solves } MRID\left(m;t^A,t^B\right) = 0 & \text{otherwise} \end{array}\right\}$$

Notice that the migration policy can be equivalently expressed as a tax level, enforcement expenditure or a migration quota. The three terminologies will be used interchangeably.

2.3 Unilateral Migration Policies

Suppose now that country A wants to maximize the utility of its inhabitants by choosing the appropriate tax level (enforcement level or migration quota given country B policy). The objective function will be:

$$U^A = M'^A p^{-\alpha}$$

where $M'^A = \frac{p\left(m\left(t^A, t^B\right); t^A, t^B\right)}{a^A_{LX}} - t^A$ and $p = p\left(m\left(t^A, t^B\right); t^A, t^B\right)$. The tax level that the government can choose must be positive ($t^A \geq 0$) and inferior to the income level of the inhabitants of the country ($t^A \leq \frac{p\left(m\left(t^A, t^B\right); t^A, t^B\right)}{a^A_{LX}}$). The Lagrangian can be written as:

$$\mathcal{L}^A = U^A + \lambda_1^A t^A + \lambda_2^A M'^A$$

The Kuhn-Tucker conditions are:

$$\begin{aligned}
\frac{\partial \mathcal{L}^A}{\partial t^A} &= \frac{\partial U^A}{\partial t^A} + \lambda_1^A + \lambda_2^A \frac{\partial M'^A}{\partial t^A} = 0 \\
\lambda_1^A t^A &= 0; \qquad \lambda_2^A M'^A = 0 \\
\lambda_1^A &\geq 0; \qquad \lambda_2^A \geq 0 \\
t^A &\geq 0; \qquad M'^A \geq 0
\end{aligned}$$

The same problem can be set up for country B:

$$U^B = M'^B p^{-\alpha}$$

where $M'^B = \frac{1}{a^B_{LY}} - t^B$, subject to $t^B \geq 0$ and $M'^B \geq 0$. The Lagrangian can be written as:

$$\mathcal{L}^B = U^B + \lambda_1^B t^B + \lambda_2^B M'^B$$

The Kuhn-Tucker conditions are:

$$\begin{aligned}
\frac{\partial \mathcal{L}^B}{\partial t^B} &= \frac{\partial U^B}{\partial t^B} + \lambda_1^B + \lambda_2^B \frac{\partial M'^B}{\partial t^B} = 0 \\
\lambda_1^B t^B &= 0; \qquad \lambda_2^B M'^B = 0 \\
\lambda_1^B &\geq 0; \qquad \lambda_2^B \geq 0 \\
t^B &\geq 0; \qquad M'^B \geq 0
\end{aligned}$$

The structure of the problem can be summarized in figure 4.

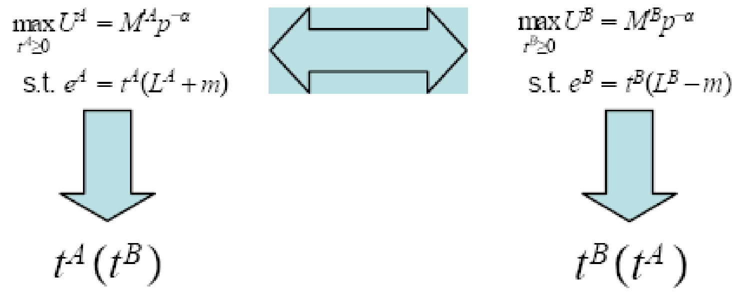

Figure 4: Structure of the problem

2.4 Optimal Migration Policies

Could a central planner improve upon the unilateral solutions described above? To see whether this is the case, the central planner will maximize a weighted sum of individual country residents' utilities (equal weights are assumed for simplicity):

$$\mathcal{L} = \mathcal{L}^A + \mathcal{L}^B$$

The first order conditions in the central planner problem are:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial t^A} &= \frac{\partial \mathcal{L}^A}{\partial t^A} + \frac{\partial \mathcal{L}^B}{\partial t^A} = 0 \\
\frac{\partial \mathcal{L}}{\partial t^B} &= \frac{\partial \mathcal{L}^A}{\partial t^B} + \frac{\partial \mathcal{L}^B}{\partial t^B} = 0
\end{aligned}$$

The rest of conditions are analogous to those in the unilateral problem. Proposition 1 follows from the direct comparison of unilateral migration policies and optimal migration policies.

Proposition 1 *The unilateral Nash solutions do not generally coincide with the optimal solution.*

The proof is shown in the appendix. The intuition is the classical one in an externality problem. Country A's migration policy is too restrictive from the point of view of country B whereas country B's unilateral decision not to spend on enforcement hurts country A. When countries set their migration policies unilaterally, they do not take into account the effect of their policies on other countries and so there is scope for efficiency gains through cooperation.

Once it is shown that the unilateral solutions do not coincide with the optimal solution, the following step is to establish the possibility of cooperation and how this cooperation will look like.

2.5 Unilateral Migration Policies and Scope for Cooperation

The unilateral migration policies in situations in which there is scope for cooperation can be characterized. In general, it could be expected that the best policy country B government can undertake in order to maximize its residents' welfare would be one in which it would not spend any resources on making it difficult for its own inhabitants to leave the country. This would imply a 0 tax on B residents. To see when this is the case, suppose that the equilibrium is of the form $\left(t_N^A > 0, t_N^B = 0\right)$ (where the subscript N will denote Nash policies). Also, suppose that this equilibrium entails a positive migration level $0 < m_N < L^B$ defined by:

$$MRID\left(m_N; t_N^A, 0\right) = 0$$

For this to be an equilibrium, the following conditions must be satisfied:

$$\begin{aligned}
\frac{\partial U^A}{\partial t^A}\left(t_N^A, 0\right) &= 0 \\
\frac{\partial U^B}{\partial t^B}\left(t_N^A, 0\right) + \lambda_{1N}^B &= 0 \\
\lambda_{1N}^B &\geq 0 \\
k &> \frac{\alpha}{1-\alpha}\frac{1}{g'(0)\left(L^A + m^*\right)}
\end{aligned}$$

The need for the last condition is shown in the appendix.

The next step is to prove that cooperation can be welfare improving for both countries. Cooperation will take the form of country A reducing its tax level or enforcement effort in exchange for country B increasing its enforcement effort. This is established in the following proposition.

