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Monetary union enlargement and international trade*

Resumo: Este artigo estuda os efeitos da ampliação da união monetária sobre o comércio internacional num modelo monetário de procura com três países (dois países instalados na união e um país em acesso). É mostrado que com a ampliação da união monetária se espera um aumento no comércio internacional e desta maneira uma melhoria no sentido de Pareto; mas também poderia provocar uma redução do comércio se a quantidade de moeda emitida é muito grande e o grau de integração entre os países instalados é muito grande relativo ao grau de integração com o país em acesso.

Palavras-chave: Procura de equilíbrio, diversificação de comércio, criação de comércio, ampliação da união monetária.

Abstract: This paper studies the effects of monetary union enlargement on international trade in a three-country (two incumbent countries and an acceding country) search monetary model. It is shown that, the enlargement of a monetary union is expected to increase international trade and thus be Pareto improving, but may result in trade reduction if too much money is issued, and the degree of integration between the ICs is too high relative to integration with the AC.

Keywords: search equilibrium, trade diversion, trade creation, monetary union.
JEL Classification numbers: C78, F33, R13.

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1 Introduction

Several Eastern European Countries (EECs) are contemplating the option of joining the European Monetary Union (EMU) in the next few years. Should they become part of the Euro area, they will likely be enjoying an increase in the volume of bilateral trade with actual EMU member states. Still, it is unclear whether also actual EMU members will experience a global trade creation effect from new EMU accessions.

The relationship between international trade and currency unions has been extensively studied in the literature. From a theoretical point of view, trade creation effects have been prominently analyzed in customs unions rather than in currency union models (e.g., [11] and [12]). Empirical analyses as in [1] and [2], for example, have estimated the effects of countries sharing the same currency on bilateral trade.

By developing a two-currency, three-country (two incumbent countries, ICs, and an acceding country, AC) extension of the search equilibrium framework of [8], this paper characterizes the aggregate level of international trade among monetary union participants, and gives conditions for expected global trade increase to occur as a consequence of new countries accessing a monetary union. The accession of a new member state increases the equilibrium fraction of buyers within the whole monetary union, and may result in expected global trade reduction if too much money is issued, unless the degree of integration between the ICs is not too high relative to integration between each IC and the AC. In this latter case, enlargement of the monetary union increases expected international trade and is Pareto improving. Moreover, a high level of economywide (i.e., throughout the ICs and the AC jointly) money supply reduces expected trade when the induced equilibrium fraction of buyers is too large relative to the ratio between the chance of a resident meeting a foreigner and the chance of a resident meeting another resident. This results in fewer chances of trade occurring.

The paper is organized as follows. Section 1 describes the model. Section 2 evaluates the expected trade creation effect from monetary union enlargement by comparing pre-accession and post-accession equilibria. Section 3 ends the paper with a brief summary of results.

2 The model

The present model is a straightforward three-country (two ICs and an AC) extension of [8]. Both the ICs, $i \in \{1, 2\}$, and the AC country, $i = 3$, are populated by a *continuum* of infinitely lived agents. Total population across countries has unit mass $\sum_{i=1}^{3} n_i = 1$, where n_i denotes the fraction of agents living in country i. Time is indexed by $t = 1, 2, \ldots, \infty$ Individuals are specialized in production, consumption and storage of goods that are indivisible. Specialization in consumption is denoted by the index k, in the sense that each type k agent can only consume the good k. The same agent type only produces the good $k + 1$ (modulo k, where k is the number of different goods), at no cost, so that the act of consuming necessarily involves a transaction between agents. Moreover, the distribution of agents is uniform across $k \geq 3$ types. This specification rules out "double coincidence of wants" so that barter equilibria are not feasible.

There are two fiat monies that are associated with the ICs (type 1 money) and the AC (type 2 money) countries. Monies are indivisible so that this model is inappropriate in studying the dispersion of money holding across agents ([3]). Nonetheless, it is possible to analyze changes in the equilibrium fraction of moneyholders across countries, and assess the consequences on the expected volumes of trade among countries.

