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*Aloisio Araujo and Marcia Leon*

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Edited by:

**Research Department (Depep)**

(E-mail: [workingpaper@bcb.gov.br](mailto:workingpaper@bcb.gov.br))

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Caixa Postal 8.670

70074-900 Brasília – DF – Brazil

Phones: (5561) 414-3710 and 414-3711

Fax: (5561) 414-3626

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70074-900 Brasília – DF – Brazil

Phones: (5561) 414 (....) 2401, 2402, 2403, 2404, 2405, 2406

DDG: 0800 992345

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# Speculative Attacks on Debts and Optimum Currency Area: A Welfare Analysis\*

Aloisio Araujo<sup>†</sup> and Marcia Leon<sup>‡</sup>

## Abstract

Resorting to an extension of the debt crisis model of Cole and Kehoe ([6], [7] and [8]), we evaluate financial aspects of an optimum currency area. Our focus is to appraise the welfare of a country, which belongs to a monetary union and might suffer a speculative attack on its public debt. A default may be avoided by an inflation tax on common-currency debt, but this decision depends on majority voting and have costs associated with it. Moreover, the model considers symmetry between national and central governments' decisions about inflation and also describes the loss in international bankers' confidence towards one country being passed on to another. One of our results is that, for a country with low weight in the voting system, common-currency regime is superior in terms of expected welfare to dollarization and may be a better choice than the local-currency one, as the central bank under the latter regime undergoes some political influence from its government.

Keywords: dollarization, optimum currency area, speculative attacks, debt crisis, sunspots

JEL Classification: F34, F36, F47, H63

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<sup>†</sup>Escola de Pós-Graduação em Economia (Fundação Getulio Vargas) and Instituto de Matemática Pura e Aplicada. E-mail: aloisioa@fgv.br; aloisio@impa.br

<sup>‡</sup>Research Department, Banco Central do Brasil. E-mail: marcia.leon@bcb.gov.br

# 1 Introduction

Emerging market economies of Latin America and Southeast Asia accumulated high levels of external debt in the 1990's. The sharp demand for foreign credits helped sustain stabilization programs and strengthen the value of national currencies. Reversal of market expectations and contagion effects changed this environment, causing financial crisis for some of these economies. Argentina and Russia actually defaulted, while Mexico, Korea, Thailand, Hong Kong and Brazil experienced severe speculative attacks.

With this background in mind, we make an extension to the Cole and Kehoe ([6], [7] and [8]) model on self-fulfilling debt crisis to describe an economy for which there is positive probability of defaulting on its external debt, but also belongs to a currency union. Under this monetary regime, a default may be avoided by inflation of the common currency, which, however, incurs costs in terms of a fall in productivity. Besides, the decision to inflate depends on majority voting and the welfare of a country with low weight in the voting system is adversely affected by antagonistic choices. We also try to evaluate the contagion among members that results from a loss in confidence of international bankers towards one country being passed on to another.

One of the advantages of the Cole-Kehoe methodology is to do welfare analysis. We use their approach to evaluate the expected welfare of a member country of a monetary union constituted of two partners. We do simulations for Brazil for the period from June 1999 until May 2001, supposing that it has high and low weight in the voting system of a monetary union. We compare the results from this model with the expected welfare given by the original Cole-Kehoe model, which we characterize as being a dollarization regime, and also to a model with local currency and central bank under political influence by its government. Our main result is that for a low-weight country with dollar debt in the crisis zone, local currency regime may be a better choice than the common-currency one, even if the central bank of the country that issues its own local money is being politically influenced

by its government. If this dependence is not too strong, the possibility to inflate, at its own will, to avoid a default under local-currency regime produces higher welfare than the need to wait on majority decision as is the case in the other regime. For the low-weight country, common currency is superior to dollarization, because under the former regime it is possible to avoid a default through inflation, while this alternative is absent in the latter.

On a more methodological ground, this paper can be viewed as part of the literature on general equilibrium with bankruptcy, which asserts that in an incomplete market situation the introduction of the possibility of bankruptcy can be welfare enhancing (see Dubey, Geanakoplos and Zame [10], for static economies, and Araujo, Páscoa and Torres-Martínez [3], on infinite horizon economies). The introduction of common currency can give rise to the possibility of a better bankruptcy technology through inflation than just the repudiation of the external debt, which can be quite costly.

## 2 The Cole-Kehoe Model

Cole and Kehoe developed a dynamic, stochastic general equilibrium model in which they consider the possibility of a self-fulfilling crisis of the public debt occurring. The crisis takes place when the government needs to renew its loans and the international bankers, realizing that it will not pay them back, decide to suspend them. Given this decision, the government defaults, confirming the creditors' initial beliefs.

### 2.1 Basic Assumptions

The basic assumptions of the original Cole-Kehoe model are: one good produced with capital,  $k$ , inelastic labor supply, and price normalized at one dollar; three participants — national consumers, international bankers and the government; one exogenous sunspot variable,  $\zeta$ , which describes the bankers confidence that the government will not default. The sunspot is supposed independent and identically distributed with uniform  $[0,1]$  distribution and the probability that the bankers

confidence is below the critical value  $\pi$  is equal to the probability of a self-fulfilling debt crisis occurring, i.e.  $P(\zeta \leq \pi) = \pi$ . The model also assumes a stock of dollar debt,  $B$ , supposed to be completely in the hands of the bankers and probability  $\pi$  of no rollover if its level lies in the crisis zone. If the government defaults, it is always total. The decision to default is characterized by the government's decision variable,  $z$ , equal to zero. Otherwise, it is equal to one.

In the original model, the representative consumer maximizes expected utility

$$\max_{c_t, k_{t+1}} E \sum_{t=0}^{\infty} \beta^t [\varrho c_t + v(g_t)] \quad (1)$$

subject to the budget constraint

$$c_t + k_{t+1} - k_t \leq (1 - \theta) [a_t f(k_t) - \delta k_t]$$

and given initial capital

$$k_0 > 0$$

At instant  $t$ , the consumer chooses how many goods to save for next period,  $k_{t+1}$ , and to consume presently,  $c_t$ . The utility has two parts: a linear function of private consumption,  $\varrho c_t$ , and a logarithmic function  $v$  of government spending,  $g_t$ . The term  $\varrho$  is the weight of the utility of private consumption relative to the utility of public consumption. The right hand side of the budget constraint corresponds to the consumer's income, after taxes ( $\theta$  is the tax rate) and capital depreciation, given by  $\delta$ . The term  $a_t$  is essential to the Cole-Kehoe model. It is the productivity factor. If the government defaults on its debt, then the economy suffers a permanent drop in national productivity,  $a_t = \alpha$ ,  $0 < \alpha < 1$ . Otherwise,  $a_t$  is equal to one.

The problem of the representative international banker is analogous to the consumer problem, except that the instantaneous utility excludes the term related to government spending, and consists of

$$\max_{x_t, b_{t+1}} E \sum_{t=0}^{\infty} \beta^t x_t \quad (2)$$

*s.t.*

$$x_t + q_t^* b_{t+1} \leq \bar{x} + z_t b_t$$

and given a initial amount of public debt

$$b_0 > 0$$

At time  $t$ , the bankers choose how many goods to consume,  $x_t$ , and the amount of government bonds to buy,  $b_{t+1}$ . The left hand side of the budget constraint shows the expenditure on new government debt, where  $q_t^*$  is the price of one-period bonds that pay one unit of the good at maturity if the government does not default. The right hand side includes the revenue received from the bonds purchased in the previous period. The decision variable  $z$  indicates government default ( $z = 0$ ) or not ( $z = 1$ ). If it defaults, then the bankers receive nothing.

The government is assumed benevolent, in the sense that it maximizes the welfare of national consumers, and with no commitment to honor its obligations. Its decision variables are: new debt,  $B_{t+1}$ , whether or not to default,  $z_t$ , and government consumption,  $g_t$ . It has a budget constraint given by

$$g_t + z_t B_t \leq \theta [a_t f(K_t) - \delta K_t] + q_t^* B_{t+1} \quad (3)$$

where the expenditure, on the left hand side of expression (3), refers to current consumption and the payment of its debt; while the revenue, on the right hand side, includes taxes and the selling of new debt. The government is also assumed to have a strategic behavior since it foresees the optimal decision of the participants, including its own,  $c_t$ ,  $k_{t+1}$ ,  $q_t^*$ ,  $z_t$  and  $g_t$ , given the initial aggregate state of the economy,  $s_t$ , and its choice of  $B_{t+1}$ .

The timing of actions within a period  $t$  is (the subscript  $t$  is omitted):

- the sunspot  $\zeta$  is realized and the aggregate state is  $s = (K, B, a_{-1}, \zeta)$ ;
- the government, given the price function  $q^* = q^*(s, B')$ , chooses  $B'$ ;
- the bankers decide whether or not to purchase  $B'$ ;
- the government chooses whether or not to default,  $z$ , and how much to consume,  $g$ ;



- finally, consumers, given  $a(s, z)$ , decide about  $c$  and  $k'$ .

## 2.2 A Recursive Equilibrium

In the construction of a recursive equilibrium, the first step is to characterize the behavior of the consumers and bankers. The optimal accumulation of capital,  $k'$ , may take three values  $k^n > k^\pi > k^d$ , depending on the consumers' expectation about the productivity factor in the next period,  $E[a']$ . When the expectation is equal to one,  $k'$  equals  $k^n$ . If consumers expect a debt crisis next period with probability  $\pi$ , then  $E[a']$  equals  $1 - \pi + \pi\alpha$  and they choose  $k^\pi$ . Finally, when consumers know that the government has defaulted or will default for sure, they expect a drop in the productivity factor to  $\alpha$  and  $k'$  is  $k^d$ . Analogously, the price that bankers pay for the new debt may take three values,  $\beta$ ,  $\beta(1 - \pi)$  and 0, depending on their expectation of whether or not the government will default next period, since  $q^* = \beta E[z']$ . For example, if bankers expect no default ( $E[z'] = 1$ ), then  $q^*$  is  $\beta$ .

The second step in the construction of a recursive equilibrium is to define the crisis zone with probability  $\pi$ . For a given maturity of government bonds, the crisis zone is the debt interval for which a crisis can occur with probability  $\pi$ . For one-period government bonds and aggregate state  $s = (k^\pi, B, 1, \zeta)$ , such that there is probability  $\pi$  of a default, the crisis zone is given by

$$\left( \bar{b}(k^n), \bar{B}(k^\pi, \pi) \right]$$

The lower limit,  $\bar{b}(k^n)$ , is the highest debt level such that the government's payoff of not defaulting,  $V_g^n$ , is greater than the payoff of defaulting,  $V_g^d$ , when it does not obtain new external loans (the second argument,  $B'$ , and the third,  $q^*$ , are zero in the condition below). This restriction is called the *no-lending condition* and is given by the expression

$$V_g^n(s, 0, 0) \geq V_g^d(s, 0, 0)$$

On the other hand, the upper limit,  $\bar{B}(k^\pi, \pi)$ , is the highest debt level such that the government prefers not to default than to default, as long as it is able to sell new

debt at positive price  $\beta(1 - \pi)$ . This condition is written as

$$V_g^\pi(s, B', \beta(1 - \pi)) \geq V_g^d(s, B', \beta(1 - \pi))$$

Given these limits of the crisis zone, if the government chooses new dollar debt below the crisis zone,  $B' \leq \bar{b}(k^n)$ , then bankers will always renew their loans. If new dollar debt is inside the crisis zone and the realization of the sunspot is such that the international bankers are confident that the government will honor its obligations, then the creditors rollover the debt and are aware of a possible default with probability  $\pi$  next period. Finally, if the new debt is above the crisis zone,  $B' > \bar{B}(k^\pi, \pi)$ , then there will be default for sure in the following period and the bankers purchase no new debt.

### 2.3 Numerical Exercise

Using their model, Cole and Kehoe [6] did a numerical exercise for Mexico for the eight months before the 1994-95 crisis. The parameters they used are: an average maturity of eight months for the public debt; capital share,  $\nu$ , equal to 0.4 applied to the production function  $f(k) = Ak^\nu$  and total productivity factor,  $A = 2.0$ ; tax rate,  $\theta = 0.2$ ; drop in productivity after default of 0.05, meaning  $\alpha = 0.95$ ; discount factor,  $\beta = 0.97$ ; depreciation factor,  $\delta = 0.05$ ; and probability of default,  $\pi = 0.02$ , corresponding to one minus the ratio of the interest rate on U.S. Treasury bills and on Mexican dollar-indexed bonds (*Tesobonos*) with equal maturities, given by

$$\pi = 1 - \frac{(1 + r^*)}{(1 + r)} \quad (4)$$

One result of their simulation is the government debt policy function. For a given current debt level, it determines the amount of new debt the government chooses. Another result of their simulation is the crisis zone for different maturities of the public debt. They show that Mexico's domestic government debt of 20%, constituted mostly of *Tesobonos*, relative to GDP and average maturity of eight months was inside the crisis zone after devaluation.

We do a similar exercise for Brazil for the 24-month period from June 1999 to May 2001. The parameters we use are the following: average maturity of public debt of 24 months; capital share,  $\nu = 0.5$ ; tax rate,  $\theta = 0.3$ ; probability of default,  $\pi = 0.06$ ; drop in national productivity after default equal to the Mexican one ( $\alpha = 0.95$ ); and depreciation factor,  $\delta = 0.24$ .