Proposition 2 *$\exists \left(t_0^A, t_0^B\right)$ close enough to $\left(t_N^A, 0\right)$ with $t_0^A < t_N^A$ and $t_0^B > 0$ such that $U^A\left(t_0^A, t_0^B\right) > U^A\left(t_N^A, 0\right)$ and $U^B\left(t_0^A, t_0^B\right) > U^B\left(t_N^A, 0\right)$*

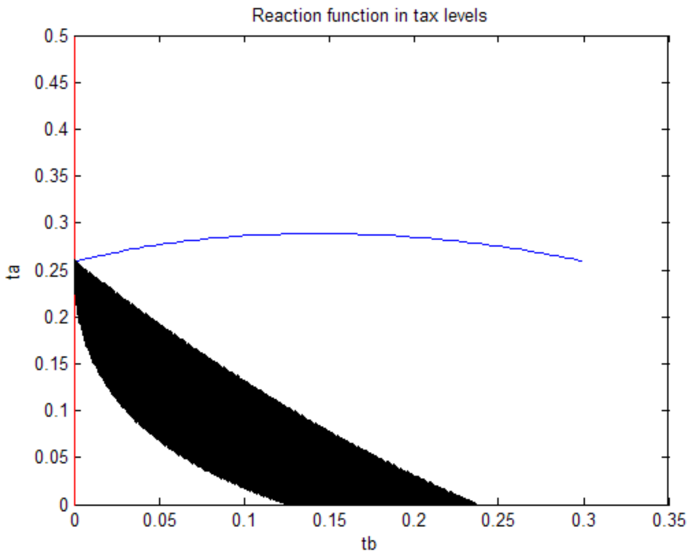

Figure 5: Representation of the reaction functions in tax levels and the scope for cooperation (shaded area)

The proof is shown in the appendix. A graphical representation of the reaction functions and the cooperation area (shadow) can be seen in figure 5, where $k = 1.25$ and $g(e) = \frac{e}{1+e}$.

Country B's advantage in the agreement comes either from an increase in the migration quota or from a direct improvement in its terms of trade with country A resulting from the agreed fiscal policy.

3 Generalization of the Model

The model can be generalized from the simple Ricardian version presented above to accomodate any other two-country model satisfying several conditions that will be discussed below.

Suppose that there are two countries A and B with original populations L^A and L^B as before. The distribution of resources is such that the nationals of country B have an incentive to migrate to country A. In the previous example, the reason was that country A had favorable terms of trade in an environment of free trade. One can also think of a typical specific factors model where country A is relatively labor scarce so that the wage workers can obtain there is higher than in country B.

Governments of both countries maximize the utility of their inhabitants through a welfare function $W^i(t^i, m)$ $(i = A, B)$. This welfare function will depend on two arguments: the tax level required to finance the migratory policy of the government and the number of migrants that the country receives or sends. Three conditions are imposed on this welfare function:

- $\frac{\partial W^i}{\partial t^i} < 0$. A higher tax level in the country directly reduces welfare by itself. Remember that the tax indicated in the function is exclusively used to finance the migratory policy of the government. Further effects of the migratory policy induced by this tax level are not reflected in this partial derivative.

- $\frac{\partial W^i}{\partial t^j} = 0$. The tax level imposed by one country has no direct effect on the welfare of the other country. The only effect of the migratory policy of one country over the other country is channeled through the number of migrants.

- $\frac{\partial W^A}{\partial m} < 0, \frac{\partial W^B}{\partial m} > 0$. An additional immigrant reduces the welfare of the receiving country whereas an additional emigrant increases the welfare (relief of the labor surplus) of the sending country. This is the reason why the receiving country government has an incentive to deter immigrants from entering its country.

However, forbidding the entry of new immigrants into the richer country (A) can only be done at a cost. The migratory policy must be enforced and the enforcement technology is modeled in the same way as in the previous section, following Ethier (1986b).

It will be assumed that the environment is such that a positive migration level exists in equilibrium. If the welfare function maximized by the government is assimilated to the welfare of a representative individual who decides whether to migrate or not, the migration level in equilibrium will be determined by the following equation:

$$W^A(1-g) + \left(W^B - k\right) g = W^B$$

From where,

$$W^A\left(t^A, m\right) - W^B\left(t^B, m\right) - k\frac{g(e)}{1-g(e)} = 0$$

Since $e = t^A L^A + t^B L^B + m\left(t^A - t^B\right)$, the migration equilibrium equation implicitly defines the function $m\left(t^A, t^B\right)$. This migration function gathers all the impact of both countries' policies on the number of migrants. In the Ricardian example described above, the terms of trade effect would also be included in this function. It will be seen later that the function $m\left(t^A, t^B\right)$ is decreasing in both arguments in a neighborhood of the Nash equilibrium.

After this presentation, the same steps developed for the Ricardian model can be followed again. First, it will be shown that the Nash equilibrium resulting from applying unilateral policies is not efficient.

Proposition 3 *The unilateral Nash solutions do not generally coincide with the optimal solution.*

The proof is developed in the appendix. The intuition is the same as before. When setting migration policies unilaterally, countries do not take into account the effect of their policies on other countries' welfare.

The following step is to characterize the unilateral Nash solutions. As it was the case in the Ricardian example, the attention can be confined to the case where the solution is of the form $\left(t_N^A > 0, t_N^B = 0\right)$ and there is a positive level of migration in equilibrium. The conditions for this are:

$$\begin{aligned}
\frac{dW^A}{dt^A}\left(t_N^A, 0\right) &= 0 \\
\frac{dW^B}{dt^B}\left(t_N^A, 0\right) + \lambda_{1N}^B &= 0 \\
\lambda_{1N}^B &\geq 0 \\
k &> \frac{\partial W^A}{\partial t^A}(0,0)\,\frac{\frac{\partial W^B}{\partial m}(0,0)}{\frac{\partial W^A}{\partial m}(0,0)}\,\frac{1}{g'(0)\left(L^A + m^*\right)}
\end{aligned}$$

The need for the last condition is also established in the appendix. The intuition is again the same as before. The poor country has no incentive to unilaterally help to enforce the migration policy of the rich country whereas the rich country has an incentive to limit the entry of immigrants as long as the enforcement technology is effective enough (high k).

However, the rich country can offer more access to its own labor market so that the poor country cooperates in enforcing its migration policy. Both countries can benefit from cooperation as it is established in proposition 4.