At time $t = 1$, the monetary authority of the ICs countries issues one unit of money 1 to a fraction $m_1 \in (0, 1)$ of the population in the ICs countries, and the government of the AC issues one unit of money 2 to a fraction $m_2 \in (0, 1)$ of its citizens. The fraction of population in country i endowed with a unit of money j is denoted by $m_{ij} \in (0, 1)$. Monies have no intrinsic value and are used for the only purpose of buying goods.

With $u > 0$ denoting the agent's instantaneous utility from consumption of her own consumption good, and r denoting a strictly positive discount rate, the value function at time t, expected on the information set at time t, can be written as

$$V_t = E\left[\sum_{s=0}^{\infty} \frac{u}{(1+r)^s} I_{t+s} \mid \Omega_t\right].$$

I_{t+s} is a random indicator function that either equals 1, in the event of consumption occurring at time $t + s$, or zero otherwise.

When an agent acquires her consumption good, she will immediately consume it, and instantaneously produce one unit of her production good. A seller, i.e. an agent endowed with a unit of production good, looks for a buyer, i.e. an agent endowed with a unit of money, to trade with. Individuals meet pairwise and randomly. When two agents meet, an exchange takes place only if both agents are strictly better off. Both monies and goods are indivisible. Also, it is assumed that each agent either holds one unit of money or one unit of production good at every instant of time, and monetary exchange is one-for-one. As in [8], the simplifying assumption that no agent disposes of either money or production good holds.

The term β_{ij} indicates the frequency of an agent from country i meeting an agent from country j, relative to the frequency of two nationals meeting (it is simply assumed that the chances of nationals meeting are equal across countries). For example, if an agent from country 1 meets an agent from country 2 with the same frequency that she meets a national, then $\beta_{12} = 1$, and the two economies are said to be perfectly integrated. Conversely, if a meeting between national fellows occurs at a frequency higher than a meeting between foreigners, then the countries are imperfectly integrated, i.e. $\beta_{ij} \in (0, 1)$.

The inventory distribution of agents can be summarized by the vector $M_i \equiv (1 - m_{i1} - m_{i2}, m_{i1}, m_{i2})$, where $(m_{i1} + m_{i2})$ is the proportion of buyers and $(1 - m_{i1} - m_{i2})$ is the proportion of sellers in country i. Hence, total supply of money 1 and money 2 amounts to $(n_1 + n_2)m_1 = n_1 m_{11} + n_2 m_{21} + n_3 m_{31}$ and $n_3 m_2 = n_1 m_{12} + n_2 m_{22} + n_3 m_{32}$, respectively.

Agents choose strategies that maximize the expected utility given both other individuals' strategies and inventory distributions. The analysis focuses only on pure strategy equilibria. The game is anonymous in the sense that the probability of a double meeting with the same agent is zero. The trade strategy of an individual living in country i about exchanging object x for object y is denoted by $\tau_{i,xy} \in \{0, 1\}$ for $x, y \in (0, 1, 2)$ where 0 indicates the production good, 1 the type-1 money, and 2 the type-2 money. If the individual agrees to exchange the object x for the object y then $\tau_{i,xy} = 1$, otherwise it is zero. In steady state, the strategies and the proportion of agents endowed with a given object, $m_{i,j}$ and $1 - m_{i,1} - m_{i,2}$, are constant in each country.

The transition matrix related to country i is

$$\Pi_i \equiv \begin{bmatrix} 1-\pi_{i,01}-\pi_{i,02} & \pi_{i,01} & \pi_{i,02} \\ \pi_{i,10} & 1-\pi_{i,10}-\pi_{i,12} & \pi_{i,12} \\ \pi_{i,20} & \pi_{i,21} & 1-\pi_{i,20}-\pi_{i,21} \end{bmatrix}$$

where $\pi_{i,xy}$ is the chance of an individual (from country i) trading object x for object y with some other agent (either from country 1, country 2 or country 3, and holding the object y.) As an example, the probability of an agent from country 1 exchanging a unit of money 1 for a unit of the consumption good, $\pi_{1,10}$, is equal to the sum of *a)* the probability of meeting a national agent that holds the consumption good (conditional on the probability of both agreeing on trading) plus *b)* the probability of meeting an agent from either country 2 or country 3 that holds a unit of consumption good (conditional on the probability of that agent agreeing on trade.)