The two-year interval is equal to the average maturity period of Brazilian government debt. We assume that the average maturity of debt denominated in local currency follows the average maturity for debt indexed by the Selic rate (the basic rate set by Banco Central do Brasil), while, for debt denominated in dollar is the same as for dollar-indexed bonds. Both average maturities are approximately 24 months for the period under study. Araujo and Leon ([2], Tabela 3) obtain that net public sector debt denominated or indexed to the dollar is 0.20 relative to GDP and, denominated in Brazilian money, 0.30, during June 1999 to May 2001. As shown in Figure 1, if we make the strong assumption that total Brazilian public sector debt could suffer a run and is subject to the mood of the international creditors, then, for an average maturity of 24 months, it would be inside the crisis zone.

### 3 A Model with Common Currency

We modify the original Cole-Kehoe model to assess the welfare of an economy that belongs to a currency union. The currency union model is mainly characterized as one with two currencies (the common one, such as the Euro, and the dollar),  $I$  member countries and a central government, equivalent to the Council of the European Union, constituted as the decision-making body for all members. Each country  $i$ ,  $i = 1, \dots, I$ , issues debt in the two currencies: dollar,  $B^i$ , and common currency,  $D^i$ . Since there is debt denominated in common currency, it is possible for the central government to collect inflation tax, but this decision depends on majority voting.

### 3.1 Basic Assumptions

The currency union model is very similar to the original Cole-Kehoe model. The basic assumptions are: participants in the market for the reference good — national consumers for  $I$  countries, international bankers, national government from  $I$  countries and the central government; the price of the good equals one dollar, or  $p_t$  units of the common currency, in all member countries; each country  $i$  issues debt denominated in dollars,  $B^i$ , which is only acquired by international bankers, there is probability  $\pi^i$  of no rollover if its level is in the crisis zone and any suspension in payment is always total; also, each country  $i$  issues debt denominated in common currency,  $D^i$ , which is only taken up by consumers from this country, there is always credit rollover and repayment may be suspended partially.

Analogous to the original model, the decision to default on dollar debt is characterized by the national government's decision variable,  $z^i$ , being equal to zero and a permanent fall in national productivity,  $a^i$ , to  $\alpha^i$ ,  $0 < \alpha^i < 1$ . Meanwhile, the decision whether or not to create inflation tax on common-currency debt is described by the central government decision variable,  $\vartheta_t^u$ , which may take one of two values: 1 or  $\phi = \frac{1}{1 + \chi}$ ,  $0 < \phi < 1$  and  $\chi$ , the inflation rate. If the central government decides for no inflation tax, then the common currency bond pays one good,  $v^u = 1$ , as the dollar bond does. Otherwise, it pays less than one unit,  $v^u = \phi$ . The national government obtains additional revenue by the lower real return paid for the common-currency bonds held by consumers after the central government decision to inflate. If there is inflation, consumers receive  $\phi$  goods per common-currency bond and believe that the government will henceforth start paying this quantity of goods per bond, while country  $i$  is affected by a permanent fall in productivity,  $a^i$ , to  $\alpha^\phi$ , which is related to the rate of inflation tax chosen. Therefore, the decision to inflate brings a cost to the member countries in terms of lower productivity, despite the benefit of the extra revenue to avoid an external default. An alternative approach to include inflation cost is to suppose a reduction in consumer's utility, but this is still a theoretical proposal.

Uncertainty is included in the model by three sunspot variables: two for each country  $i$ ,  $\zeta^i$  and  $\eta^i$ , and one for the union,  $\eta^u$ . The sunspot  $\zeta^i$ , as in the original Cole-Kehoe model, describes the bankers' confidence that government  $i$  will not default on its external debt. We assume that  $\zeta^i$ , from country  $i$ , is affected by sunspot  $\zeta^j$  from another country  $j$  belonging to the currency union in the following way: first, we suppose that the probability that bankers' confidence in government  $i$  is below the critical value  $\pi^i$  given that their confidence in government  $j$  is higher than the critical value  $\pi^j$  is  $\pi^i$ , where  $\pi^i$  is the probability of a self-fulfilling dollar debt crisis occurring in country  $i$  given that there is no crisis in country  $j$ , i.e.  $P(\zeta^i \leq \pi^i \mid \zeta^j > \pi^j) = \pi^i$ ; and second, we assume analogously that  $P(\zeta^i \leq \pi^i \mid \zeta^j \leq \pi^j) = \pi^{ij}$ , where  $\pi^{ij}$  is the the probability of a self-fulfilling dollar debt crisis occurring in country  $i$ , given an external debt crisis occurred in country  $j$ . Supposing a currency union with only two countries, Table 1 and Table 2, in the Appendix, show the conditional probability of  $\zeta^2$  given  $\zeta^1$  and their joint probability.

The other sunspot for country  $i$ ,  $\eta^i$ , is conditional on  $\zeta^i$  and describes the confidence that consumers from country  $i$  have that the central government will honor its obligations regarding payment of the common currency bonds. We assume that the probability that the confidence of consumers from country  $i$  is below the critical value  $\xi^i$ , given that international bankers have little confidence in government  $i$ , is  $\xi^i$ , i.e.  $P(\eta^i \leq \xi^i \mid \zeta^i \leq \pi^i) = \xi^i$ , where  $\xi^i$  is the probability that government  $i$  votes for inflation tax. Table 3 shows the conditional probability of  $\eta^i$  given  $\zeta^i$ . The national government's choice about inflation influences the central government decision according to the weight of each country in the voting system,  $\varphi^i$ . If the majority of member countries is not under a speculative attack, then the realization of the sunspots  $\eta^i$  for all  $i$  is irrelevant, since there is no reason to inflate.

Finally, the sunspot  $\eta^u$  gathers all  $\eta^i$  and describes the confidence that consumers from the union have about the central government decision not to inflate the common currency. We assume that the probability that the confidence of consumers from the union is below the critical value  $\xi^u$ , given that the confidence of the consumers from

the majority of countries is below the critical value  $\xi^i$ , is  $\xi^u$ . We define  $\xi^u$  as the average  $\xi^i$  for all member countries according to their weight in the voting system and it corresponds to the probability that the members vote in favor of inflation tax.

Table 4 shows, for a currency union constituted of two countries, the conditional probability of  $\eta^u$  given that the confidence of the consumers from each country,  $\eta^1$  and  $\eta^2$ , are affected by the low confidence of the international bankers. The realization of the sunspots  $\eta^1$  and  $\eta^2$  may be symmetrical or asymmetrical. In case of symmetry, the consumers' confidence may be both small with  $\eta^1 \leq \xi^1$  and  $\eta^2 \leq \xi^2$  (and inducing national governments 1 and 2 to vote in favor of inflating the common currency) or both big with  $\eta^1 > \xi^1$  and  $\eta^2 > \xi^2$  (and both governments voting against inflation) . If  $\eta^1$  and  $\eta^2$  are small, then  $\eta^u$  is also small ( $\eta^u \leq \xi^u$ ). The conditional probability that  $\eta^u \leq \xi^u$ , given that  $\eta^1$  and  $\eta^2$  are symmetrical, is  $\xi^u$ , which is defined as the weighted average of  $\xi^1$  and  $\xi^2$ , as shown in cell (1,1) of Table 4. In case of asymmetry, we assume that country 1 has the highest weight in the voting system and, consequently, the union's confidence reflects the one from country 1. According to this hypothesis,  $\xi^{u^u}$  is defined as the conditional probability that the union's confidence is small,  $\eta^u \leq \xi^u$ , given that the consumers' confidence from country 1 is also small,  $\eta^1 \leq \xi^1$ , and from country 2 is big,  $\eta^2 > \xi^2$ . On the other hand,  $(1 - \xi^{u^u})$  is the conditional probability that the union's confidence is big when the consumers' confidence from country 1 is big and, from country 2, is small .

Table 5 presents the joint probability of the three sunspots  $\eta^1$ ,  $\eta^2$  and  $\eta^u$ . The probability  $si$  refers to the joint probability of symmetry ( $s$ ) between  $\eta^1$  and  $\eta^2$  and inflation ( $i$ ),  $sni$  refers to symmetry ( $s$ ) and no inflation ( $ni$ ). Analogously, we define the probabilities  $asi$  and  $asni$ , for the case of asymmetry ( $a$ ).

The different realizations of  $\eta^i$  for each country correspond to the political risk that national government  $i$  faces in adopting a common currency. The realization of the sunspot variables  $\eta^i$  and  $\eta^u$  indicates whether the government of country  $i$

and the central government are in harmony regarding price versus output stability. Antagonistic types of national governments can result in different preferences regarding the conduct of common monetary policy. This same question is analyzed by Alesina and Grilli [1], but using a different theoretical approach.

Figure 2 is a tree diagram for two countries in a currency union in one period. The branches of the tree indicate the probabilities that the market participants face before realization of the sunspot variables, when the initial state is such that there has not been inflation tax and both countries may default on their dollar debts.

### 3.2 Description of Participants

At time  $t$ , the representative consumer from country  $i$  maximizes the expected utility, given by expression (1), subject to the new budget constraint

$$c_t^i + k_{t+1}^i - k_t^i + q_t^i d_{t+1}^i \leq (1 - \theta^i) [d_t^i f(k_t^i) - \delta^i k_t^i] + \vartheta_t^u d_t^i$$

Besides  $k_{t+1}^i$  and  $c_t^i$ , the representative consumer from country  $i$  chooses the amount of new common-currency debt,  $d_{t+1}^i$ . The common-currency debt consists of zero-coupon bonds maturing in one period that pay one unit of the good if there is no inflation. Otherwise, it pays  $\phi$  units. The right-hand side of the budget constraint includes the expenditure on new common currency debt,  $q_t^i d_{t+1}^i$ , and the left-hand side, the payment of the debt purchased in the previous period,  $\vartheta_t^u d_t^i$ . We also assume that the consumer holds an amount  $d_0^i$  of the common-currency debt initially.

International bankers maximize the expected utility given by the expression (2), subject to the budget constraint

$$x_t + \sum_{i=1}^I q_t^{*i} b_{t+1}^i \leq \bar{x} + \sum_{i=1}^I z_t^i b_t^i$$

which includes purchase and redemption of dollar debt of the  $I$  member countries. Each banker chooses dollar-denominated bonds of country  $i$  at time  $t$ ,  $b_{t+1}^i$ , and pays  $q_t^{*i}$  goods per bond. Initially, external creditors hold the amount  $b_0^i$  of dollar debt of each country  $i$ .

At time  $t$ , the national government of country  $i$  makes the following choices: new dollar debt,  $B_{t+1}^i$ , new common-currency debt,  $D_{t+1}^i$ , whether or not to default on its dollar debt,  $z_t^i$ , and current government consumption,  $g_t^i$ . The budget constraint at time  $t$  is

$$g_t^i + z_t^i B_t^i + \vartheta_t^u D_t^i \leq \theta^i \left[ a_{t,f}^i(K_t^i) - \delta^i K_t^i \right] + q_t^{*i} B_{t+1}^i + q_t^i D_{t+1}^i$$

which is rewritten as,

$$g_t^i \leq \theta^i \left[ a_{t,f}^i(K_t^i) - \delta^i K_t^i \right] - z_t^i B_t^i + q_t^{*i} B_{t+1}^i + (1 - \vartheta_t^u) D_t^i + q_t^i D_{t+1}^i - D_t^i \quad (5)$$

where  $(1 - \vartheta_t^u) D_t^i$  refers to the additional revenue that the national government  $i$  obtains by the lower real return of the common-currency debt held by consumers.

Finally, the central government is also assumed benevolent, since maximizes the welfare of the consumers from the union. It decides whether or not to inflate the common-currency debt,  $\vartheta_t^u$ , which depends on the decisions of the member countries and their relative influence in the voting system,  $\varphi^i$ ,  $i = 1, \dots, I$ . If the sum of the weights of the countries that do not wish to inflate the common currency is greater than, for example, two-thirds of the total votes, then the central government chooses  $\vartheta^u = 1$ . Otherwise, it chooses  $\vartheta^u = \phi$ . We do not model how the inflation  $\phi$  is chosen.

At the initial period, for each country  $i$ , the supply of dollar debt  $B_0^i$  is equal to the demand for this debt,  $b_0^i$ ; the supply of common-currency debt  $D_0^i$  is equal to the demand for this type of debt,  $d_0^i$ ; and the aggregate capital stock per worker,  $K_0^i$ , is equal to the individual capital stock,  $k_0^i$ .

### 3.2.1 Timing of actions within a period for country $i$

- the sunspot variables  $\zeta^i$ ,  $\eta^i$  and  $\eta^u$  are realized and the aggregate state of economy  $i$  is  $s^i = (K^i, B^i, D^i, a_{-1}^i, \vartheta_{-1}^u, \zeta^i, \zeta^j, \eta^i, \eta^u)$ ;
- the government of country  $i$ , taking the dollar-bond price schedule  $q^{*i} = q^{*i}(s^i, B^i)$  as given, chooses the new dollar debt,  $B^i$ ;
- the international bankers, taking  $q^{*i}$  and  $\vartheta^u$  as given, choose whether to purchase  $B^i$ ,  $i = 1, \dots, I$ ;



- the government of country  $i$ , taking the common-currency-bond price schedule,  $q^i = q^i(s^i, B^1, \dots, B^I)$  as given, chooses the new common-currency debt,  $D^i$ ;
- consumers, considering  $q^{*i}$ ,  $q^i$  and  $\vartheta^u$  as given, decide whether to acquire  $D^i$ ;
- the central government decides whether or not to inflate the common currency,  $\vartheta^u$  and national government  $i$  decides whether or not to default on its dollar debts,  $z^i$ , and its current consumption,  $g^i$ ;
- consumers, taking  $a^i = a^i(s^i, z^i, \vartheta^u)$  as given, choose  $c^i$  and  $k^i$ .