Proposition 4 *If the unilateral solution is of the form* $\left(t_N^A > 0, t_N^B = 0\right)$ *and*
$k > -\frac{\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)}{L^B - m\left(t_N^A,0\right)} \frac{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}{g'\left(e\left(t_N^A,0\right)\right)}$, *then*
$\exists \left(t_0^A, t_0^B\right)$ *close enough to* $\left(t_N^A, 0\right)$ *with* $t_0^A < t_N^A$ *and* $t_0^B > 0$ *such that*
$W^A\left(t_0^A, t_0^B\right) > W^A\left(t_N^A, 0\right)$ *and* $W^B\left(t_0^A, t_0^B\right) > W^B\left(t_N^A, 0\right)$

The proof is also shown in the appendix. The additional condition on k is necessary to make the number of migrants decreasing in the tax level of the poor country in a neighborhood of the Nash equilibrium. Increasing the tax level has two effects on the number of migrants. The tax decreases welfare in the emigrant sending country and it thus induces more individuals to migrate. The second effect is the opposite: the tax is used to finance a tighter enforcement of the migratory policy and that reduces migration. If k is big enough, the latter effect will dominate the former in a neighborhood of the equilibrium and there will be incentives for cooperation.

4 Conclusions

Many bilateral agreements have addressed the regulation of migration flows during the past few years (176 such agreements involving OECD members existed in 2004; OECD (2004)). This paper addresses the economic rationale for such agreements. Emigrant-sending countries declare they are willing to sign migration agreements with immigrant-receiving countries in order to relieve their labor surplus. Immigrant-receiving countries, on their part, mainly want to combat irregular migration. In other words, there are migration agreements between countries wanting emigrants to leave and countries not willing to take them in.

The reason that makes these agreements possible is that closing the doors to economic migrants is not free. An immigrant-receiving country can only maintain its income differential with an emigrant-sending country by imposing a cost on those who would otherwise have an incentive to migrate. Enforcement policy accomplishes this goal but it must be financed by the immigrant-receiving country population. Thus, there is a trade-off between letting immigrants in and taxing nationals. Even without decreasing returns to scale in the enforcement technology, the immigrant-receiving country gets to a point where it is preferred to translate part of the enforcement effort to the emigrant-sending country in exchange for accepting more immigrants. From the point of view of the emigrant-sending country, at the margin, there is also a benefit from cooperating in the enforcement of the migration policy of the immigrant-receiving country by taxing its own inhabitants in exchange for a higher number of emigrants leaving their own country.

The decentralized equilibrium does not reach this optimal solution because countries do not internalize the effect of their migratory policies on other countries. When the immigrant-receiving country decides to restrict migration flows unilaterally, it restricts them too much and thus taxes its own citizens too much because it does not take into account how its action hurts the emigrant-sending country. The fact that there are economic gains from migration makes the cooperative solution, in which the overall level of migration is higher, a Pareto improvement.

Bibliography

Bagwell, K., and R. W. Staiger (2003): *The Economics of the World Trading System*. The MIT Press, Cambridge, Massachusetts.

Bandyopadhyay, S., and S. C. Bandyopadhyay (1998): "Illegal Immigration: A Supply Side Analysis," *Journal of Development Economics*, 57(2), 343–360.

Barbou des Places, S., and B. Deffains (2004): "Cooperation in the shadow of regulatory competition: the case of asylum legislation in Europe," *International Review of Law and Economics*, 23, 345–364.

Becker, G. (1968): "Crime and Punishment: An Economic Approach," *Journal of Political Economy*, 76, 169–217.

Bond, E. W., and T.-J. Chen (1987): "The Welfare Effects of Illegal Immigration," *Journal of International Economics*, 23, 315–328.

Calvo, G., and S. Wellisz (1983): "International Factor Mobility and National Advantage," *Journal of International Economics*, 14, 103–114.

Casella, A. (2005): "Redistribution Policy: A European Model," *Journal of Public Economics*, 89(7), 1305–1331.

Dula, G., N. Kahana, and T. Lecker (2006): "How to partly bounce back the struggle against illegal immigration to the source countries," *Journal of Population Economics*, 19, 315–325.

Ethier, W. J. (1986a): "Illegal Immigration," *The American Economic Review*, 76(2), 258–262, Papers and Proceedings of the Ninety-Eight Annual Meeting of the American Economic Association.

——— (1986b): "Illegal Immigration: The Host-Country Problem," *American Economic Review*, 76(1), 56–71.

Findlay, R. E. (1982): "International Distributive Justice. A Trade Theoretic Approach," *Journal of International Economics*, 13, 1–14.

Hamilton, B., and J. Whalley (1984): "Efficiency and distributional implications of global restrictions on labour mobility. Calculations and Policy Implications," *Journal of Development Economics*, 14(1), 61–75.

Hanson, G. H., and A. Spilimbergo (1999): "Illegal Immigration, Border Enforcement, and Relative Wages: Evidence from Apprehensions at the U.S.-Mexico Border," *American Economic Review*, 89(5), 1337–1357.

Hatton, T. J. (2007): "Should We Have a WTO for International Migration?," *Economic Policy*, pp. 339–383.

IOM/World Bank/WTO (2004): "Trade and Migration Seminar Background Paper," Geneva, 4-5 October.

MacDougall, G. (1960): "The Benefits and Costs of Private Investment from Abroad: A Theoretical Approach," *Economic Record*, 36, 13–35.

Myers, G. M. (1990): "Optimality, Free Mobility and the Regional Authority in a Federation," *Journal of Public Economics*, 43, 107–121.

OECD (2004): "Migration for Employment: Bilateral Agreements at a Crossroads," Discussion paper, OECD, Report obtained from www.oecd.org.

Ramaswami, V. (1968): "International Factor Movement and the National Advantage," *Economica*, 35, 309–310.

Rodrik, D. (2002): “Feasible Globalizations,” *NBER Working Paper Series*, 9129.

Sandler, T., and K. Hartley (2001): “Economics of Alliances: The Lessons for Collective Action,” *Journal of Economic Literature*, 39(3), 869–896.

Schiff, M. (2007): “Optimal Immigration Policy: Permanent, Guest-Worker, or Mode IV,” *IZA Discussion Paper Series*, 3083.

Stark, O., A. Casarico, C. Devillanova, and S. Uebelmesser (2007): “International Migration, Human Capital Formation, and the Setting of Migration-Control Policies: Mapping the Gains,” *In The Political Economy of Productive Factors, edited by János Kornai, László Mátyás, and Gérard Roland.*

Woodland, A. D., and C. Yoshida (2006): “Risk Preference, Immigration Policy and Illegal Immigration,” *Journal of Development Economics*, 81, 500–513.

World Bank (2006): *Global Economic Prospects. Economic Implications of Remittances and Migration.* Washington, D.C.