The value functions of an agent living in country i are

$$\begin{aligned} V_{i,0} &= \frac{1}{1+r}[\pi_{i,01}V_{i,1} + \pi_{i,02}V_{i,2} + V_{i,0}(1-\pi_{i,02}-\pi_{i,01})], \\ V_{i,1} &= \frac{1}{1+r}(\pi_{i,10}u) + \frac{1}{1+r}[\pi_{i,10}V_{i,0} + \pi_{i,12}V_{i,2} + V_{i,1}(1-\pi_{i,12}-\pi_{i,10})], \quad (1) \\ V_{i,2} &= \frac{1}{1+r}(\pi_{i,20}u) + \frac{1}{1+r}[\pi_{i,20}V_{i,0} + \pi_{i,21}V_{i,1} + V_{i,2}(1-\pi_{i,21}-\pi_{i,20})], \end{aligned}$$

when she either holds the production good, money 1 or money 2, respectively. For example, the (indirect) utility from holding one unit of production good at time t, $V_{i,0}$, is equal to the probability of exchanging the production good for money 1 in the next period times the utility from holding a unit of money 1, $\pi_{i,01}V_{i,1}$, plus the probability of exchanging a unit of production good for a unit of money 2 in the next period, times the utility from holding money 2, $\pi_{i,02}V_{i,2}$, plus the probability of no exchange occurring in the next period, times the utility from holding the production good, $(1 - \pi_{i,02} - \pi_{i,01})V_{i,0}$, each term discounted by the factor $1 / (1 + r)$.

An agent exchanges with another agent only if she is strictly better off, i.e. (*i*) $\tau_{i,0x} = 1 \Leftrightarrow V_{i,0} < V_{i,x}$ for any $x = 1, 2$; (*ii*) $\tau_{i,x0} = 1 \Leftrightarrow V_{i,x} < V_{i,0} + u$ for any $x = 1, 2$; (*iii*) $\tau_{i,xy} = 1 \Leftrightarrow V_{i,x} <$

$V_{i,y}$ such that $x \neq y$ and $x, y \neq 0$. The production process always yields positive utility if the production good can be exchanged at least with one type of money, i.e., max $\{V_{i,1}, V_{i,2}\} > V_{i,0} > 0$. $V_{i,0} \geq 0$ follows from the zero production and storage costs assumptions.

The following assumptions hold throughout the paper

(A1) $n_i = 1/3$ for any $i \in \{1, 2, 3\}$;

(A2) $2m_1 = m_2 = m \in (0, 1)$;

(A3) $\beta_{1,3} = \beta_{2,3} = \beta_3$;

(A4) $V_{i,1}, V_{i,2} < V_{i,0} + u$ for any $i \in \{1, 2, 3\}$;

(A5) every agent of type k can costlessly store up to one unit of good $k + 1$, without being able of storing any other type of goods.

(*A1*) and (*A2*) restrict the analysis to the simplest case in which countries have symmetric population and money supply. By (*A3*), both countries 1 and 2 share the same degree of integration with country 3. These assumptions enable to focus the analysis on international trade when a new country joins a monetary union. By (*A4*), the utility, $V_{i,0}$, from holding one unit of production good plus the utility, u, from consumption is greater than the utility, $V_{i,1}$ and $V_{i,2}$, from holding a unit of money. Hence, it is always profitable for an individual endowed with a unit of money to acquire the consumption good, so that exchanging a unit of money for a unit of his/her consumption good is a dominant strategy for a money-holder. As a consequence of (*A4*) and (*A5*) jointly, only monetary exchanges take place, which enables to focus the analysis on the role of monetary union enlargement in providing increased chances for trade to occur.

The expected level of imports of country i from country j, denoted as $T_{i,j}$, is obtained by multiplying the proportion of moneyholders living in country i, at the beginning of the period, times the probability of a moneyholder in country i meeting an agent from country j holding her consumption. For $i = j$, one gets the expected level of transactions among agents of the same country i (*domestic trade*).