### 3.3 A Recursive Equilibrium

Following the Cole-Kehoe model, we define a recursive equilibrium for one country belonging to a currency union constituted of two partners. We assume that one of the countries has the highest weight in the voting system,  $\varphi^1 > 0.5$ , and call it country 1. The highest weight means that its choice is actually the decision of the central government. The other country with weight  $(1 - \varphi^1)$  is named country 2. Our purpose is to define a recursive equilibrium and do welfare analysis for both countries. First, we describe the behavior of consumers and bankers.

#### Consumers

At time  $t$ , consumers know  $\vartheta_t^u$ ,  $g_t^i$  and  $z_t^i$  when making their decisions as to  $c_t^i$  and  $k_{t+1}^i$  and take these variables as given when deciding on  $d_{t+1}^i$ . The optimization problem at time  $t$  corresponds to

$$\max_{c_t^i, k_{t+1}^i, d_{t+1}^i} c_t^i + \beta E c_{t+1}^i$$

*s.t.*

$$\begin{aligned} c_t^i + k_{t+1}^i - k_t^i + q_t^i d_{t+1}^i &= (1 - \theta^i) \left[ a_t^i f(k_t^i) - \delta^i k_t^i \right] + \vartheta_t^u d_t^i \\ c_{t+1}^i + k_{t+2}^i - k_{t+1}^i + q_{t+1}^i d_{t+2}^i &= (1 - \theta^i) \left[ a_{t+1}^i f(k_{t+1}^i) - \delta^i k_{t+1}^i \right] + \vartheta_{t+1}^u d_{t+1}^i \\ c_t^i, c_{t+1}^i, k_{t+1}^i, d_{t+1}^i &\geq 0 \end{aligned}$$

The first order condition for capital accumulation is the same as in the original Cole-Kehoe model, given production function  $f(k) = Ak^\nu$ . It depends on the consumers' expectation regarding the productivity of the economy in the following period,  $E_t [a_{t+1}^i]$ , as shown in the expression below

$$k_{t+1}^i = \left\{ \left[ \left( \frac{1}{\beta} - 1 \right) \frac{1}{1 - \theta^i} + \delta^i \right] \frac{1}{E_t [a_{t+1}^i] A^i \nu^i} \right\} \frac{1}{\nu^i - 1} \quad (6)$$

Moreover, the price that the consumers pay for the new common-currency debt is given by

$$q_t^i = \beta E_t [\vartheta_{t+1}^u]$$

For consumers from country 1, the possible choices of capital accumulation are  $k^{\pi\xi^u}$ ,  $k^{\pi\phi}$ ,  $k^{n\phi}$ ,  $k^d$  and  $k^n$  and of the price of new common-currency debt are  $q^{\pi\xi^u}$ ,  $q^\phi$  and  $q^n$ . National consumers from country 1 save  $k^{\pi\xi^u}$ , because they expect that the productivity factor next period,  $E_t [a_{t+1}]$ , to be  $\pi\pi^{21} [(si+asi)\alpha^\phi + (sni+asni)\alpha] + \pi(1 - \pi^{21}) [\xi^1\alpha^\phi + (1 - \xi^1)\alpha] + (1 - \pi)$ , where  $\pi$  is the probability of default from country 1 and  $\pi^{21}$ , from country 2 given that country 1 is under crisis. Also, they pay price  $q^{\pi\xi^u}$  when  $E_t [\vartheta_{t+1}^u]$  is  $\pi\pi^{21} [(si+asi)\phi + (sni+asni)] + \pi(1 - \pi^{21}) [\xi^1\phi + (1 - \xi^1)] + (1 - \pi)$ . The choice of  $k^{\pi\xi^u}$  and  $q^{\pi\xi^u}$  is related to an initial state in which it is possible that one or both countries default on the dollar debt or that a default can be avoided through an inflation tax on common-currency debt (the initial state in Figure 2). In the same fashion, consumers decide on  $k^{\pi\phi}$  when there has been inflation tax and it is possible that country 1 defaults on the dollar debt next period. Consequently,  $E_t [a_{t+1}] = (1 - \pi)\alpha^\phi + \pi^1\alpha$ , meaning that the productivity factor is maintained at  $\alpha^\phi$  if sunspot  $\zeta^1$  is such that international bankers renew their loans, or falls to  $\alpha$  otherwise. If the central government decides to inflate, then consumers pay  $q^\phi$ , defined as  $\beta\phi$ , for new common-currency debt from then on, regardless of the realization of the sunspot  $\zeta^1$ . The expectation on productivity associated with capital levels  $k^{n\phi}$ ,  $k^d$  and  $k^n$  are  $\alpha^\phi$ ,  $\alpha$  and 1, respectively. The capital level  $k^d$  is chosen if the national government defaults on dollar debt. If the private sector is confident that the government will not default, then they select  $k^{n\phi}$  or  $k^n$ . In case

there had been inflation tax,  $k^{n\phi}$  is the one picked, otherwise, they choose  $k^n$  and pay price  $q^n$ , defined as  $\beta$ , for new common-currency bonds.

For consumers from country 2, the possible choices of optimal capital are:  $k^{\pi\pi^2\xi^u}$ ,  $k^{\pi\xi^1}$ ,  $k^{\pi\pi^{21}\phi}$ ,  $k^{\pi^2\phi}$ ,  $k^{n\phi}$ ,  $k^{n\phi^n}$ ,  $k^{\pi^2}$ ,  $k^d$  and  $k^n$ . The first one in the list refers to the optimal choice when  $E[a_{t+1}] = \pi\pi^{21} [(si + asi)\alpha^\phi + (asni + sni)\alpha] + \pi(1 - \pi^{21})(\xi^1\alpha^\phi + 1 - \xi^1) + (1 - \pi)[1 - \pi^2(1 - \alpha)]$ . Consumers have this belief when it is possible for one or both countries to default on the dollar debt or for a default to be avoided through an inflation tax on common-currency debt in the following period (the initial state in Figure 4). Also according to these beliefs, consumers from country 2 pay price  $q^{\pi\xi^u}$ . On the other hand, when it is possible that only country 1 defaults or votes for inflation, then the optimal capital is denoted by  $k^{\pi\xi^1}$ , meaning that just the sunspots  $\zeta^1$  and  $\eta^1$  matter. For  $k^{\pi\xi^1}$ ,  $E[a_{t+1}]$  corresponds to  $1 - \pi + \pi si0 + \pi asi0 \alpha^{\phi^n}$  and the price that consumers from country 2 pay for new common-currency debt is  $q^{\pi\xi^1}$  equal to  $\beta(1 - \pi + \pi si0 + \pi asi0 \phi^n)$ , where  $asi0$  is the probability of asymmetry and  $si0$  of symmetry between the decisions of the two national governments not to inflate the common currency, given that consumers from country 2 would rather not have inflation for sure. Actually,  $si0$  is equal to  $(1 - \xi^1)$  and  $asi0$ , to  $\xi^1$ .

The distinction between  $\alpha^{\phi^n}$  and  $\alpha^\phi$  is related to the abatement factor of the common-currency debt,  $\vartheta^u$ , and specifically to the vote of country 2 to inflate. Supposing that the sunspot of country 1 influences country 2, two situations may happen: sunspot  $\zeta^2$  matters or not at present, which depends on the level of dollar debt of government 2. If  $\zeta^2$  matters and country 1 prefers not to default and votes for inflation, then the abatement factor  $\vartheta^u$  is equal to  $\phi$ . On the other hand, if  $\zeta^2$  does not count and country 1 votes for inflation, then  $\vartheta^u$  is  $\phi^n$ , indicating that country 2 surely chooses no inflation.

Given the initial state of the economy  $s^2 = (k^{\pi\pi^2\xi^u}, B^2, D^2, a_{-1}^2, \vartheta_{-1}^u, \zeta^1, \zeta^2, \eta^u, \eta^2)$ , with  $a_{-1}^2 = 1$ ,  $\vartheta_{-1}^u = 1$ ,  $\zeta^1 \leq \pi^1$ ,  $\zeta^2 \leq \pi^2$ ,  $\eta^1 \leq \xi^1$  and any  $\eta^2$ , the central government decides for inflation and both countries do not default on their external debts, as indicated by the realization of the sunspots  $\zeta^1$  and  $\eta^1$ . The optimal

accumulation of capital for next period may take two values:  $k^{\pi\pi^{21}\phi}$ , if sunspots  $\zeta^1$  and  $\zeta^2$  matter in the following period, with the expectation of the productivity factor,  $E_t[a_{t+1}]$ , equal to  $(1 - \pi^1)(1 - \pi^2)\alpha^\phi + (1 - \pi^1)\pi^2\alpha + \pi^1(1 - \pi^{21})\alpha^\phi + \pi^1\pi^{21}\alpha$ ; or the optimal capital is  $k^{\pi^2\phi}$ , defined by  $E[a_{t+1}]$  equal to  $\pi^2\alpha + (1 - \pi^2)\alpha^\phi$ , if sunspot  $\zeta^2$  is the only one taken into account by the private sector for the following period. Again, after inflation, consumers pay a price  $q^\phi$  for common currency debt.

Finally, consumers choose  $k^{\pi^2}$ , given by  $E[a_{t+1}] = 1 - \pi^2(1 - \alpha)$ , and pay price  $\beta$  for common currency debt, when consumers from country 2 know that country 1 decided to default instead of inflating.

### International Bankers

At time  $t$ , international bankers solve

$$\max_{x_t, b_{t+1}^1, \dots, b_{t+1}^I} x_t + \beta E_t[x_{t+1}]$$

*s.t.*

$$x_t + q_t^{*1}b_{t+1}^1 + \dots + q_t^{*I}b_{t+1}^I = \bar{x} + z_t^1b_t^1 + \dots + z_t^Ib_t^I$$

and the first-order condition for  $b_{t+1}^i$  is

$$q_t^{*i} = \beta E_t[z_{t+1}^i]$$

The price that external creditors pay for new dollar debt of country 1 may take four values: 0,  $\beta$ ,  $\beta(1 - \pi)$ , and  $q^{*\pi\xi^u}$ . For new dollar debt issued by government 2, the price that external creditors are willing to pay may take five values: 0,  $\beta$ ,  $\beta(1 - \pi^2)$ ,  $q^{*\pi\pi^{21}\phi}$  and  $q^{*\pi\pi^2\xi^u}$ . If the central government has undertaken an inflation tax and bankers believe that the national government  $i$  will default on the dollar debt with probability  $\pi^i$  in the following period, they pay  $\beta(1 - \pi^i)$  for new dollar debt from this country. However, if the national government currently defaults on dollar debt, then international bankers pay price zero. In case external creditors are sure that the government will not resort to a dollar debt moratorium, they pay  $\beta$ . For country 1, the price  $q^{*\pi\xi^u}$  is defined by  $E_t[z_{t+1}^1]$  equal to  $\pi\pi^{21}(si + asi) + \pi(1 - \pi^{21})\xi^1$

+ (1 -  $\pi$ ) and, for country 2, the price  $q^{\pi\pi^{21}\xi^u}$  is related to  $E_t [z_{t+1}^2] = \pi(1 - \pi^{21}) + (1 - \pi)(1 - \pi^2) + \pi\pi^{21}(si + asi)$ . In both cases, external creditors expect that one or the other country or both may default on their dollar debt or that a default can be avoided through an inflation tax on debt denominated in common currency. Finally,  $q^{*\pi\pi^{21}\phi}$  refers to an expectation of default of  $[\pi(1 - \pi^{21}) + (1 - \pi)(1 - \pi^2)]$  and is chosen after the central government has decided to inflate and both sunspots  $\zeta^1$  and  $\zeta^2$  matter.

In the next step to construct an equilibrium, we describe the crisis zone using the following assumptions: (i) there has not been a debt crisis in any of the countries of the monetary union, nor partial moratoria of common-currency debt, up to the initial state (i.e.,  $a_{-1}^i = 1$  for all  $i$  and  $\vartheta_{-1}^u = 1$ ); and (ii) the common-currency debt is fixed at level  $D$ .

### 3.4 The Crisis Zone

The crisis zone is defined as the dollar debt interval for which the international bankers attribute positive probability for country  $i$  to default on its external debt in the following period. First, we obtain the crisis zone for the country with the highest weight in the voting system and afterwards, for the country with the lowest weight.