A Proof of proposition 1

The unilateral Nash solutions do not generally coincide with the optimal solution.

Proof. For the central planner solution to coincide with the unilateral Nash solutions, it must be true that:

$$\frac{\partial \mathcal{L}^B}{\partial t^A} = \frac{\partial \mathcal{L}^A}{\partial t^B} = 0$$

Taking the first expression:

$$\frac{\partial \mathcal{L}^B}{\partial t^A} = \frac{\partial U^B}{\partial t^A} = -\alpha M'^B p^{-\alpha-1} \frac{dp}{dt^A}$$

This is 0 either if $\frac{dp}{dt^A} = 0$ or $M'^B = 0$ when we evaluate it at the global solution. If $M'^B = 0$, then $t^B = \frac{1}{a^B_{LY}}$.

As for the second expression:

$$\begin{aligned}
\frac{\partial \mathcal{L}^A}{\partial t^B} &= \frac{\partial U^A}{\partial t^B} + \lambda_2^A \frac{\partial M'^A}{\partial t^B} = \frac{\partial M'^A}{\partial t^B} p^{-\alpha} - \alpha M'^A p^{-\alpha-1} \frac{dp}{dt^B} + \lambda_2^A \frac{\partial M'^A}{\partial t^B} = \\
&= \frac{dp}{dt^B}\left(p^{-\alpha}\left(\frac{1}{a_{LX}^A} - \alpha M'^A p^{-1}\right) + \lambda_2^A\right) = \\
&= \frac{dp}{dt^B}\left(p^{-\alpha}\left(\frac{1-\alpha}{a_{LX}^A} + \alpha \frac{t^A}{p}\right) + \lambda_2^A\right)
\end{aligned}$$

Since $\lambda_2^A \geq 0$ and $p^{-\alpha}\left(\frac{1-\alpha}{a_{LX}^A} + \alpha \frac{t^A}{p}\right) > 0$, $\frac{\partial \mathcal{L}^A}{\partial t^B} = 0$ only if $\frac{dp}{dt^B} = 0$.

Suppose now that the unilateral solutions replicate the optimal solution. Then, it must be the case that, at the solution, either $\frac{dp}{dt^A} = \frac{dp}{dt^B} = 0$ or $\frac{dp}{dt^B} = 0$ and $t^B = \frac{1}{a_{LY}^B}$. The first case can be plugged in the first order condition for country A.:

$\frac{\partial U^A}{\partial t^A} + \lambda_1^A + \lambda_2^A \frac{\partial M'^A}{\partial t^A} = 0$

$p^{-\alpha}\left(\frac{1}{a_{LX}^A}\frac{dp}{dt^A} - 1 - \alpha \frac{M'^A}{p}\frac{dp}{dt^A}\right) + \lambda_1^A + \lambda_2^A\left(\frac{1}{a_{LX}^A}\frac{dp}{dt^A} - 1\right) = 0$

$-p^{-\alpha} + \lambda_1^A - \lambda_2^A = 0$

$\lambda_1^A - \lambda_2^A = p^{-\alpha} > 0 \Rightarrow \lambda_1^A > 0$ since $\lambda_2^A \geq 0$

Since $\lambda_1^A t^A = 0$, this implies $t^A = 0$ must always be the solution for the unilateral problem if this is going to coincide with the global solution.

The same exercise can be repeated for country B's problem:

$\frac{\partial U^B}{\partial t^B} + \lambda_1^B + \lambda_2^B \frac{\partial M'^B}{\partial t^B} = 0$

$p^{-\alpha}\left(-1 - \alpha \frac{M'^B}{p}\frac{dp}{dt^B}\right) + \lambda_1^B - \lambda_2^B = 0$

$-p^{-\alpha} + \lambda_1^B - \lambda_2^B = 0 \Rightarrow \lambda_1^B > 0 \Rightarrow t^B = 0$

This enters in contradiction with the second case where $\frac{dp}{dt^B} = M'^B = 0$ and $t^B = \frac{1}{a_{LY}^B} > 0$. Thus, this second case can be disregarded and the attention can focus in possible cases where $t^A = t^B = 0$ is not a solution to the unilateral problem.

The proof can then be completed by contradiction. Suppose that $t^A = t^B = 0$ is a solution to the unilateral problem. Is it possible that $\frac{dp}{dt^A}(0,0) = 0$ in that case?

$\frac{dp}{dt^A} = \frac{\partial p}{\partial m}\frac{dm}{dt^A} + \frac{\partial p}{\partial t^A} = 0$

Remember the function:

$$m\left(t^A, t^B\right) = \left\{\begin{array}{ll} = 0 & \text{if } MRID\left(0; t^A, t^B\right) \leq 0 \\ = L^B & \text{if } MRID\left(L^B; t^A, t^B\right) > 0 \\ \text{solves } MRID\left(m; t^A, t^B\right) = 0 & \text{otherwise} \end{array}\right\}$$

If we evaluate it at (0,0), we are at the third part where $MRID\left(m;t^A,t^B\right)=0$. We can then calculate $\frac{dm}{dt^A}$ using the implicit function theorem:

$\frac{dm}{dt^A}=-\frac{\frac{\partial RID\left(m;t^A,t^B\right)}{\partial t^A}-k\frac{g'(e)}{(1-g(e))^2}\left(L^A+m\right)}{\frac{\partial RID\left(m;t^A,t^B\right)}{\partial m}-k\frac{g'(e)}{(1-g(e))^2}\left(t^A-t^B\right)}$

where $\frac{\partial RID(m^*;0,0)}{\partial t^A}=-\frac{1}{1-\alpha}<0$ and $\frac{\partial RID(m^*;0,0)}{\partial m}=-\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m^*)^2}M'^B<0$ when $t^A=t^B=0$. If we now evaluate $\frac{dm}{dt^A}$ at this same point, we obtain:

$\frac{dm}{dt^A}(0,0)=-\frac{-\frac{1}{1-\alpha}-kg'(0)\left(L^A+m^*\right)}{-\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m^*)^2}M'^B}=-\frac{\frac{1}{1-\alpha}+kg'(0)\left(L^A+m^*\right)}{\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m^*)^2}M'^B}<0$

As for the price function, since $m(0,0)=m^*$, we will always be in the case where $p\left(m;t^A,t^B\right)=\frac{\alpha}{1-\alpha}\frac{a^A_{LX}}{a^B_{LY}}\frac{L^B-m}{L^A+m}-\frac{\alpha}{1-\alpha}a^A_{LX}t^A-\frac{\alpha}{1-\alpha}\frac{L^B-m}{L^A+m}a^A_{LX}t^B$. Then, the price derivatives can be calculated as:

$\frac{\partial p}{\partial m}=-\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m^*)^2}a^A_{LX}M'^B<0$

$\frac{\partial p}{\partial t^A}=-\frac{\alpha}{1-\alpha}a^A_{LX}<0$

Coming back to the expression $\frac{dp}{dt^A}=\frac{\partial p}{\partial m}\frac{dm}{dt^A}+\frac{\partial p}{\partial t^A}$

$\frac{dp}{dt^A}(0,0)=\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m^*)^2}a^A_{LX}M'^B\frac{\frac{1}{1-\alpha}+kg'(0)\left(L^A+m^*\right)}{\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m^*)^2}M'^B}-\frac{\alpha}{1-\alpha}a^A_{LX}=$

$=a^A_{LX}\left(\frac{1}{1-\alpha}+kg'(0)\left(L^A+m^*\right)\right)-\frac{\alpha}{1-\alpha}a^A_{LX}=$

$=a^A_{LX}\left(1+kg'(0)\left(L^A+m^*\right)\right)>0$ which is a contradiction since we should have $\frac{dp}{dt^A}(0,0)=0$ if the unilateral and optimal solutions were to coincide.

q.e.d. ■

B Condition for $\left(t^A_N>0,t^B_N=0\right)$ to constitute an equilibrium in the Ricardian model

Suppose country B chooses $t^B=0$. What is country A's best response?

$$\begin{aligned}
\frac{\partial\mathcal{L}^A}{\partial t^A} &= \frac{\partial U^A}{\partial t^A}+\lambda^A_1+\lambda^A_2\frac{\partial M'^A}{\partial t^A}=0\\
\lambda^A_1 t^A &= 0; \qquad \lambda^A_2 M'^A=0\\
\lambda^A_1 &\geq 0; \qquad \lambda^A_2\geq 0\\
t^A &\geq 0; \qquad M'^A\geq 0
\end{aligned}$$

Is it $t^A=0$?

$\frac{\partial U^A}{\partial t^A} + \lambda_1^A = 0$
$p^{-\alpha}\left(\frac{dp}{dt^A}\left(\frac{1-\alpha}{a_{LX}^A} + \alpha\frac{t^A}{p}\right) - 1\right) + \lambda_1^A = 0$
$p^{-\alpha}\left(\frac{dp}{dt^A}\frac{1-\alpha}{a_{LX}^A} - 1\right) + \lambda_1^A = 0$
$\lambda_1^A = p^{-\alpha}\left(1 - \frac{dp}{dt^A}\frac{1-\alpha}{a_{LX}^A}\right) \geq 0$
We need $1 - \frac{dp}{dt^A}\frac{1-\alpha}{a_{LX}^A} \geq 0 \Rightarrow \frac{dp}{dt^A}(0,0) \leq \frac{a_{LX}^A}{1-\alpha}$
$\frac{dp}{dt^A} = \frac{\partial p}{\partial m}\frac{dm}{dt^A} + \frac{\partial p}{\partial t^A} =$

$$= \frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m)^2}a_{LX}^A M'^B \frac{\frac{\partial RID\left(m;t^A,t^B\right)}{\partial t^A} - k\frac{g'(e)}{(1-g(e))^2}\left(L^A+m\right)}{\frac{\partial RID\left(m;t^A,t^B\right)}{\partial m} - k\frac{g'(e)}{(1-g(e))^2}\left(t^A-t^B\right)} - \frac{\alpha}{1-\alpha}a_{LX}^A =$$

$$= \frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m)^2}a_{LX}^A M'^B \frac{-\frac{1}{1-\alpha} - k\frac{g'(e)}{(1-g(e))^2}\left(L^A+m\right)}{-\frac{\alpha}{1-\alpha}\frac{L^A+L^B}{(L^A+m)^2}M'^B - k\frac{g'(e)}{(1-g(e))^2}\left(t^A-t^B\right)} - \frac{\alpha}{1-\alpha}a_{LX}^A$$

$\frac{dp}{dt^A}(0,0) = a_{LX}^A\left(\frac{1}{1-\alpha} + kg'(0)\left(L^A+m^*\right)\right) - \frac{\alpha}{1-\alpha}a_{LX}^A =$
$= a_{LX}^A\left(1 + kg'(0)\left(L^A+m^*\right)\right)$
$a_{LX}^A\left(1 + kg'(0)\left(L^A+m^*\right)\right) \leq \frac{a_{LX}^A}{1-\alpha}$
$kg'(0)\left(L^A+m^*\right) \leq \frac{1}{1-\alpha} - 1$
$k \leq \frac{\alpha}{1-\alpha}\frac{1}{g'(0)(L^A+m^*)}$
We need $k > \frac{\alpha}{1-\alpha}\frac{1}{g'(0)(L^A+m^*)}$ for $(0,0)$ not to be a solution.

C Proof of proposition 2

$\exists\left(t_0^A, t_0^B\right)$ *close enough to* $\left(t_N^A, 0\right)$ *with* $t_0^A < t_N^A$ *and* $t_0^B > 0$ *such that*
$U^A\left(t_0^A, t_0^B\right) > U^A\left(t_N^A, 0\right)$ *and* $U^B\left(t_0^A, t_0^B\right) > U^B\left(t_N^A, 0\right)$

Proof. Since it has been proved that $\left(t_N^A, 0\right)$ is not a Pareto optimum, we know that there exists some $\left(t_0^A, t_0^B\right)$ with $U^A\left(t_0^A, t_0^B\right) > U^A\left(t_N^A, 0\right)$ and $U^B\left(t_0^A, t_0^B\right) > U^B\left(t_N^A, 0\right)$. Now, assume to the contrary that $t_0^A \geq t_N^A$. We know that, in a neighborhood of $\left(t_N^A, 0\right)$:

$\frac{\partial U^B}{\partial t^A}\left(t^A, 0\right) = -\alpha M'^B p^{-\alpha-1}\frac{dp}{dt^A}\left(t^A, 0\right) \leq 0$ because $\frac{dp}{dt^A}\left(t^A, 0\right) \geq 0$

This can be established because $\frac{\partial U^A}{\partial t^A}\left(t_N^A, 0\right) = \frac{dp}{dt^A}\left(t_N^A, 0\right)\left(\frac{1-\alpha}{a_{LX}^A} + \alpha\frac{t_N^A}{p\left(t_N^A, 0\right)}\right) - 1 = 0$. Since $\left(\frac{1-\alpha}{a_{LX}^A} + \alpha\frac{t_N^A}{p\left(t_N^A, 0\right)}\right) > 0$, it is required that $\frac{dp}{dt^A}\left(t_N^A, 0\right) > 0$. In a neighborhood of $\left(t_N^A, 0\right)$, $\frac{dp}{dt^A}\left(t^A, 0\right)$ must also be positive.