By (*A1*) and (*A2*), it holds that

$$m = \sum_{i=1}^{3} m_{i,j}, \tag{2}$$

where i denotes the country, and j the money type.

3 Expected trade creation effects

This section characterizes steady state equilibria, before and after an additional country acceding the monetary union. Pre-accession equilibria are characterized by the fact that both money 1 is the unique money circulating inside the monetary union and money 1 is not circulating inside the AC. In the accession equilibrium both currencies are perfect substitutes throughout the enlarged monetary union.

3.1 Pre-accession equilibrium

In the steady state pre-accession equilibrium it holds that $m = m_{1,1} + m_{1,2}$, $m = m_{3,2}$, $m_{1,2} = m_{3,1} = m_{2,2} = 0$, and $\tau_{1,02} = \tau_{2,02} = \tau_{3,01}$. Hence, the related transition probabilities are (see appendix)

$$\begin{aligned}
&\pi_{1,02} = \pi_{2,02} = \pi_{3,01} = 0, \quad \pi_{1,01} = \pi_{2,01} = \frac{m(1+\beta_{1,2})}{6K}, \\
&\pi_{3,10} = \frac{\beta_3(2-m)}{3K}, \quad \pi_{1,10} = \pi_{2,10} = \frac{(2-m)(1+\beta_{1,2})}{6K}, \\
&\pi_{3,20} = \frac{(1-m)}{3K}, \quad \pi_{1,20} = \pi_{2,20} = \beta_3\frac{(1-m)}{3K}, \\
&\pi_{3,02} = \frac{m}{3K}.
\end{aligned} \tag{3}$$

The markovian steady state property $\mathbf{M}_i\mathbf{\Pi}_i = \mathbf{M}_i$ implies that $m_{1,1} = m_{2,1} = m / 2$. The sufficient conditions for the existence of the pre-accession equilibrium are

$$\begin{aligned}
V_{1,2} &< V_{1,0} \\
V_{2,2} &< V_{2,0} \\
V_{3,1} &< V_{3,0}
\end{aligned} \tag{4}$$

which turn out to be satisfied if and only if both of the following inequalities

$$\beta_3 < \frac{m(2-m)\left(1+\beta_{1,2}\right)^2}{3(1-m)\left[6Kr + 2\left(1+\beta_{1,2}\right)\right]}, \tag{5}$$

$$\beta_3 < \frac{m(1-m)}{(2-m)[3Kr+1]}, \tag{5'}$$

hold. Using (3), the *trade-flow matrix* can be written as

$$T^P \equiv \begin{bmatrix} \frac{m(2-m)}{36K} & \frac{\beta_{1,2}m(2-m)}{36K} & 0 \\ \frac{\beta_{1,2}m(2-m)}{36K} & \frac{m(2-m)}{36K} & 0 \\ 0 & 0 & \frac{4m(1-m)}{36K} \end{bmatrix} \tag{6}$$

This matrix is symmetric, because of equal population size and money supply across countries. The i-th element on the principal diagonal is the level of domestic trade in country i. As shown in (6), the expected volumes of international trade between country 3 and countries 1 and 2, denoted as $T^P_{3,1} + T^P_{1,3}$ and $T^P_{3,2} + T^P_{2,3}$ respectively, are zero in the pre-accession equilibrium. The reason for this being that any transaction involving agents from either both countries 1 or 2, on one hand, and country 3, on the other hand, cannot occur since a country 3 agent is not willing to accept money 1 and a resident either in country 1 or in country 2 does not accept money 2 in transactions.

3.2 Accession equilibrium

In the accession equilibrium, the buyers' value function is the same regardless of the type of money held. This implies that monies 1 and 2 are perfect substitutes.