*Crisis zone for country 1 (country with high weight in voting system)*

The crisis zone is given by the interval  $(\bar{b}(k^n, D), \bar{B}(k^{\pi\xi^u}, D, \pi, \xi^u)]$ . The lower bound  $\bar{b}(k^n, D)$  is the highest dollar debt level,  $B^1$ , for which the following restriction is satisfied in equilibrium:

$$V^n(s^1, 0, 0, D, \beta) \geq V^d(s^1, 0, 0, D, \beta) \quad (7)$$

where  $s^1 = (k^n, B^1, D, 1, 1, \cdot, \cdot, \cdot)$  is an initial state in which country 1 has not defaulted on the dollar debt ( $a_{-1}^i = 1$ ), the central government has not inflated the common-currency debt ( $\vartheta_{-1}^u = 1$ ) and the sunspots do not matter. The welfare levels  $V^n(s^1, 0, 0, D, \beta)$  and  $V^d(s^1, 0, 0, D, \beta)$  refer to the government decision,

respectively, not to default (superscript  $n$ ) than to default (superscript  $d$ ), even if it does not sell new dollar bonds at a positive price in the current period. The second and third positions of the argument of the welfare functions mean that new dollar debt  $B^1$  and  $q^{*1}$  are zero. The fourth and fifth arguments indicate that new debt in common currency,  $D$ , is sold for  $\beta$ . This lower bound is obtained in a similar way as in the original Cole-Kehoe model, except that in the common-currency model the purchase and payment of common-currency debt is included. The welfare levels are

$$V^n(s^1, 0, 0, D, \beta) = v [\theta y^n - B^1 - (1 - \beta)D] + \rho [(1 - \theta) y^n + (1 - \beta)D] + \beta \cdot wnD(0) \quad (0)$$

$$wnD(0) = \frac{1}{(1 - \beta)} \{v [\theta y^n - (1 - \beta)D] + \rho [(1 - \theta) y^n + (1 - \beta)D]\}$$

$$y^n = A(k^n)^\gamma - \delta k^n$$

$$V^d(s^1, 0, 0, D, \beta) = v [\theta y^{nd} - (1 - \beta)D] + \rho [(1 - \theta) y^{nd} + k^n - k^d + (1 - \beta)D] + \beta \cdot wdD$$

$$y^{nd} = \alpha A(k^n)^\gamma - \delta k^n$$

$$wdD = \frac{1}{(1 - \beta)} \{v [\theta y^d - (1 - \beta)D] + \rho [(1 - \theta) y^d + (1 - \beta)D]\}$$

The upper bound of the crisis zone,  $\bar{B}(k^{\pi^{\xi^u}}, D, \pi, \xi^u)$ , is the highest dollar debt for which international bankers extend loans to country 1, given probability  $\pi^i$  for each member country to default and probability  $\xi^u$  for the central government to inflate in the following period. It is obtained as the highest dollar debt such that the following restrictions are simultaneously satisfied in equilibrium, given initial state  $s^1 = (k^{\pi^{\xi^u}}, B^1, D, 1, 1, \zeta^1, \zeta^2, \eta^1)$ , with  $a_{-1}^i = 1$ ,  $\vartheta_{-1}^u = 1$

$$V^{\pi^1 \xi^u}(s^1, B^1, q^{*1}, D, q^1) \geq V^d(s^1, B^1, q^{*1}, D, q^1) \quad (8)$$

$$V^{\pi^1}(s^1, B^1, q^{*1}, D, \beta \phi) \geq V^d(s^1, B^1, q^{*1}, D, \beta) \quad (9)$$

Condition (8) says that government 1 prefers not to default than to default and also decides for no inflation tax, because the realization of the sunspot  $\zeta^1 > \pi^1$  is such that the bankers are confident in government 1 and renew their loans. Restriction (9) says that government 1 prefers not to default than to default on the dollar debt,

as long as it sells new dollar debt at price  $q^{*1}$  and new common-currency debt at price  $\beta\phi$ . Under this condition, the realization of the sunspots is  $\zeta^1 \leq \pi^1$  and  $\eta^1 \leq \xi^1$ , meaning that the external and internal creditors have lost their confidence in government 1, but it does not default because the central government creates inflation tax.

*Crisis zone for country 2 (country with low in the voting system)*

Since we assume that country 1 always chooses dollar debt inside the crisis zone, then the crisis zone for country 2 depends on the realization of the sunspots  $\zeta^1$  and  $\eta^1$  and is denoted by  $(\bar{b}(k^{\pi\xi^1}, D, \pi, \xi^1), \bar{B}(k^{\pi\pi^2\xi^u}, D, \pi, \pi^2, \xi^1, \xi^2))$ . The lower bound  $\bar{b}(k^{\pi\xi^1}, D, \pi, \xi^1)$  is the highest dollar debt for which the following restriction is satisfied in equilibrium:

$$V^n(s^2, 0, 0, D, q^{\pi\xi^1}) \geq V^d(s^2, 0, 0, D, q^{\pi\xi^1}) \quad (10)$$

where  $s^2 = (k^{\pi\xi^1}, B^2, D, 1, 1, \zeta^1, \cdot, \eta^1, \cdot)$  is an initial state in which country 2 has not defaulted on the dollar debt ( $a_{-1}^2 = 1$ ), the central government has not inflated the common-currency debt ( $v_{-1}^u = 1$ ) and the sunspots  $\zeta^1$  and  $\eta^1$  matter, whereas  $\zeta^2$  and  $\eta^2$  do not. The payoffs  $V^n(s^2, 0, 0, D, q^{\pi\xi^1})$  and  $V^d(s^2, 0, 0, D, q^{\pi\xi^1})$  refer to the decision of government 2 not to default and to default, even if it does not sell new dollar bonds at a positive price in the current period. New debt in common currency is sold for  $q^{\pi\xi^1}$ . The characterization of both payoffs is available upon request.

The upper limit of the crisis zone for country 2,  $\bar{B}(k^{\pi\pi^2\xi^u}, D, \pi^1, \pi^2, \xi^1, \xi^2)$ , given initial state  $s^2 = (k^{\pi\pi^2\xi^u}, B^2, D, 1, 1, \zeta^1, \zeta^2, \eta^1, \eta^2)$  is constructed analogously to the crisis zone of country 1. It corresponds to the highest dollar debt level for which the following three restrictions are satisfied simultaneously:

$$V^{\pi\pi^2\xi^u}(s^2, B^{2'}, q^{*\pi\pi^2\xi^u}, D, q^{\pi\xi^u}) \geq V^d(s^2, B^{2'}, q^{*\pi\pi^2\xi^u}, D, q^{\pi\xi^u}) \quad (11)$$

$$V^{\pi\pi^{21}\phi}(s^2, B^{2'}, q^{*\pi\pi^{21}\phi}, D, \beta\phi) \geq V^d(s^2, B^{2'}, q^{*\pi\pi^{21}\phi}, D, \beta\phi) \quad (12)$$

$$V^{\pi^2} (s^2, B^{2'}, \beta (1 - \pi^2), D, \beta) \geq V^d (s^2, B^{2'}, \beta (1 - \pi^2), D, \beta) \quad (13)$$

In condition (11), the sunspot realizations are  $\zeta^1 > \pi^1$  and  $\zeta^2 > \pi^2$ , which indicate that the international bankers are confident that both countries will not default on their dollar debts. They renew their dollar loans to country 2 up to the level  $B^{2'} = \bar{B}(k^{\pi^2 \xi^u}, D, \pi^1, \pi^2, \xi^1, \xi^2)$  and government 2 prefers not to default than to default, because it sells new dollar debt at price  $q^{*\pi^2 \xi^u}$  and new common-currency debt at price  $q^{\pi^2 \xi^u}$ . Restriction (12) says that government 2 prefers not to default than to default, because the central government creates inflation tax on common-currency debt, given the realization of the sunspots  $\zeta^1 \leq \pi^1$ ,  $\eta^1 \leq \xi^1$  and  $\zeta^2 \leq \pi^2$ . Accordingly, government 2 would rather not default since it sells new dollar debt for  $q^{*\pi^2 \xi^u}$  and common-currency debt for  $\beta \phi$ . Condition (13) indicates that it would be better for government 2 not to default than to default, after the sunspot results  $\zeta^1 \leq \pi^1$ ,  $\eta^1 > \xi^1$  and  $\zeta^2 > \pi^2$ . In this case, country 1 defaults and international bankers roll over the dollar debt of country 2. In sum, given initial state  $s^2 = (k^{\pi^2 \xi^u}, B^2, D, 1, 1, \zeta^1, \zeta^2, \eta^1, \eta^2)$  and before the realization of the sunspots, these three conditions are the ones under which external creditors are sure that government 2 will not default. As long as all three are satisfied, then they renew the loans to this country. These payoffs are characterized applying the Cole-Kehoe methodology and the optimal choices for the market participants described in this section.

### 3.5 Optimal decisions of national government $i$

Following the same procedure as Cole and Kehoe [8], we obtain the national government optimal behavior when its dollar debt is in the no-crisis zone and in the crisis zone. We do this exercise just for country 1. For the other country, the procedure is analogous.

#### *Dollar debt in the no-crisis zone after inflation*

The no-crisis zone is the dollar debt region below the lower limit of the crisis zone. After inflation, the lower limit is denoted by  $\bar{b}(k^{n\phi}, D, \phi)$ . Given  $B_t^1 \leq \bar{b}(k^{n\phi}, D, \phi)$ ,  $K_{t+1}^1 = k^{n\phi}$  and  $B_{t+2}^1 < \bar{b}(k^{n\phi}, D, \phi)$ , the national government  $g_t^1$ ,  $g_{t+1}^1$  and



$B_{t+1}^1$ , to be sure not to default next period and solves

$$\max_{B_{t+1}^1} \beta^t v(g_t^1) + \beta^{t+1} E v(g_{t+1}^1)$$

s.t.

$$\begin{aligned} g_t^1 &= \theta y^{n\phi} + \beta B_{t+1}^1 - B_t^1 - \phi(1 - \beta) D \\ g_{t+1}^1 &= \theta y^{n\phi} + \beta B_{t+2}^1 - B_{t+1}^1 - \phi(1 - \beta) D \\ g_t^1, g_{t+1}^1 &> 0 \end{aligned}$$

The expectation refers to the possibility of an inflation tax on common-currency debt in the following period. Since we suppose that it has already occurred, then  $\vartheta^u$  equals  $\phi$  and  $q$  is  $\beta\phi$  forever. Moreover, if the government wishes no default, it chooses  $z^1 = 1$  and new dollar debt such that the bankers pay price  $\beta$  and consumers  $k^{n\phi}$  every time. The first-order condition regarding  $B_{t+1}^1$  results in  $v'(g_t^1) = v'(g_{t+1}^1)$  and the optimal behavior of the national government consists of holding its current consumption steady,  $g_t^1 = g_{t+1}^1$ . Hence, if at the start the dollar debt is  $B_0^1$  in the no-crisis zone, then the optimal new dollar debt is to maintain this same level.

#### *Dollar debt in the crisis zone*

Given  $B_t^1 \in (\bar{b}(k^n, D), \bar{B}(k^{\pi\xi^u}, D, \pi, \xi^u)]$ ,  $K_{t+1}^1 = k^{\pi\xi^u}$  and  $B_{t+2}^1$  also in the crisis zone, the first-order condition related to  $B_{t+1}^1$  is

$$v'(g_t^1) q^{*\pi\xi^u} = \tag{14}$$

$$\beta(1 - \pi^1) v'(g_{t+1}^{\pi\xi^u}) + [\pi^1 \pi^{21}(si + asi) + \pi^1(1 - \pi^{21})\xi^1] v'(g_{t+1}^{\pi\phi})$$

s.t.

$$\begin{aligned} g_t^{\pi\xi^u} &= \theta y^{\pi\xi^u} - B_t^1 + q^{*\pi\xi^u} B_{t+1}^1 - D + q^{\pi\xi^u} D \\ g_{t+1}^{\pi\xi^u} &= \theta y^{\pi\xi^u} - B_{t+1}^1 + q^{*\pi\xi^u} B_{t+2}^1 - D + q^{\pi\xi^u} D \\ g_{t+1}^{\pi\phi} &= \theta y^{\pi\phi} - B_{t+1}^1 + \beta(1 - \pi) B_{t+2}^1 - \phi(1 - \beta) D \end{aligned}$$

where  $y^{\pi\xi^u} = A(k^{\pi\xi^u})^\gamma - \delta k^{\pi\xi^u}$  and  $y^{\pi\phi} = \alpha^\phi A(k^{\pi\xi^u})^\gamma - \delta k^{\pi\xi^u}$ .  $g_{t+1}^{\pi\xi^u}$  and  $g_{t+1}^{\pi\phi}$  are the consumption levels of national government 1, when the central government

decides, respectively, not to create an inflation tax and to do it, given that it did not default on its dollar debt but there is positive probability  $\pi$  of doing so in the following period.

Condition (14) does not result in constant government consumption. It is more complex than the one obtained in the original Cole-Kehoe model, since we are considering the possibility of an inflation tax on common-currency debt. The optimal solution for new dollar debt,  $B_{t+1}^1$ , given its current level,  $B_t^1$ , in the crisis zone, is obtained in numerical form in the simulations.

The assumption of future dollar debt in the crisis zone has to be confronted with other possible situations. For example, the government may choose new dollar debt in the no-crisis zone, a sequence of future dollar debts that runs down to the lower limit of the crisis zone in  $T$  periods or never leave the crisis zone. The optimal new dollar debt is the one that provides the highest welfare.

### 3.6 Welfare for the national government $i$

The model with common currency is employed to evaluate the expected welfare of the national government of country  $i$  with high and low weight in the voting system of a monetary union constituted of two members. The welfare of a country with low weight in the union's voting system takes into account non-perfect correlation between the decisions of the member countries to create inflation tax. Since the low-weight country has to follow the decision of the majority, which is represented by the high-weight country, its welfare is affected by opposite choices.