Then:

$U^B\left(t_0^A, t_0^B\right) \leq U^B\left(t_0^A, 0\right)$ since 0 is country B's best response for any policy country A may undertake in a close neighborhood of $\left(t_N^A, 0\right)$. To see this, consider country B's first order conditions:

$$\begin{aligned}\frac{\partial U^B}{\partial t^B}\left(t_N^A,0\right)+\lambda_{1N}^B &= 0\\ \lambda_{1N}^B &\geq 0\end{aligned}$$

We have then:

$\lambda_{1N}^B=-\frac{\partial U^B}{\partial t^B}\left(t_N^A,0\right)\geq 0\Rightarrow\frac{\partial U^B}{\partial t^B}\left(t_N^A,0\right)\leq 0$

$\frac{\partial U^B}{\partial t^B}\left(t_N^A,0\right)=p\left(t_N^A,0\right)^{-\alpha}\left(-1-\alpha\frac{M'^B}{p\left(t_N^A,0\right)}\frac{dp}{dt^B}\left(t_N^A,0\right)\right)\leq 0$

$-1-\alpha\frac{M'^B}{p\left(t_N^A,0\right)}\frac{dp}{dt^B}\left(t_N^A,0\right)\leq 0$

$\frac{dp}{dt^B}\left(t_N^A,0\right)\geq\frac{a_{LY}^B}{\alpha}p\left(t_N^A,0\right)>0\Rightarrow\frac{\partial U^B}{\partial t^B}\left(t_N^A,0\right)<0\Rightarrow\frac{\partial U^B}{\partial t^B}\left(t^A,t^B\right)\leq 0$ in a neighborhood of $\left(t_N^A,0\right)$.

$U^B\left(t_0^A,t_0^B\right)\leq U^B\left(t_0^A,0\right)\leq U^B\left(t_N^A,0\right)$ since $t_N^A\leq t_0^A$ and $\frac{\partial U^B}{\partial t^A}\left(t^A,0\right)\leq 0$. But this contradicts the initial statement. So: $t_0^A<t_N^A$.

Once this is established, assume again to the contrary that $t_0^B\leq 0$. We have:

$\frac{\partial U^A}{\partial t^B}\left(t_N^A,0\right)=p\left(t_N^A,0\right)^{-\alpha}\frac{dp}{dt^B}\left(t_N^A,0\right)\left(\frac{1}{a_{LX}^A}-\alpha\frac{M'^A}{p\left(t_N^A,0\right)}\right)>0$ because

$\frac{dp}{dt^B}\left(t_N^A,0\right)>0$ and $\frac{1}{a_{LX}^A}-\alpha\frac{M'^A}{p\left(t_N^A,0\right)}=\frac{1-\alpha}{a_{LX}^A}+\frac{t_N^A}{p\left(t_N^A,0\right)}>0$

Then:

$U^A\left(t_0^A,t_0^B\right)\leq U^A\left(t_{BR}^A\left(t_0^B\right),t_0^B\right)$ where $t_{BR}^A\left(t_0^B\right)$ is A's best response function, implicitly defined by $\frac{\partial U^A}{\partial t^A}\left(t_{BR}^A\left(t_0^B\right),t_0^B\right)=0$.

$U^A\left(t_0^A,t_0^B\right)\leq U^A\left(t_{BR}^A\left(t_0^B\right),t_0^B\right)\leq U^A\left(t_{BR}^A(0)=t_N^A,0\right)$ since $t_0^B\leq 0$ (but close enough to 0) and $\frac{\partial U^A}{\partial t^B}\left(t_N^A,0\right)>0$ and continuous in a neighborhood of $\left(t_N^A,0\right)$. But this contradicts the initial statement. So: $t_0^B>0$.

q.e.d. ■

D Proof of proposition 3

The unilateral Nash solutions do not generally coincide with the optimal solution.

Proof. The unilateral solutions are obtained by maximizing the welfare functions of both countries, taking into account the migration equilibrium equation. In the case of country A, the Lagrangian is the following:

$$\mathcal{L}^A = W^A + \lambda_1^A t^A + \lambda_2^A M'^A$$

The Kuhn-Tucker conditions are:

$$\begin{aligned}
\frac{\partial \mathcal{L}^A}{\partial t^A} &= \frac{dW^A}{dt^A} + \lambda_1^A + \lambda_2^A \frac{dM'^A}{dt^A} = 0 \\
\lambda_1^A t^A &= 0; \qquad \lambda_2^A M'^A = 0 \\
\lambda_1^A &\geq 0; \qquad \lambda_2^A \geq 0 \\
t^A &\geq 0; \qquad M'^A \geq 0
\end{aligned}$$

For country B, the Lagrangian and the first order conditions of the unilateral problem are:

$$\mathcal{L}^B = W^B + \lambda_1^B t^B + \lambda_2^B M'^B$$

$$\begin{aligned}
\frac{\partial \mathcal{L}^B}{\partial t^B} &= \frac{dW^B}{dt^B} + \lambda_1^B + \lambda_2^B \frac{dM'^B}{dt^B} = 0 \\
\lambda_1^B t^B &= 0; \qquad \lambda_2^B M'^B = 0 \\
\lambda_1^B &\geq 0; \qquad \lambda_2^B \geq 0 \\
t^B &\geq 0; \qquad M'^B \geq 0
\end{aligned}$$

The Lagrangian for the central planner problem can be written as:

$$\mathcal{L} = \mathcal{L}^A + \mathcal{L}^B$$

The first order conditions in the central planner problem are:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial t^A} &= \frac{\partial \mathcal{L}^A}{\partial t^A} + \frac{\partial \mathcal{L}^B}{\partial t^A} = 0 \\
\frac{\partial \mathcal{L}}{\partial t^B} &= \frac{\partial \mathcal{L}^A}{\partial t^B} + \frac{\partial \mathcal{L}^B}{\partial t^B} = 0
\end{aligned}$$

For the central planner solution to coincide with the unilateral Nash solutions, it must be true that:

$$\frac{\partial \mathcal{L}^B}{\partial t^A} = \frac{\partial \mathcal{L}^A}{\partial t^B} = 0$$