In steady state, it holds that, $m_{1,1} = m_{1,2} = m_{2,1} = m_{2,2} = m_{3,1} = m_{3,2}$, and the transition probabilities are

$$\begin{aligned} \pi_{1,01} &= \pi_{2,01} = \pi_{1,02} = \pi_{2,02} = \frac{(1+\beta_{1,2}+\beta_3)m}{9K}, \\ \pi_{1,10} &= \pi_{1,20} = \pi_{2,10} = \pi_{2,20} = \frac{(3-2m)(1+\beta_{1,2}+\beta_3)}{9K}, \\ \pi_{3,01} &= \pi_{3,02} = \frac{(1+2\beta_3)m}{9K}, \\ \pi_{3,10} &= \pi_{3,20} = \frac{(3-2m)(1+2\beta_3)}{9K}, \end{aligned} \quad (7)$$

as shown in the appendix. Therefore, in steady state, the following holds

$$m_{i,j} = \frac{m}{3}, i = 1, 2, 3, \ j = 1, 2$$

with i and j denoting country and money types, respectively. The associated trade-flow matrix is

$$T^A \equiv \begin{bmatrix} \frac{2m(3-2m)}{81K} & \frac{2\beta_{1,2}m(3-2m)}{81K} & \frac{2\beta_3 m(3-2m)}{81K} \\ \frac{2\beta_{1,2}m(3-2m)}{81K} & \frac{2m(3-2m)}{81K} & \frac{2\beta_3 m(3-2m)}{81K} \\ \frac{2\beta_3 m(3-2m)}{81K} & \frac{2\beta_3 m(3-2m)}{81K} & \frac{2m(3-2m)}{81K} \end{bmatrix} \quad (8)$$

in the accession equilibrium. As max $\{V_{i,1}, V_{i,2}\} > V_{i,0}$ holds when monies 1 and 2 are equally valued, the accession equilibrium exists. Assumption ($A2$) ensures $m < 3/2$. This implies both $T^A_{1,3} > 0$ and $T^A_{2,3} > 0$, ruling out cases where no trade occurs due trivially to the fact that nobody is specialized in production.

The following Lemma shows that the fraction of buyers is greater in the enlarged monetary union.

Lemma 1 *The pre-accession fraction of buyers within the monetary union is* $m_{i,1} + m_{i,2} = m / 2$*, i = 1, 2, and* $m_{3,1} + m_{3,2} = m_{3,2} = m$*. The accession fraction of buyers is* $m_{i,1} + m_{i,2} = 2m / 3$, $i = 1,2,3$.

Proof. (*Pre-accession equilibrium.*) In the pre-accession equilibrium the following expressions are satisfied, $m_{3,2} = m_2 = m$, $m_{1,1} = m_{2,1} = m / 2$ and $m_{1,2} = m_{2,2} = m_{3,1} = 0$.

(*Accession equilibrium.*) In the accession equilibrium, it holds that $m_{i,j} = m/3$, $i = 1, 2, 3$ $j = 1, 2$ where i denotes the country and j the money type.

In the presence of market frictions as in [5], there are expected trade creation and diversion effects that are entailed by the sole accession to a monetary union. These effects are on both inter ICs and on global trade, and are caused by a change in the equilibrium fraction of buyers. The change in the equilibrium fraction of buyers affects the expected volume of trade between ICs as in the following

Proposition 2 $m < 6 / 7$ *is a necessary and sufficient condition for inter-ICs expected trade creation (i.e. between IC countries.)*

Proof. Assume

$$m < \frac{6}{7} \quad (9)$$

which is equivalent to

$$8(3 - 2m) - 9(2 - m) > 0. \quad (10)$$

Since $\beta_{1,2}$, $m \in (0,1)$ and $K > 0$, (10) is equivalent to

$$\frac{1}{9}\frac{1}{36}\frac{\beta_{1,2}m}{K}\left[8(3-2m)-9(2-m)\right] > 0 \quad (11)$$

which, in turn, is equivalent to

$$\frac{2\beta_{1,2}m(3-2m)}{81K} - \frac{\beta_{1,2}m(2-m)}{36K} > 0, \quad (12)$$

i.e. $T^A_{1,2} - T^P_{1,2}$ is strictly positive.

Proposition 2 states that a new accession reduces the expected bilateral volume of trade between pre-accession monetary union members if the fraction of money holders is too large. The reason is clear from Lemma 1: enlargement of the monetary union in the form of dual currency circulation increases the fraction of buyers across incumbent member countries, thus resulting in fewer chances of meeting an individual specialized in the production of moneyholder's consumption good. Hence, if m is large enough, a new accession reduces trade opportunities between ICs as the event of an ICs buyer matching an ICs seller becomes less likely.