#### 3.6.1 Welfare for member country with high weight in voting system

- *Dollar debt in the no-crisis zone for  $s^1 = (k^n, B^1, D, 1, 1, \cdot, \cdot, \cdot, \cdot)$*

For dollar debt levels in the no-crisis zone, external creditors know that the national government always prefers to pay back its debts, no matter what the realization of the sunspot variables is. The expected welfare for country 1 is

$$V^n(s^1) = \tag{15}$$

$$\frac{1}{1-\beta} \left\{ v \left[ \theta y^n - (1-\beta) B^1 - (1-\beta) D \right] + \varrho \left[ (1-\theta) y^n + (1-\beta) D \right] \right\}$$

- *Dollar debt in the crisis zone for  $s^1 = (k^{\pi\xi^u}, B^1, D, 1, 1, \zeta^1, \zeta^2, \eta^1, \cdot)$*

When dollar debt is in the crisis zone, the realization of the sunspot variables has bearing. Given and the expected welfare is

$$\begin{aligned} V^{\pi\xi^u}(s^1) &= (1-\pi) V^{\pi\xi^u}(s^1, B^1, q^{*\pi\xi^u}, D, q^{\pi\xi^u}) + \\ &\left[ \pi\pi^{21}(si + asi) + \pi(1-\pi^{21})\xi^1 \right] V^{\pi\phi}(s^1, B^1, \beta(1-\pi), D, \beta\phi) + \\ &\left[ \pi\pi^{21}(sni + asni) + \pi(1-\pi^{21})(1-\xi^1) \right] V^d(s^1, 0, 0, D, \beta) \end{aligned} \quad (16)$$

where,  $V^{\pi\xi^u}(s^1, B^1, q^{*\pi\xi^u}, D, q^{\pi\xi^u})$  is the expected welfare with positive probability that country 1 defaults on dollar debt or that an inflation tax is created in the following period,  $V^{\pi\phi}(s^1, B^1, \beta(1-\pi), D, \beta\phi)$  is the expected welfare after inflation tax on common-currency debt and possibility of a moratorium on dollar debt next period, and  $V^d(s^1, 0, 0, D, \beta)$ , after country 1 defaults.

### 3.6.2 Welfare for member country with low weight in voting system

- *Dollar debt in the no-crisis zone for  $s^2 = (k^{\pi\xi^1}, B^2, D, 1, 1, \zeta^1, \cdot, \eta^1, \cdot)$*

The expected welfare depends on sunspots from country 1 and is equal to

$$\begin{aligned} V^{\pi\xi^1}(s^2) &= (1-\pi) V^{\pi\xi^1}(s^2, B'^2, \beta, D, q^{\pi\xi^1}) + \\ &\pi asi0 V^{\pi\phi}(s^2, B'^2, \beta, D, \beta\phi) + \pi si0 V^d(s^2, B'^2, \beta, D, \beta) \end{aligned} \quad (17)$$

where  $V^{\pi\xi^1}(s^2, B'^2, \beta, D, q^{\pi\xi^1})$  is the expected welfare when sunspots for country 1 indicates possible default on dollar debt or inflation in the following period,  $V^{\pi\phi}(s^2, B'^2, \beta, D, \beta\phi)$  is the expected welfare if the central government creates inflation tax, and  $V^d(s^2, B'^2, \beta, D, \beta)$  is the payoff when country 1 defaults. As long as dollar debt for country 2 belongs to the no-crisis zone and country 1 has defaulted, then the private sector pays  $\beta$  for debts from country 2 in both currencies.

- Dollar debt in the crisis zone for  $s^2 = (k^{\pi\xi^u}, B^2, D, 1, 1, \zeta^1, \zeta^2, \eta^1, \eta^2)$

$$\begin{aligned}
V^{\pi\pi^2\xi^u}(s^2) = & \tag{18} \\
& (1 - \pi) (1 - \pi^2) V^{\pi\pi^2\xi^u}(s^2, B'^2, q^{*\pi\pi^2\xi^u}, D, q^{\pi\xi^u}) + \\
& [\pi\pi^{21}(si + asi) + \pi(1 - \pi^{21})\xi^1] V^{\pi\pi^{21}\phi}(s^2, B'^2, q^{*\pi\pi^{21}\phi}, D, \beta\phi) \\
& \pi(1 - \pi^{21})(1 - \xi^1) V^{\pi^2}(s^2, B'^2, \beta(1 - \pi^2), D, \beta) + \\
& [\pi\pi^{21}(sni + asni) + (1 - \pi)\pi^2] V^d(s^2, 0, 0, D, \beta)
\end{aligned}$$

where  $V^{\pi\pi^2\xi^u}(s^2, B'^2, q^{*\pi\pi^2\xi^u}, D, q^{\pi\xi^u})$  is the expected welfare when there is positive probability of default in both countries or inflation tax on common-currency debt next period,  $V^{\pi\pi^{21}\phi}(s^2, B'^2, q^{*\pi\pi^{21}\phi}, D, \beta\phi)$ , when the central government has created inflation tax, but both countries may still default on their dollar debts in the following period,  $V^{\pi^2}(s^2, B'^2, \beta(1 - \pi^2), D, \beta)$ , when country 1 defaults and there is positive probability that country 2 will default in the future, and  $V^d(s^2, B'^2, \beta, D, \beta)$ , after country 2 defaults.

### 3.6.3 Welfare when central bank is under political pressure

As with common currency, local currency is used with the subterfuge that the monetary authorities have some control over monetary policy. In contrast, to the central bank of a monetary union whose decisions considers all member countries, we assume that the central bank from a country that issues its own local currency may be subject to political influence of its government not so strongly committed with fiscal discipline. Given the ability to inflate local currency, the private sector anticipates that the central bank may create an inflation tax despite the absence of an external debt crisis.

The dependence of the central bank on the political decision of its government is captured by the probability  $\psi\xi$  that the central bank will inflate even though the external creditors renew their loans. We assume that, before the realization of the sunspots, the probability that the consumers' confidence that the government

will not inflate the local-currency debt, given that the bankers' confidence in the government is high, is  $\psi\xi$ , i.e.  $P[\eta \leq \xi \mid \zeta > \pi] = \psi\xi$ . When  $\psi$  equals zero, the central bank is independent (denoted as strong) and resorts to inflation only to avoid an external debt crisis, as we assume throughout the model with common-currency. When  $\psi$  is positive, the private sector attributes probability  $\psi\xi$  that the central bank is dependent (called weak) and practices a monetary policy influenced by the government. Political pressure is absent in the original Cole-Kehoe model.

## 4 A Numerical Exercise

We carry out simulations for the Brazilian economy, as if Brazil were a member of a monetary union with two member countries. We consider two situations: one in which it has high weight in the voting system ( $\varphi^1 > 0.5$ ) and the other, low weight ( $\varphi^1 \leq 0.5$ ).

### 4.1 Parameters for the Brazilian Economy

The parameters refer to the Brazilian economy from June 1999 to May 2001. The 24-months interval matches the average maturity of the Brazilian government domestic debt, in particular, of bonds indexed by the Selic rate and by the dollar.

The other parameters used in the simulations are: production function  $f(k) = Ak^\nu$  with capital share,  $\nu = 0.5$  and total factor productivity,  $A = 0.8$ ; tax rate,  $\theta = 0.3$ ; utility function of public goods,  $v(g) = (1/10)\log(g) + 1$ ; weight of utility of private relative to public consumption,  $\varrho = 0.7$ ; drop in productivity after default,  $\alpha = 0.95$ ; discount factor,  $\beta = 0.93$ ; depreciation factor,  $\delta = 0.20$ ; total common-currency debt relative to gross domestic product,  $D/GDP = 0.3$ .

In the original numerical exercise for Mexico,  $v$  is a logarithmic function,  $\ln(g)$ . With this specification, Cole and Kehoe obtained positive values for this utility, whereas our simulations for Brazil produce only negative values for all levels of the dollar debt. Therefore, we changed  $v(g)$  to  $(1/10)\log(g) + 1$  to overcome this problem, but we still need to do further work on this. Besides, to lessen the weight

of private consumption,  $c$ , in consumer utility, we reduced the parameter  $\varrho$  from one to 0.7.

### *Public Sector Debt*

According to our model,  $D$  is the government debt that may be inflated away in case of an external debt crisis. In the numerical exercises, it is parameterized as the internal net public sector debt denominated in Brazilian money. To exclude dollar-indexed debt, we assume that the fraction of dollar-indexed bonds in the internal net public sector debt is the same as its share in the amount of federal government bonds outside central bank. In this way, we obtain that common-currency debt,  $D$ , relative to GDP is approximately equal to 0.30 for the period under analysis (Araujo and Leon [2], Tabela 3).

On the other hand, the model defines  $B$  as the government debt that may suffer a speculative attack, if its level is in the crisis zone. In Araujo and Leon ([2], Tabela 3),  $B$  is described as the Brazilian public sector debt denominated in dollar and equivalent to the sum of external public sector debt (less international reserves) and internal net public sector debt indexed to the dollar. For the period under analysis, its average value is 0.20 relative to GDP. According to the results of the present paper, at this level,  $B$  is below the crisis zone, since the lower limit of the crisis zone is obtained around 0.38 relative to GDP. However, it would be more reasonable if the Brazilian public sector debt denominated in dollar were in the crisis zone and this is the exercise that we do using our model.

In the numerical exercises, we make the strong hypothesis that the Brazilian public sector dollar debt relative to GDP is 0.50. This number refers to the sum of internal net public sector debt indexed to the dollar and total external debt (private plus public, not just public). This assumption finds some ground on the practice of sovereign credit rating agencies. After the Asian crisis, they became more concerned about implicit government support of private sector claims (Bhatia [5], p. 23). In the simulations, total external debt refers to annual gross external debt (excluding intercompany loans). Using data by Banco Central do Brasil, in billion dollars, it is

216.9, for 2000, and 209.9, for 2001; Brazilian GDP, in billion dollars, is 590.7, for 2000, and 541.9, for the following year; and finally, external debt relative to GDP is 0.37 and 0.39, respectively. Furthermore, in Araujo and Leon ([2], Tabela 3), public sector debt indexed to the dollar is obtained around 0.10 relative to GDP, on average, from June 1999 to May 2001. Therefore, using our strong hypothesis, public sector dollar debt relative to GDP is close to 0.50.

Since common-currency debt,  $D$ , is fixed at 0.30 relative to GDP, then public sector debt (common plus dollar denominated) is equal to 0.80. Such high magnitude for the Brazilian public sector debt is more in conformity with estimations from credit rating agencies than with official figures, but our main objective so far is to develop a procedure to analyse public sector debt subject to a speculative attack. Additional research on the specification of the utility functions could possibly produce a more reasonable crisis zone than the one we obtained in our numerical exercise and in this way avoid the hypothesis of government responsibility for private sector external debt. This is a suggestion for future studies.

#### *Abatement Factor, $\phi$*

The abatement factor,  $\phi$ , is supposed to be a function of the probability that government  $i$  votes for inflation tax,  $\xi^i$ , in the following way. By analogy with  $\pi$ ,  $\xi^i$  is defined as the ratio between the tax rate for bonds denominated in common currency,  $i^i$ , and bonds denominated in dollars,  $r^i$ , both issued by country  $i$ , given by

$$\xi^i = 1 - \left( \frac{1 + i^i}{1 + r^i} \right)$$

According to the uncovered interest parity,  $1/(1 - \xi^i)$  is equal to one plus the rate of devaluation of the common currency relative to the dollar that consumers from country  $i$  expect. Assuming  $\xi^i$  is small, then we can approximate  $\xi^i$  as the expected rate of devaluation of the common currency in country  $i$ . The expected rate of devaluation of the common currency by all consumers from the union is defined as

$$\xi^u = \varphi^1 \xi^1 + (1 - \varphi^1) \xi^2$$

where  $\varphi^1$  is the weight of country 1 in the voting system. We make the hypothesis that one plus the expected rate of devaluation of the common currency and one plus the expected rate of inflation are equal and, by rational expectations, the expected rate of inflation actually occurs. Therefore, we have

$$1/(1 - \xi^u) = 1 + \chi^e = 1 + \chi = \frac{1}{\phi} \quad (19)$$

or

$$1 - \phi = \xi^u$$

As we can see, the inflation tax on common currency debt,  $(1 - \phi)$ , is equal to the rate of devaluation of the common currency,  $\xi^u$ , which in turn depends only on the expected rate of devaluation in each country and the weight of country 1 in the voting system. To simplify the numerical exercises, we assume two cases ( $\xi^2 = 0.75 \xi^1$  and  $\xi^2 = 1.25 \xi^1$ ) and make a grid of values for  $\xi^1 \leq 0.5$ . Another parameter used in the simulations to represent the abatement of the real return on common-currency debt is  $\phi^n$ , for the case of  $\xi^2$  being equal to zero.