Taking the first expression:

$$\frac{\partial \mathcal{L}^B}{\partial t^A} = \frac{dW^B}{dt^A} = \frac{\partial W^B}{\partial t^A} + \frac{\partial W^B}{\partial m}\frac{dm}{dt^A} + \lambda_2^B \frac{dM'^B}{dt^A}$$

At a solution, it must be true that $M'^B > 0$ so that $\lambda_2^B = 0$. Since $\frac{\partial W^B}{\partial t^A} = 0$ by assumption, the expression can be rewritten as:

$$\frac{\partial \mathcal{L}^B}{\partial t^A} = \frac{\partial W^B}{\partial m}\frac{dm}{dt^A}$$

$\frac{\partial W^B}{\partial m} > 0$ by assumption. As for the other argument:
$\frac{dm}{dt^A} = -\frac{\frac{\partial W^A}{\partial t^A} - \frac{\partial W^B}{\partial t^A} - k\frac{g'(e)}{1-g(e)}\left(L^A+m\right)}{\frac{\partial W^A}{\partial m} - \frac{\partial W^B}{\partial m} - k\frac{g'(e)}{1-g(e)}(t^A-t^B)} = \frac{-\frac{\partial W^A}{\partial t^A} + k\frac{g'(e)}{1-g(e)}\left(L^A+m\right)}{\frac{\partial W^A}{\partial m} - \frac{\partial W^B}{\partial m} - k\frac{g'(e)}{1-g(e)}(t^A-t^B)}$
$\frac{dm}{dt^A}$ is negative as long as $t^A > t^B$. Since this is the case at the solution $\left(t_N^A > 0, t_N^B = 0\right)$ that will be studied later, then it must be true that, at this solution: $\frac{\partial \mathcal{L}^B}{\partial t^A} < 0$, which contradicts the equality to 0 required for this to be an efficient equilibrium.

q.e.d. ■

E Condition for $\left(t_N^A > 0, t_N^B = 0\right)$ to constitute an equilibrium in the generalized model

Suppose country B chooses $t^B = 0$. What is country A's best response?

$$\begin{aligned}
\frac{\partial \mathcal{L}^A}{\partial t^A} &= \frac{dW^A}{dt^A} + \lambda_1^A + \lambda_2^A \frac{dM'^A}{dt^A} = 0 \\
\lambda_1^A t^A &= 0; \qquad \lambda_2^A M'^A = 0 \\
\lambda_1^A &\geq 0; \qquad \lambda_2^A \geq 0 \\
t^A &\geq 0; \qquad M'^A \geq 0
\end{aligned}$$

Is it $t^A = 0$?
$\frac{dW^A}{dt^A} + \lambda_1^A = 0$
$\frac{\partial W^A}{\partial t^A} + \frac{\partial W^A}{\partial m}\frac{dm}{dt^A} + \lambda_1^A = 0$
$\lambda_1^A = -\frac{\partial W^A}{\partial t^A} - \frac{\partial W^A}{\partial m}\frac{dm}{dt^A} \geq 0$

We need $-\frac{\partial W^A}{\partial t^A}(0,0)-\frac{\partial W^A}{\partial m}(0,0)\frac{dm}{dt^A}(0,0)\geq 0$

$\frac{dm}{dt^A}=-\frac{\frac{\partial W^A}{\partial t^A}-\frac{\partial W^B}{\partial t^A}-k\frac{g'(e)}{(1-g(e))^2}\left(L^A+m\right)}{\frac{\partial W^A}{\partial m}-\frac{\partial W^B}{\partial m}-k\frac{g'(e)}{(1-g(e))^2}(t^A-t^B)}=\frac{-\frac{\partial W^A}{\partial t^A}+k\frac{g'(e)}{(1-g(e))^2}\left(L^A+m\right)}{\frac{\partial W^A}{\partial m}-\frac{\partial W^B}{\partial m}-k\frac{g'(e)}{(1-g(e))^2}(t^A-t^B)}$

$\frac{dm}{dt^A}(0,0)=\frac{-\frac{\partial W^A}{\partial t^A}(0,0)+kg'(0)\left(L^A+m^*\right)}{\frac{\partial W^A}{\partial m}(0,0)-\frac{\partial W^B}{\partial m}(0,0)}$

Plugging in this expression:

$-\frac{\partial W^A}{\partial t^A}(0,0)-\frac{\partial W^A}{\partial m}(0,0)\frac{-\frac{\partial W^A}{\partial t^A}(0,0)+kg'(0)\left(L^A+m^*\right)}{\frac{\partial W^A}{\partial m}(0,0)-\frac{\partial W^B}{\partial m}(0,0)}\geq 0$

$$-\frac{\partial W^A}{\partial t^A}(0,0)\left(\frac{\partial W^A}{\partial m}(0,0)-\frac{\partial W^B}{\partial m}(0,0)\right)-$$
$$-\frac{\partial W^A}{\partial m}(0,0)\left(-\frac{\partial W^A}{\partial t^A}(0,0)+kg'(0)\left(L^A+m^*\right)\right)\geq 0$$

$\frac{\partial W^A}{\partial t^A}(0,0)\frac{\partial W^B}{\partial m}(0,0)-kg'(0)\left(L^A+m^*\right)\frac{\partial W^A}{\partial m}(0,0)\geq 0$

$k\leq\frac{\partial W^A}{\partial t^A}(0,0)\frac{\frac{\partial W^B}{\partial m}(0,0)}{\frac{\partial W^A}{\partial m}(0,0)}\frac{1}{g'(0)(L^A+m^*)}$

We need $k>\frac{\partial W^A}{\partial t^A}(0,0)\frac{\frac{\partial W^B}{\partial m}(0,0)}{\frac{\partial W^A}{\partial m}(0,0)}\frac{1}{g'(0)(L^A+m^*)}>0$ for $(0,0)$ not to be a solution.

Now, why is $t^B=0$ country B's best response?