Proposition 3 $m < 6 (\beta_{1,2} + 4\beta_3) / (7\beta_{1,2} + 16\beta_3)$ *is a necessary and sufficient condition for expected global (i.e. among the ICs and AC) trade creation.*

Proof. Assume

$$m < \frac{6\left(\beta_{1,2} + 4\beta_3\right)}{7\beta_{1,2} + 16\beta_3} \quad (13)$$

This is equivalent to

$$8\left(\beta_{1,2} + \beta_3\right)(3-2m) - 9\beta_{1,2}(2-m) > 0, \quad (14)$$

which is equivalent to

$$\left(\beta_{1,2} + \beta_3\right)\frac{2m(3-2m)}{81K} - \beta_{1,2}\frac{m(2-m)}{36K} > 0, \quad (15)$$

i.e. $T^A_{1,2} + T^A_{1,3} - \left(T^P_{1,2} + T^P_{1,3}\right)$ is strictly positive. Proposition 3 states that each IC country's *global trade* is expected to increase as a consequence of the AC accessing the monetary union if and only if m satisfies (13).

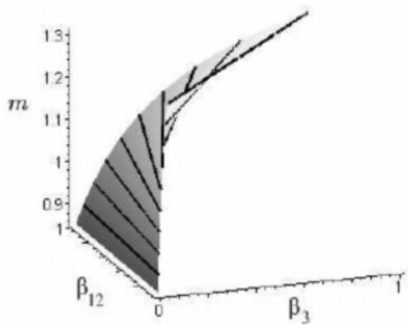

Figure 1 The new accession is Pareto improving for parameter values to the right of the plotted surface.

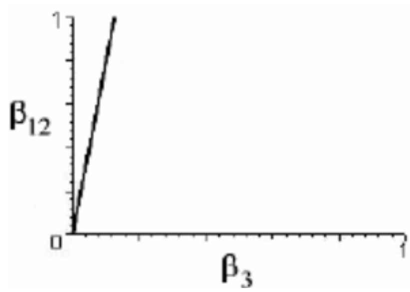

Figure 2 The surface in Figure 1 collapses to the depicted line when *m* equals 1.

The last result of this paper is a sufficient condition for expected global trade creation that is independent of the amount of money issued.

Proposition 4 *If* $\beta_3 > \beta_{1,2}/8$, *then the expected additional volume of trade between ICs and the AC more than offsets the expected reduction of trade between ICs.*

Proof. Assume $\beta_{1,2}/8 < \beta_3$, then

$$\beta_{1,2} + \beta_3 > \beta_{1,2} + \frac{\beta_{1,2}}{8}. \quad (16)$$

This is equivalent to

$$\left(\beta_{1,2} + \beta_3\right)\frac{2m(3-2m)}{81K} > \left(\beta_{1,2} + \frac{\beta_{12}}{8}\right)\frac{2m(3-2m)}{36K} \quad (17)$$

or, upon rearranging terms,

$$\left(\beta_{1,2} + \beta_3\right)\frac{2m(3-2m)}{81K} > \beta_{1,2}\frac{m(3-2m)}{36K} \quad (18)$$

which implies that

$$\left(\beta_{1,2} + \beta_3\right)\frac{2m(3-2m)}{81K} > \beta_{1,2}\frac{m(2-m)}{36K}, \quad (19)$$

i.e., $T^A_{1,2} + T^A_{1,3} > T^P_{1,2} + T^P_{1,3}$, since $(3-2m)$ can be rewritten as $(2-m) + (1-m)$, with $0 < (1-m) < 1$ by definition.

Proposition 4 states that the enlargement of a monetary union always results in expected global trade creation if the degree of integration between each IC and the AC is not too small relative to the inter-ICs degree of integration.

4 Conclusions

Within a three-country (two ICs and an AC) extension of the search equilibrium framework of [8], this paper characterizes conditions for global trade creation to occur as a consequence of new countries accessing a monetary union.

The enlargement of a monetary union is expected to increase international trade and thus be Pareto improving, but may result in trade reduction if too much money is issued, and the degree of integration between the ICs is too high relative to integration with the AC.