### *Inflation Cost*

Another parameter to be considered is  $\alpha^\phi$ , the productivity of the economy after inflation. Simonsen and Cysne ([9], p.14) calculate the cost of inflation in Brazil as a fraction of GDP for a given inflation rate. Their equation is

$$F(\chi_l) = 1.105 \log(1 + 0.0368 \chi_l^{0.475}) \quad (20)$$

where  $F(\chi_l)$  is the inflation cost relative to GDP and  $\chi_l$  is the annual periodic inflation rate in logarithmic form.  $\chi_l$  is related to the parameter  $\phi$  (of the common-currency model) by expression  $\chi_l = \log(1/\phi)$ . To compute  $\alpha^\phi$  for different values of  $\phi$ , we compare the cost of inflation given by expression (20) to the welfare loss after inflation in the Cole-Kehoe model. To simplify the calculations, we suppose that dollar debt is stationary at  $\bar{b}(k^n, D)$ . Therefore, for given  $\phi$ , we have the following equation with  $\alpha^\phi$  unknown

$$F(\phi) = \frac{u^\phi(s^1) - u^n(s^1)}{(1/2) A (k^n)^\gamma}$$



where  $u^n(s^1)$  and  $u^\phi(s^1)$  are one-period utility without and with inflation, specified as

$$u^\phi(s^1) = v \left[ \theta y^{n\phi} - (1 - \beta) \bar{b}(k^n, D) - \phi(1 - \beta) D \right] + \varrho \left[ (1 - \theta) y^{n\phi} + \phi(1 - \beta) D \right]$$

$$u^n(s^1) = v \left[ \theta y^n - (1 - \beta) \bar{b}(k^n, D) - (1 - \beta) D \right] + \varrho \left[ (1 - \theta) y^n + (1 - \beta) D \right]$$

with  $s^1 = (k^n, \bar{b}(k^n, D), D, 1, 1, \cdot, \cdot, \cdot, \cdot)$  and  $y^{n\phi} = \alpha^\phi A(k^n)^\gamma - \delta k^n$ . We assume inappropriately that the consumer's investment after inflation is  $k^n$  instead of  $k^{n\phi}$ . Nevertheless, the difference between them is small numerically. A similar procedure is applied to obtain  $\alpha^{\phi^n}$ , in which  $\phi^n$  substitutes for  $\phi$ .

#### *Correlation between $\zeta^1$ and $\zeta^2$*

The parameter  $\pi^i$  is the probability that country  $i$  defaults, given that other countries with strong commercial and financial ties with it are not under a speculative attack. When we assume that Brazil has more than 50 percent weight in the voting system, the probability of default for country 1,  $\pi$ , is estimated as the average EMBI<sup>+</sup> sovereign spread calculated by J. P. Morgan. A crisis that affects international bankers' confidence in Brazil also influences another country that is integrated to it, like Argentina. Therefore, when Brazil is country 1, we consider Argentina country 2. Accordingly,  $\pi^2$  is the sovereign spread for Argentina when Brazil is not under a speculative attack and  $\pi^{21}$ , when it is. We define  $\pi^{21}$  as

$$\pi^{21} = \pi^2 + \Delta\pi^2 \tag{21}$$

and  $\Delta\pi^2$  is the change in sovereign spread of country 2 when country 1 is under a speculative attack on its dollar debt.

Following the procedure of Hernández and Valdés [11] in a simpler way, a linear regression model is used to represent the relation between the changes in sovereign spreads of the two countries,  $\Delta\pi^1$  and  $\Delta\pi^2$ , when country 1 is under an external debt crisis

$$\Delta\pi^2 = b \Delta\pi^1 \tag{22}$$

To obtain the time series for  $\Delta\pi^1$  and  $\Delta\pi^2$ , we consider the second half of 1998 a time of speculative attack in Brazil. From August 3 until December 31, 1998, the average Argentine sovereign spread reached 817 and the Brazilian one, 1163, as a result of the reduced confidence in Brazil after the Russian default. The regression coefficient is equal to 0.88, which is approximated to unity in the simulations. For the period under study (June 1, 1999 until May 31, 2001), the average EMBI<sup>+</sup> sovereign spread for Brazil is 801 and for Argentina, 723. Since both spreads are rather similar, we assume that  $\pi^1 = \pi^2 = 0.08$  in the simulations, in which Brazil is considered country 1. Furthermore, we regard a tranquil period for Brazil the seven months before the Russian crisis (December 31, 1997 to July 31, 1998). During this time, the average Argentine sovereign spread is 447 and the Brazilian one, 542. Therefore, when a crisis occurs in Brazil its average sovereign spread rises by 600 bps and we assume that  $\Delta\pi^1 = 0.06$ , which is the difference in averages during crisis and tranquil periods.

We also do simulations as if Brazil were a small country (country 2) and use the same hypothesis as for the Argentina-Brazil case. We consider  $\pi^1 = \pi^2 = 0.08$  and suppose that if country 1 defaults, then its sovereign spread rises by 600 bps causing an increase in the Brazilian sovereign spread given by the regression equation with coefficient equal to unity.

## 4.2 Preliminary Results

The first result obtained in the simulations is that, for a given positive risk of devaluation of the common currency,  $\xi^u$ , the expected welfare of a small country in a monetary union with two member countries is an increasing function of its weight in the voting system. This result can be seen in Figure 3. The horizontal axis refers to the country's weight in the voting system and the vertical one, to the expected welfare according to the common-currency model. In the simulations, dollar debt relative to GDP is parameterized as 0.50 and, at this level, the debt is in the crisis zone either the country has low or high weight in the voting system.

When Brazil is supposed big (country 1), the change in its sovereign spread under a speculative attack,  $\Delta\pi^1$ , equals to 0.06, the regression coefficient is one (meaning that  $\Delta\pi^2 = \Delta\pi^1$ ) and consequently the probability of default of the small country (country 2) is  $\pi^{21} = 0.08 + 0.06 = 0.14$ . When Brazil is supposed small (country 2), we make the same assumptions:  $\Delta\pi^1 = 0.06$  and  $\pi^{21} = 0.14$ . We also propose, in Figure 3, that  $\xi^2$  equals to 0.75 times  $\xi^1$ . Therefore, the consumers from the big country attributes higher probability than the consumers from the small country that the central government will create inflation tax.

The welfare levels for Brazil, as a small country, are represented by the curves whose weight in the voting system varies from zero to 0.5. Each curve is associated to a probability of devaluation of the common-currency,  $\xi^u$ , which is the inflation tax itself and equivalent to  $(0.75 + 0.25\varphi^1)\xi^1$ . For given  $\xi^1$ , the welfare for the country with low weight in the voting system increases as its weight rises (or as  $\varphi^1$ , the weight of country 1, decreases), because of its effect on reducing the inflation tax for the union. For the low-weight country, welfare varies inversely with inflation tax, because there are states of nature in which there is inflation, and costs associated to it, even though the small country does not vote for it. This result is also evident for a given weight of country 2 and different values of the probability of creating inflation tax,  $\xi^u$ . As the decision to inflate depends on majority voting, which is represented by the choice of country 1, the expected welfare is lower for the small country as the beliefs of the consumers from the big country in favor of inflation tax,  $\xi^1$ , increases.

In contrast, since the big country represents the majority decision about inflation and uses this alternative to avoid an external default, we can see that as the inflation tax increases, the highest is its welfare for a given weight in the voting system. Figure 4 provides a closer view of the welfare levels for the high-weight country, the one whose weight is in the range 0.5 to one. The welfare increases with  $\xi^1$  and varies very little with the weight  $\varphi^1$ . Actually, welfare decreases with the weight of country 1 when  $\xi^2 = 0.75 \xi^1$ , as in Figure 4. This result is clearer for high values of  $\xi^1$ , as

at the top of the figure. Since  $\xi^2$  is smaller than  $\xi^1$ , the inflation tax that the union chooses,  $\xi^u = (0.75 + 0.25\varphi^1)\xi^1$ , is less than or equal to  $\xi^1$  and increases with  $\varphi^1$ . The greater the inflation rate, the higher are the costs associated to it, for given  $\xi^1$ . On the contrary, when  $\xi^2 = 1.25 \xi^1$ , as in Figure 5, country 2 contributes with a higher inflation to the union rate, but this effect diminishes as the weight of country 1 in the voting system rises, increasing its welfare. On the other hand, the assumption  $\xi^2$  equals to 1.25 times  $\xi^1$  does not produce significant change in welfare of the small country, as compared to the hypothesis  $\xi^2 = 0.75 \xi^1$ , when we do an analogous exercise as the one in Figure 3.

Another result obtained in the simulations is that for the country with majority vote in the union, the expected welfare is close to the welfare of a country with local currency and strong central bank. Meanwhile, for the country with low weight in the voting system, the common-currency regime is better in terms of welfare than the local-currency one, as the central bank under local-currency regime suffers political influence from its government. This result is shown in Figure 6, which reproduces the same group of common-currency curves from Figure 3.

Under local-currency regime the government decides whether or not to create an inflation tax on its debt denominated in local currency. We suppose that its central bank is strong when inflation is created only to avoid a default on the dollar debt, while it is considered weak, when inflation is used for political purposes. In the latter case, we say that there is dependence of the central bank on its government. In Figure 6, the six curves representing the welfare levels under local-currency regime are linked to the six different levels of the inflation tax,  $\xi^1$ . In particular, it is a solid-horizontal line when  $\xi^1$  is zero. For the local-currency curves, the horizontal axis refers to the degree of central bank dependence,  $\psi$ , that varies from zero to 0.20, as indicated by the numbers on the upper row of the horizontal axis. When central bank is strong ( $\psi = 0$ ), the expected welfare levels under local-currency regime for different values of  $\xi^1$  are close together at the left-hand side of the figure, around the 16.83 level. Moving horizontally to the right, we observe that they are

approximately at the same level as the ones for the big country in a monetary union. Furthermore, for a given probability of inflating the local currency,  $\xi^1$ , the welfare of the local currency regime decreases as the degree of dependence increases (higher positive values on the horizontal axis). For a non-zero dependence of the national central bank, the highest welfare is associated with the lowest inflation tax to be collected for political purposes, since the decision to inflate in the absence of external debt crisis decreases welfare. Next, we compare welfare levels of the local-currency regime when central bank is dependent with welfare levels of the small country under a common-currency regime. According to the parametrization, the country with minority voting in the union is better off belonging to a monetary union than to have its own local currency when the degree of central bank dependence is high (above 0.04). A preliminary exercise estimates  $\varphi^1 = 0.14$  for Brazil.

Figure 6 also presents a line parallel to the horizontal axis that portrays the welfare under dollarization, estimated using the original Cole-Kehoe model with probability of default of 0.08. This regime is characterized by public debt denominated only in dollars and no possibility to inflate it. For the country under analysis total public debt is equal to 0.80 relative to GDP.

Further exercises aim at obtaining level curves (isolines) for the expected welfare of Brazil with high and low weight in the voting system. In the simulations, we assume that in a monetary union constituted of two countries, the weight of the big country is 0.90, dollar debt relative to GDP is 0.50 and common-currency debt relative to GDP, 0.30. Figure 7 shows the level curves as they change with the probability of default and the admitted inflation rate of the common currency. The consumers from the union admit an inflation rate of  $[(1/(1-\xi^u))^{1/2}-1]$  in percent per year. For probability of default 0.07, the welfare is highest when inflation rate of the common currency is expected to be above ten percent per year and for probability of default of 0.05, it is greatest for inflation rate above 20 percent per year. Figure 8 is analogous to Figure 7 and considers the country with low weight ( $1 - \varphi^1 = 0.10$ ). Supposing dollar debt of 50 percent relative to GDP and probability of default of

0.07, the expected welfare levels are highest for admitted inflation rates below ten percent.

The last exercise compares the welfare levels under the three monetary regimes (dollarization, common-currency and local-currency) according to admitted inflation rate and probability of default. In the simulations, dollar debt relative to GDP is 0.50 and common- (or local-) currency debt is 0.30 relative to GDP. The welfare level under common-currency regime refers to a country with low weight in the voting system ( $1 - \varphi^1 = 0.10$ ) and, under local currency, the central bank is a weak one with degree of dependence equal to 0.04. The admitted inflation, indicated in the vertical axis, is equivalent to  $[(1/(1 - \xi^1))^{1/2} - 1]$ . To obtain the inflation of the common currency,  $\xi^1$  is replaced by  $\xi^u = (0.75 + 0.25 \cdot 0.90)\xi^1$ , for  $\varphi^1 = 0.90$ .

The result from the simulations is shown in Figure 9. Three regions come out of the inflation rate and probability of default plane. One of them is indicated by **Common > Dollar > Local**, which means that for values of probability of default and admitted inflation rate to the left of the curve marked with plus sign, the welfare of the common-currency regime is better than dollarization, which in turn is superior to the local-currency one. The other region, located to the right of the curve marked with plus signs and to the left of the curve marked with circles, the welfare of the common-currency regime is better than the other two, but, now, local currency is superior to dollarization. This region is denoted by **Common > Local > Dollar**. The difference between the curve marked with circles and the one marked with diamonds refers to the effect of contagion that country 1 exerts on country 2 that we suppose occurs under common-currency regime. The curve with circles is associated with  $\Delta\pi^1 = 0.06$  and accordingly, the probability of default of country 2 associated to it is  $\pi^{21}$  as in expression (21). The curve with diamonds is linked to  $\Delta\pi^1 = 0$ . Therefore, the common-currency regime is better than the local-currency one for country 2 at higher values of its probability of default,  $\pi^2$ , as the adverse external shock that hits country 1 does not affect country 2.