The required conditions are $\frac{dW^B}{dt^B}\left(t_N^A,0\right)+\lambda_{1N}^B=0$ and $\lambda_{1N}^B\geq 0$. Putting them together:

$\lambda_{1N}^B=-\frac{dW^B}{dt^B}\left(t_N^A,0\right)\geq 0$

$\frac{dW^B}{dt^B}\left(t_N^A,0\right)=\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)+\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)\frac{dm}{dt^B}\left(t_N^A,0\right)\leq 0$

$\frac{dm}{dt^B}=-\frac{\frac{\partial W^A}{\partial t^B}-\frac{\partial W^B}{\partial t^B}-k\frac{g'(e)}{(1-g(e))^2}\left(L^B-m\right)}{\frac{\partial W^A}{\partial m}-\frac{\partial W^B}{\partial m}-k\frac{g'(e)}{(1-g(e))^2}(t^A-t^B)}=\frac{\frac{\partial W^B}{\partial t^B}+k\frac{g'(e)}{(1-g(e))^2}\left(L^B-m\right)}{\frac{\partial W^A}{\partial m}-\frac{\partial W^B}{\partial m}-k\frac{g'(e)}{(1-g(e))^2}(t^A-t^B)}$

$$\frac{dm}{dt^B}\left(t_N^A,0\right)=\frac{\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)+k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}\left(L^B-m\left(t_N^A,0\right)\right)}{\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)-\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)-k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}t_N^A}$$

$$\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)+\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)\frac{\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)+k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}\left(L^B-m\left(t_N^A,0\right)\right)}{\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)-\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)-k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}t_N^A}\leq 0$$

Dividing by the negative quantity

$\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)-\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)-k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}t_N^A<0.$

$$\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)\left(\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)-\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)-k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}t_N^A\right)+$$
$$+\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)\left(\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)+k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}\left(L^B-m\left(t_N^A,0\right)\right)\right)\geq 0$$

$$\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)\left(\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)-k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}t_N^A\right)+$$
$$+k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}\left(L^B-m\left(t_N^A,0\right)\right)\frac{\partial W^B}{\partial m}\left(t_N^A,0\right)>0$$

which is the required condition because it implies $\frac{dW^B}{dt^B}\left(t_N^A,0\right)<0$.

F Proof of proposition 4

If the unilateral solution is of the form $\left(t_N^A>0,t_N^B=0\right)$ *and*

$k>-\frac{\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)}{L^B-m\left(t_N^A,0\right)}\frac{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}{g'\left(e\left(t_N^A,0\right)\right)}$

then $\exists\left(t_0^A,t_0^B\right)$ *close enough to* $\left(t_N^A,0\right)$ *with* $t_0^A<t_N^A$ *and* $t_0^B>0$ *such that* $W^A\left(t_0^A,t_0^B\right)>W^A\left(t_N^A,0\right)$ *and* $W^B\left(t_0^A,t_0^B\right)>W^B\left(t_N^A,0\right)$.

Proof. Since it has been proved that $\left(t_N^A,0\right)$ is not a Pareto optimum, we know that there exists some $\left(t_0^A,t_0^B\right)$ with $W^A\left(t_0^A,t_0^B\right)>W^A\left(t_N^A,0\right)$ and $W^B\left(t_0^A,t_0^B\right)>W^B\left(t_N^A,0\right)$. Now, assume to the contrary that $t_0^A\geq t_N^A$. We know that, in a neighborhood of $\left(t_N^A,0\right)$:

$\frac{dW^B}{dt^A}\left(t^A,0\right)=\frac{\partial W^B}{\partial m}\left(t^A,0\right)\frac{dm}{dt^A}\left(t^A,0\right)<0$ because

$\frac{\partial W^B}{\partial m}\left(t^A,0\right)>0$ and $\frac{dm}{dt^A}\left(t^A,0\right)=\frac{-\frac{\partial W^A}{\partial t^A}+k\frac{g'(e)}{(1-g(e))^2}\left(L^A+m\right)}{\frac{\partial W^A}{\partial m}-\frac{\partial W^B}{\partial m}-k\frac{g'(e)}{(1-g(e))^2}t^A}<0$

Then:

$W^B\left(t_0^A,t_0^B\right)\leq W^B\left(t_0^A,0\right)$ since 0 is country B's best response for any policy country A may undertake in a neighborhood of $\left(t_N^A,0\right)$. It was shown at the end of the last section that $\frac{dW^B}{dt^B}\left(t_N^A,0\right)<0\Rightarrow\frac{dW^B}{dt^B}\left(t^A,t^B\right)\leq 0$ in a neighborhood of $\left(t_N^A,0\right)$.

$W^B\left(t_0^A,t_0^B\right)\leq W^B\left(t_0^A,0\right)\leq W^B\left(t_N^A,0\right)$ since $t_N^A\leq t_0^A$ and $\frac{dW^B}{dt^B}\left(t^A,0\right)\leq 0$. But this contradicts the initial statement. So: $t_0^A<t_N^A$.

Once this is established, assume again to the contrary that $t_0^B\leq 0$. We have:

$\frac{dW^A}{dt^B}\left(t_N^A,0\right)=\frac{\partial W^A}{\partial t^B}\left(t_N^A,0\right)+\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)\frac{dm}{dt^B}\left(t_N^A,0\right)=$

$=\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)\frac{dm}{dt^B}\left(t_N^A,0\right)>0$ because $\frac{\partial W^A}{\partial t^B}\left(t_N^A,0\right)=0$ and

$\frac{\partial W^A}{\partial m}\left(t_N^A,0\right)<0$ by assumption. As for the other term, $\frac{dm}{dt^B}\left(t_N^A,0\right)<0$ whenever

$\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)+k\frac{g'\left(e\left(t_N^A,0\right)\right)}{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}\left(L^B-m\left(t_N^A,0\right)\right)>0$

That is:

$k>-\frac{\frac{\partial W^B}{\partial t^B}\left(t_N^A,0\right)}{L^B-m\left(t_N^A,0\right)}\frac{\left(1-g\left(e\left(t_N^A,0\right)\right)\right)^2}{g'\left(e\left(t_N^A,0\right)\right)}>0$

which the established additional condition.

Then:

$W^A\left(t_0^A,t_0^B\right)\leq W^A\left(t_{BR}^A\left(t_0^B\right),t_0^B\right)$ where $t_{BR}^A\left(t_0^B\right)$ is A's best response function, implicitly defined by $\frac{dW^A}{dt^A}\left(t_{BR}^A\left(t_0^B\right),t_0^B\right)=0$.

$W^A\left(t_0^A,t_0^B\right)\leq W^A\left(t_{BR}^A\left(t_0^B\right),t_0^B\right)\leq W^A\left(t_{BR}^A(0)=t_N^A,0\right)$ since $t_0^B\leq 0$ (but close enough to 0) and $\frac{dW^A}{dt^B}\left(t_N^A, 0\right) > 0$ and continuous in a neighborhood of $\left(t_N^A, 0\right)$. But this contradicts the initial statement. So: $t_0^B > 0$.

q.e.d. ■