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Appendix

Let $\pi_{i,xy}$ denote the chance of an individual (from country *i*) trading object *x* for object *y* with some other agent (either from country 1, country 2 or country 3, and holding the object *y*.) For example, the probability of an agent from country 1 exchanging a unit of money 1 for a unit of the consumption good, $\pi_{1,10}$, is equal to the sum of two terms. The first term is the probability of meeting a national agent that holds the desired consumption good conditional on the probability of both agreeing on trading, i.e. $(1 - m_{1,1} - m_{1,2})\tau_{1,01} / 3K$. The second term is the probability of meeting an agent from either country 2 or country 3 that holds a unit of consumption good conditional on the probability of that agent agreeing on trade, i.e. $\left[\beta_{1,2}\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,01}+\beta_3\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,01}\right]/3K$. Thus, it holds that

$$\pi_{1,01}=\frac{m_{1,1}\tau_{1,01}+\beta_{1,2}m_{2,1}\tau_{1,01}+\beta_3 m_{3,1}\tau_{1,01}}{3K},\quad \pi_{1,02}=\frac{m_{1,2}\tau_{1,02}+\beta_{1,2}m_{2,2}\tau_{1,02}+\beta_3 m_{3,2}\tau_{1,02}}{3K}$$
$$\pi_{2,01}=\frac{\beta_{1,2}m_{1,1}\tau_{2,01}+m_{2,1}\tau_{2,01}+\beta_3 m_{3,1}\tau_{2,01}}{3K},\quad \pi_{2,02}=\frac{\beta_{1,2}m_{1,2}\tau_{2,02}+m_{2,2}\tau_{2,02}+\beta_3 m_{3,2}\tau_{2,02}}{3K}$$
$$\pi_{3,01}=\frac{\beta_3 m_{1,1}\tau_{3,01}+\beta_3 m_{2,1}\tau_{3,01}+m_{3,1}\tau_{3,01}}{3K},\quad \pi_{3,02}=\frac{\beta_3 m_{1,2}\tau_{3,02}+\beta_3 m_{2,2}\tau_{3,02}+m_{3,2}\tau_{3,02}}{3K}$$
$$\pi_{3,10}=\frac{\beta_3\left(1-m_{1,1}-m_{1,2}\right)\tau_{1,01}+\beta_3\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,01}+\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,01}}{3K},$$
$$\pi_{3,20}=\frac{\beta_3\left(1-m_{1,1}-m_{1,2}\right)\tau_{1,02}+\beta_3\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,02}+\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,02}}{3K}, \tag{A1}$$
$$\pi_{1,10}=\frac{\left(1-m_{1,1}-m_{1,2}\right)\tau_{1,01}+\beta_{1,2}\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,01}+\beta_3\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,01}}{3K},$$
$$\pi_{1,20}=\frac{\left(1-m_{1,1}-m_{1,2}\right)\tau_{1,02}+\beta_{1,2}\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,02}+\beta_3\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,02}}{3K},$$
$$\pi_{2,10}=\frac{\beta_{1,2}\left(1-m_{1,1}-m_{1,2}\right)\tau_{1,01}+\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,01}+\beta_3\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,01}}{3K},$$
$$\pi_{2,20}=\frac{\beta_{1,2}\left(1-m_{1,1}-m_{1,2}\right)\tau_{1,02}+\left(1-m_{2,1}-m_{2,2}\right)\tau_{2,02}+\beta_3\left(1-m_{3,1}-m_{3,2}\right)\tau_{3,02}}{3K}.$$

In the steady state pre-accession equilibrium it holds that $m_{1,1} = m_{2,1} = m / 2$, $m = m_{3,2}$, $m_{1,2} = m_{3,1} = m_{2,2} = 0$, and $\pi_{1,02} = \pi_{2,02} = \pi_{3,01} = 0$. Using these terms into (A1) one obtains the transition probabilities in (3).

In steady state accession equilibrium it holds that, $m_{i,j} = m / 3$ and $t_{i,0j} = 1$ for any *i,j*. Substituting these terms into (A1) one gets (7).