The above result is in accordance with the following conclusion obtained from

Figure 9: for a country with low weight in the voting system, the common-currency regime is better in terms of welfare than the local-currency one, the lowest is its probability of default on the dollar debt. The reason for this is that the less the private sector believes that the small country needs inflation tax to avoid an external default, which is captured by the probability of default, the better the common-currency regime is. The decision to inflate depends on majority vote. Therefore, country 2 can not use the inflation alternative to avoid an external debt crisis as it pleases, like country 1 does. The third region is indicated by **Local > Common > Dollar**, which shows that local currency is a better choice than common currency, even if the central bank of the country that issues its own local currency is being politically influenced. This option produces higher welfare compared to the regime in which the country has to default because the majority is against inflation. Besides, Figure 9 shows that common-currency regime is a better choice than dollarization. The advantage rests on the possibility of the first being rescued of a default by inflation of the common currency, while, for the second, this alternative is absent.

## 5 Conclusions and Extensions

The paper brings into discussion one aspect of the debate about monetary regimes for countries heavily dependent on international lending. This task is accomplished by means of a macroeconomic model that incorporates microfundamentals, rational expectations and dynamic optimization.

The Cole-Kehoe model for obtaining the welfare of an economy subject to a speculative attack on its external debt is the starting point to describe alternative monetary regimes. The model developed in this paper includes public debt denominated in common currency, thus allowing the central government to resort to lowering the real return on it. The inflation tax so extracted is used to avoid a default on the external debt, whose consequences could be worse in terms of welfare. Besides, we have taken into account inflation costs associated with raising this

revenue and the symmetry between the national and central governments' decisions about whether or not to inflate. We went a bit further to describe the contagion that results from a loss in confidence regarding one government's commitment to repay its external debt being passed on to another country that belongs to the currency union.

The model is used to run simulations of the Brazilian economy for the 24-months period from June 1999 until May 2001. In the numerical exercises, Brazil is assumed to belong to a monetary union made up of two countries, as a country with high weight in the voting system (greater than 50 percent) and also as a country with low weight (less than 50 percent). When we assume that it is a high-weight country, Argentina is the other country with strong commercial and financial ties with it and the one that suffers contagion from a bad realization of the sunspot variable corresponding to international bankers' confidence in the Brazilian government. When Brazil is supposed to be a low-weight country, we make the same assumptions and consider country 1 a fictitious one.

The preliminary results indicate that the expected welfare for Brazil, as a country with low weight in a monetary union of two member countries, decreases with the probability of inflating the common currency, while, as a country with high weight, its welfare rises. Another result points out that Brazil, as a country with high weight, has an expected welfare close to the welfare of a country with local currency and central bank under no political pressure (i.e., that only resorts to inflation tax in case of an external crisis). On the other hand, if Brazil has low weight, the expected welfare under the common-currency regime may be greater than the welfare under local currency, as the central bank under this latter regime suffers strong political influence by its government.

The original Cole-Kehoe model and its extensions allow the comparison of welfare levels under common-currency, local-currency and dollarization regimes for a country, according to its probability of default and probability to inflate the local or common currencies. Moreover, the common-currency model could also be used to



compare welfare levels for a country under two situations: one, in which it has low weight and the sovereign spread of the high-weight country is lower than its own; and the other, in which both countries that constitute the monetary union have high sovereign spreads. These exercises could bring some light to the discussion of whether Brazil should adhere to a monetary union with the United States, as in the first situation, or with Argentina, in the second one. For Argentina and Brazil, we have already given a start here, but more effort must be put on improving the calibration of the parameters. The framework developed in this paper would also be suitable for discussing alternative monetary regimes in Mexico. A numerical exercise of the common-currency model would provide, for instance, the welfare gain that might be achieved if Mexico's weight in the voting system of a monetary union with the United States were increased.

Future extensions of the model should be aimed at carrying out simulations in which debt denominated in common currency is not fixed, but instead results from an optimization exercise as is the case of dollar debt. Also, political influence should be considered in the common-currency model, since national governments of a monetary union might influence the central government's decision to create inflation tax even though it is not the majority's choice.

## A Tables and Figures

Table 1: Conditional Probability of  $\zeta^2$  given  $\zeta^1$

	$\zeta^1 > \pi^1$	$\zeta^1 \leq \pi^1$
$\zeta^2 > \pi^2$	$(1 - \pi^2)$	$(1 - \pi^{21})$
$\zeta^2 \leq \pi^2$	$\pi^2$	$\pi^{21}$

Table 2: Joint Probability of  $\zeta^1$  and  $\zeta^2$

	$\zeta^1 > \pi^1$	$\zeta^1 \leq \pi^1$
$\zeta^2 > \pi^2$	$(1 - \pi^2)(1 - \pi^1)$	$(1 - \pi^{21})\pi^1$
$\zeta^2 \leq \pi^2$	$\pi^2(1 - \pi^1)$	$\pi^{21}\pi^1$

Table 3: Conditional Probability of  $\eta^i$  given  $\zeta^i$

	$\zeta^i \leq \pi^i$	$\zeta^i > \pi^i$
$\eta^i \leq \xi^i$	$\xi^i$	<b>0</b>
$\eta^i > \xi^i$	$1 - \xi^i$	<b>1</b>

Table 4: Conditional Probability of  $\eta^u$  given  $\eta^1$  and  $\eta^2$

	Symmetrical $\eta^1$ and $\eta^2$	Asymmetrical $\eta^1$ and $\eta^2$
$\eta^u \leq \xi^u$	$\varphi^1 \xi^1 + (1 - \varphi^1) \xi^2 \equiv \xi^u$	$\varphi^1 \xi^1 + (1 - \varphi^1) (1 - \xi^2) \equiv \xi^{uu}$
$\eta^u > \xi^u$	$\varphi^1 (1 - \xi^1) + (1 - \varphi^1) (1 - \xi^2) \equiv (1 - \xi^u)$	$\varphi^1 (1 - \xi^1) + (1 - \varphi^1) \xi^2 \equiv (1 - \xi^{uu})$

Table 5: Joint Probability of  $\eta^1$ ,  $\eta^2$  and  $\eta^u$

	Symmetrical $\eta^1$ and $\eta^2$	Asymmetrical $\eta^1$ and $\eta^2$
$\eta^u \leq \xi^u$	$[\xi^1 \xi^2 + (1 - \xi^1)(1 - \xi^2)] \xi^u \equiv si$	$[\xi^1(1 - \xi^2) + (1 - \xi^1)\xi^2] \xi^{uu} \equiv asi$
$\eta^u > \xi^u$	$[\xi^1 \xi^2 + (1 - \xi^1)(1 - \xi^2)] (1 - \xi^u) \equiv sni$	$[\xi^1(1 - \xi^2) + (1 - \xi^1)\xi^2] (1 - \xi^{uu}) \equiv asni$

Figure 1: Brazil 1999-2002 – The Crisis Zone for Different Maturities

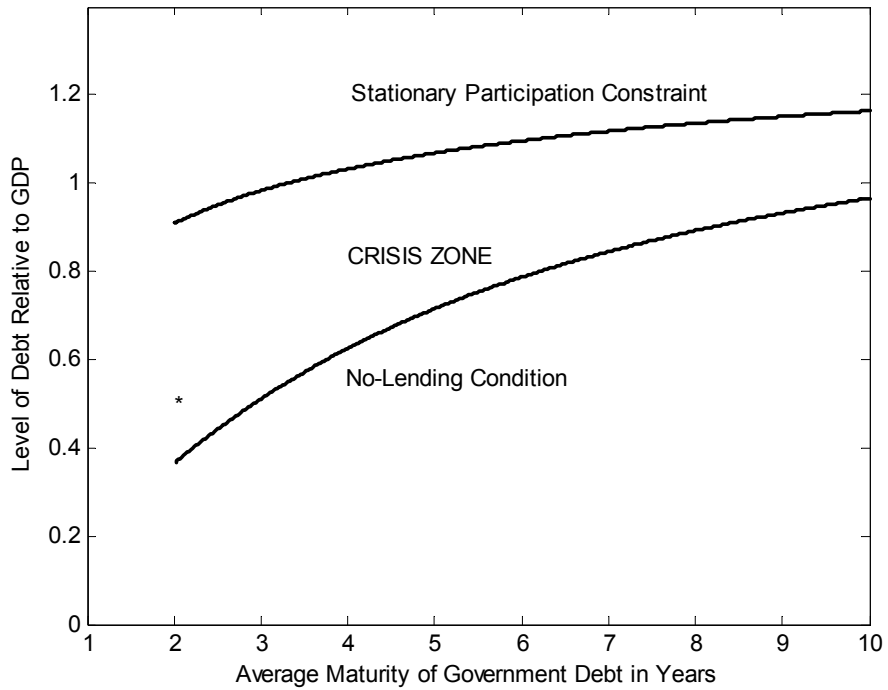


Figure 2: Tree Diagram

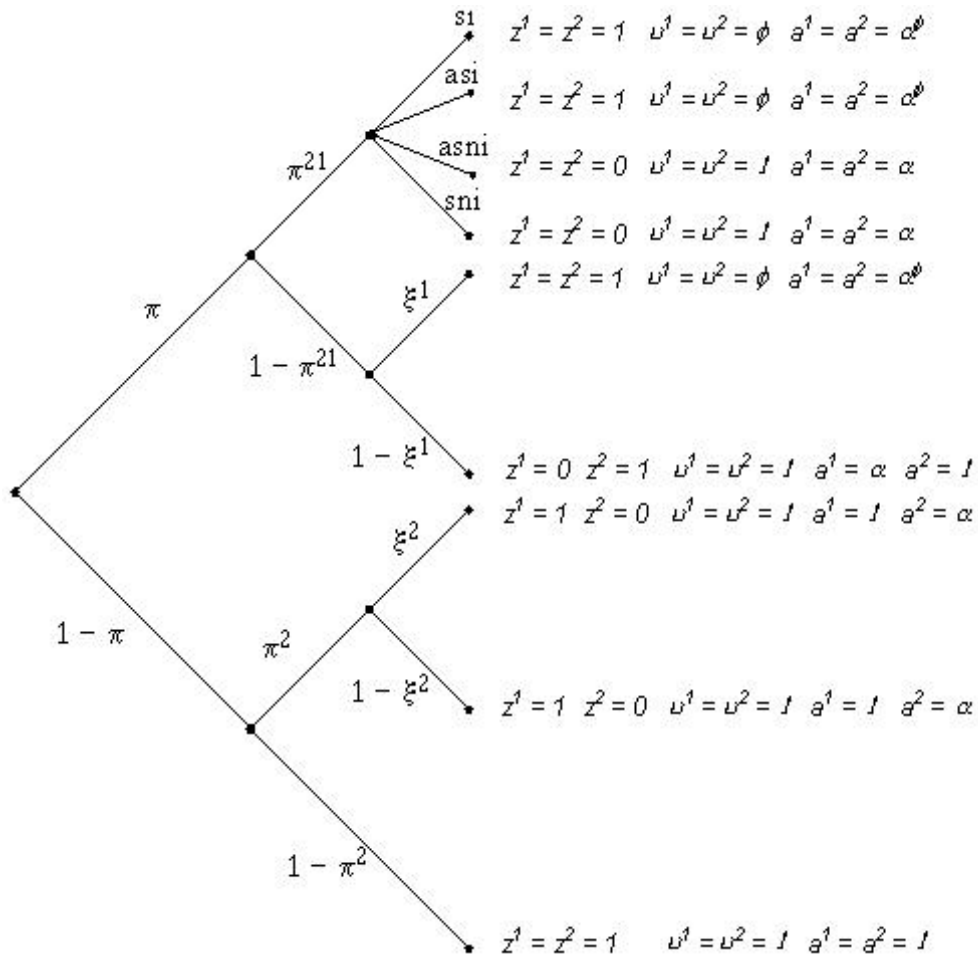


Figure 3: Expected Welfare in a Monetary Union and  $\xi^2 = 0.75\xi^1$

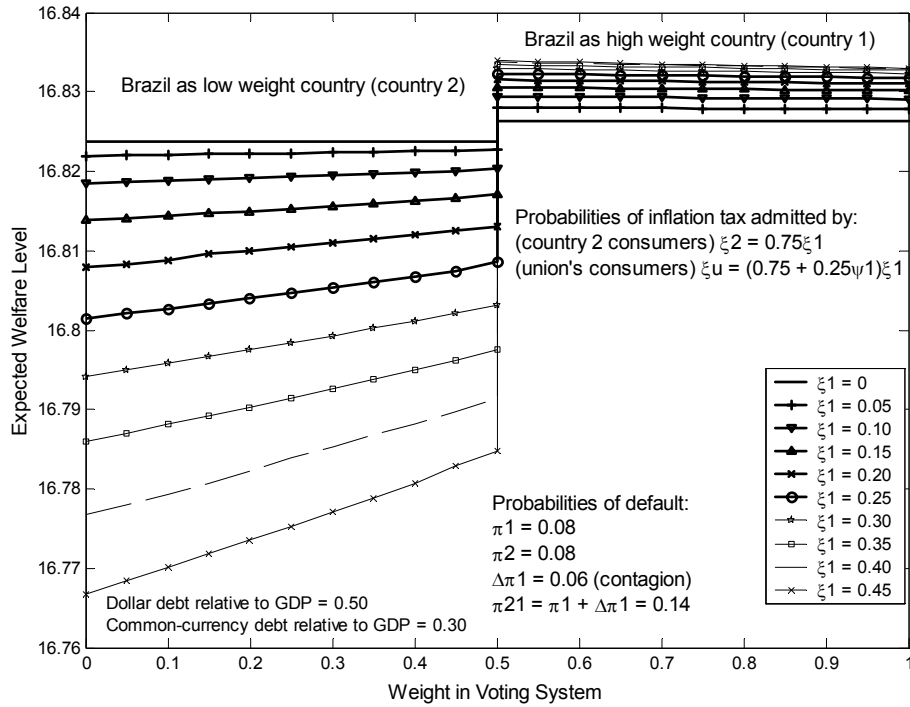


Figure 4: Expected Welfare for High-Weight Country and  $\xi^2 = 0.75\xi^1$

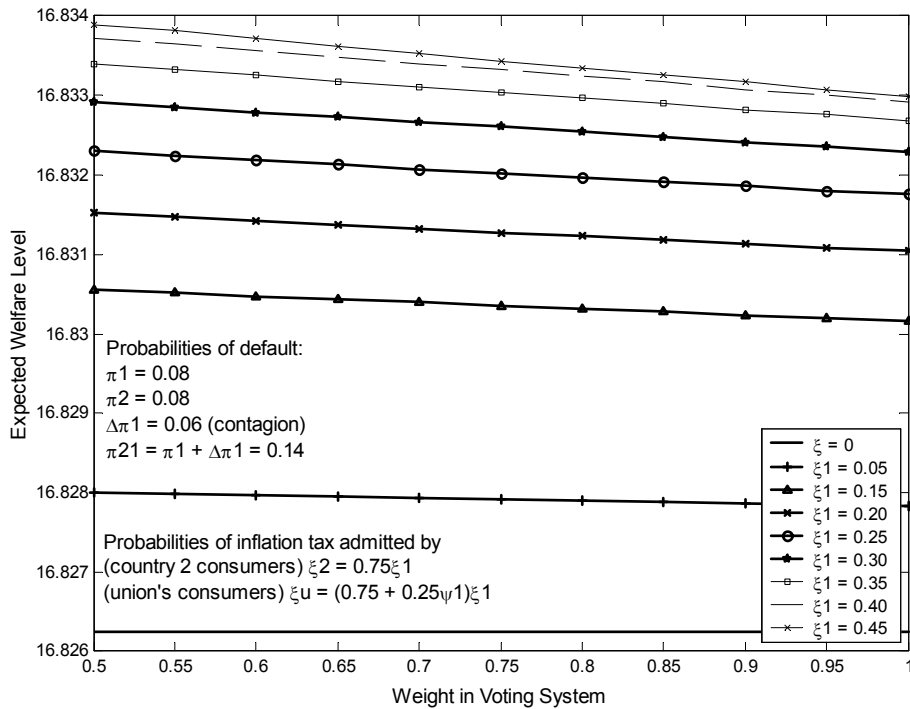


Figure 5: Expected Welfare for High-Weight Country and  $\xi^2 = 1.25\xi^1$

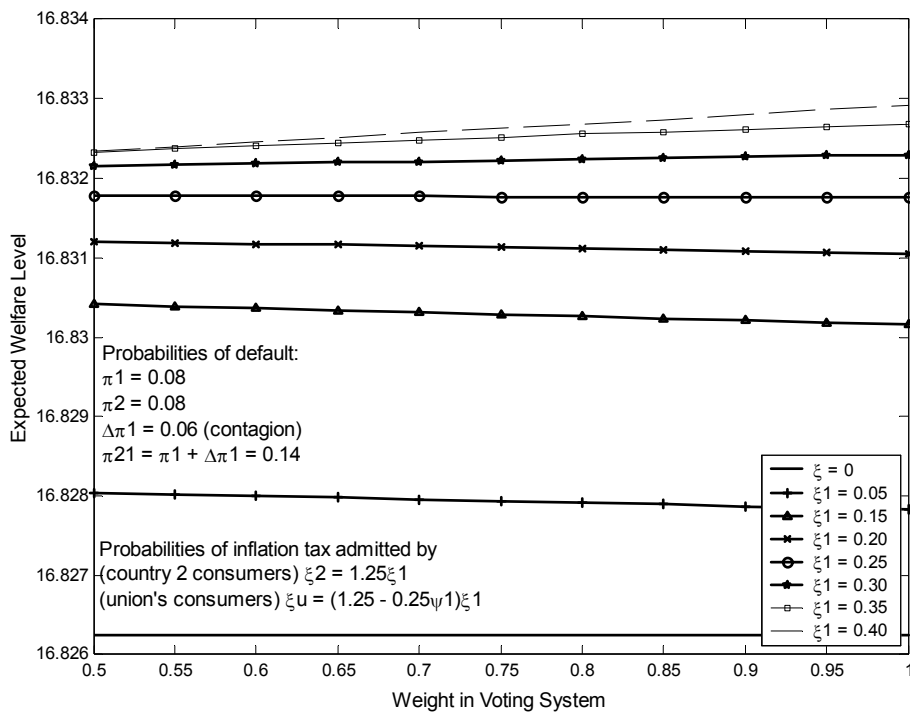


Figure 6: Expected Welfare under Alternative Monetary Regimes

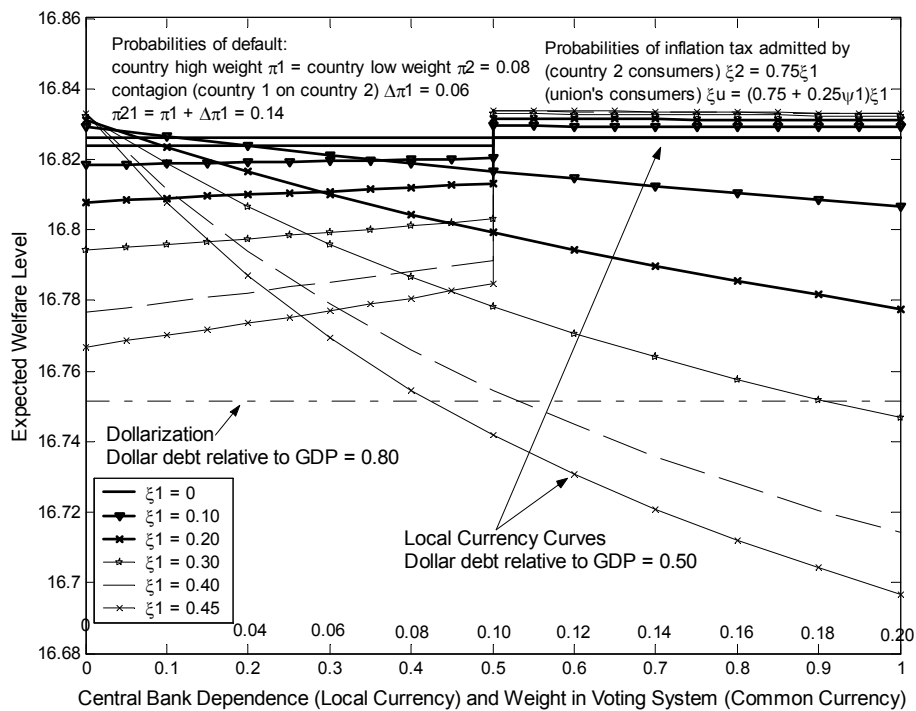


Figure 7: Level Curves for the Welfare of High Weight Country

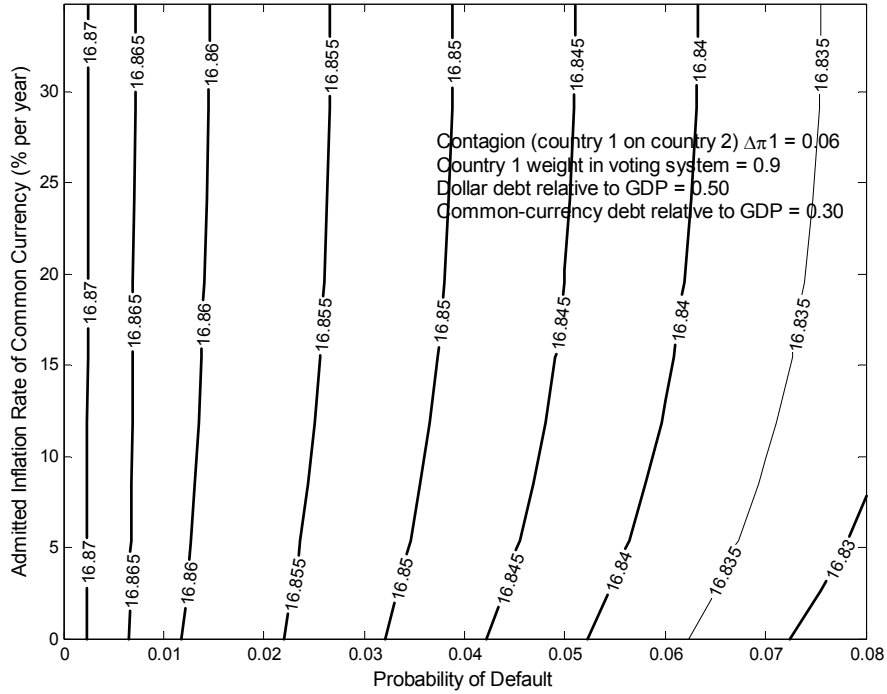


Figure 8: Level Curves for Welfare of Low-Weight Country

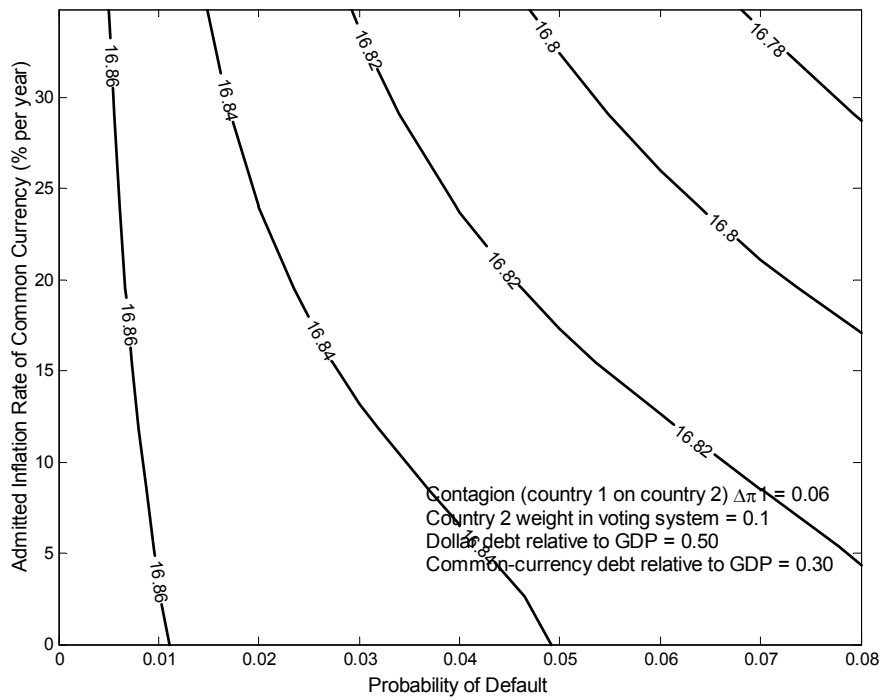
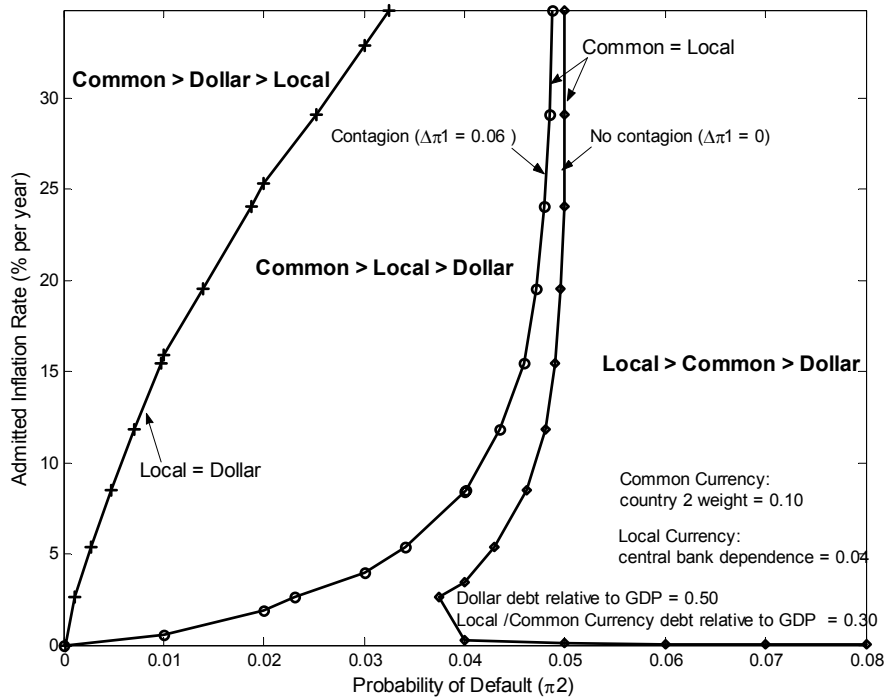


Figure 9: Comparison of Monetary Regimes for a Low-Weight Country



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