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IBMEC RJ ECONOMICS DISCUSSION PAPER 2006-03
Full series available at http://professores.ibmecrj.br/erg/dp/dp.htm.

IMPLICATIONS OF THE MODIGLIANI-MILLER THEOREM FOR THE STUDY OF EXCHANGE RATE REGIMES

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Implications of the Modigliani-Miller Theorem for the Study of Exchange Rate Regimes*†

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Abstract: We extend the Modigliani-Miller Theorem to the composition of the public debt and show that in a deterministic model the structure of a government's assets and liabilities is undetermined. Hence, a floating exchange rate regime can implement any attainable competitive equilibrium. Concerning stochastic economies, if the government issues nominal bonds of several maturities, then the same result may hold. Thus, a conceivable link between floating policies and economic outcomes may be due to factors often not considered in standard macroeconomic models.
Keywords: Modigliani-Miller Theorem, exchange rate regime, indeterminacy.
JEL classification: E42, E58, F31, F41, G32.

1 Introduction

Most economists agree that the implementation of distinct exchange rate regimes will have different consequences on economic variables. Friedman [19], Mundell [34], Calvo [10], Tornell and Velasco [46], Corden [15] and Calvo and Mishkin [11] are good examples of this view. In this paper we show that the nature of a possible mapping from exchange rate policies into macroeconomic performance may be subtler than often assumed.

Fixed and floating are supposed to be the two polar exchange rate regimes. Between these two alternatives, there are many other policy options. The need to characterize

†This paper benefited from comments by Eurilton Araújo, Hector Calvo Pardo, Luciane Carpena, Timothy Kehoe, Emanuel Ornelas, Harald Uhlig and participants of several conferences and seminars. Financial support from the Brazilian Council of Science and Technology (CNPq) is gratefully acknowledged. Of course, the usual disclaimer applies.
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these intermediate policies has demanded some research effort. Moreover, governments often claim to pursue a type of exchange rate policy different from the one they actually implement. Hence, scholars have also been concerned with characterizing and classifying the observed policies. Relevant contributions in this field are Calvo and Reinhart [12], Reinhart and Rogoff [42] and Levy-Yeyati and Sturzenegger [31].

A natural consequence of the notion that different exchange rate regimes lead to distinct outcomes is the emergence of a research line aimed at identifying the empirical regularities associated with each regime. Baxter and Stockman [8] wrote a highly influential paper in this field. More recent efforts in the area are the contributions of Flood and Rose [18], Levy-Yeyati and Sturzenegger [30], Edwards and Levy-Yeyati [17], Husain, Mody and Rogoff [22], Klein and Shambaugh [27], and Ramcharam [41].

The book by Gosh, Gulde and Wolf [21] is a good example of how the literature on exchange rate regimes revolves around the triad theory, classification and stylized facts. In Chapter 3 of that text, the authors surveyed some theoretical issues on the subject. In Chapter 4 they discussed the problem of classifying exchange rate regimes. In Chapter 5 they presented some empirical evidence on exchange rates and some other macroeconomic variables.

The Modigliani-Miller Theorem is the cornerstone of modern corporate finance. This proposition shows that in a frictionless, perfectly competitive world, it is irrelevant whether a firm finances its investments with equity or debt. As we discuss next, the Modigliani-Miller Theorem is also known for having implications for the study of macroeconomic policies.

Barro [6] showed that the initial value and the time path of the public debt are irrelevant if the government has access to lump-sum taxes. As Sargent [43] pointed out, Barro's conclusion can be interpreted as an equivalent of the Modigliani-Miller Theorem for government funding.

Other authors later obtained similar indeterminacy conclusions. Wallace [47] and Chamley and Polemarchakis [13] showed that open market operations between real assets and money would be irrelevant if money was used just for storage of value. Recently, Bassetto and Kocherlakota [7] established the irrelevance of the time path of public debt in a model with taxes levied on income earned in the past. All these authors emphasized the connection of their findings to Modigliani and Miller's proposition. Additionally, Jeanne [23] also pointed out that the study of the structure of countries' external debt and the analysis of the composition of firms' liabilities are closely related problems.

Sargent and Smith [44] derived related indeterminacy results in an open economy setup. They considered a two-country stochastic overlapping generation model with a single storable consumption good. Each country issued its own currency. Governments had access to lump-sum taxes. People and governments traded state contingent claims on the consumption good. Markets were complete. These authors showed that if both currencies were dominated in rate of return by storage, then a government could change its holdings of foreign currency without affecting prices and quantities. The same result was obtained when just one currency was dominated in rate of return. However, in this last case the government could be required to use its lump-sum instruments to rebate earning differentials associated to distinct portfolios.

Backus and Kehoe [4] reached conclusions similar to those of Sargent and Smith [44]. The former authors adopted a many-country stochastic model with a single infinitely lived household in each nation. Each country issued its own money. Cash-in-advance constraints induced people to hold its country money. Lump-sum taxes were not available. Each government issued a set of bonds with state contingent returns denominated in its own currency as well as the other nations currencies. If markets were complete, then the composition of a government portfolio was not determined in a competitive equilibrium. Concerning incomplete markets, the same result could hold, provided that the securities satisfied some spanning condition.

This paper builds on Sargent and Smith [44], Backus and Kehoe [4] and all the literature on the relation between macroeconomic policy and the Modigliani-Miller Theorem. We show that the composition of government assets and liabilities between foreign and domestic instruments can be irrelevant in a competitive equilibrium whenever a government issues risk-free bonds, of different maturities, denominated on its own currency. We then investigate the implications of this conclusion for the study of exchange rate policies.

We adopt a small open economy variation of the cash-credit model of Lucas and Stokey [32]. There exists a single consumption good. People face a cash-in-advance constraint on a fraction of their purchases of that good. Labor is the only input. There are exogenous distorting taxes on labor income. No lump-sum tax or subsidy is available. There is free financial capital mobility. Hence, people and government can purchase and sell, at an exogenous price, a security that pays one unit of a foreign currency. The government issues bonds that pay one unit of the domestic currency. We consider both deterministic and stochastic versions of this economy by letting the government consumption be first exogenous and then aleatory.

Similarly to the Modigliani-Miller Theorem, in a deterministic setup a competitive equilibrium pins down only the total government debt and not its composition. Hence, contrary to the conventional wisdom on exchange rate regimes, competitive equilibrium prices and allocations are consistent with any path for the government's foreign assets. In this sense, it is not relevant whether the exchange rate floats or not.

It is well known that Modigliani and Miller's result holds in a stochastic economy if the markets are complete. Hence, as in Sargent and Smith [44] and in Backus and Kehoe [4], our indeterminacy result should hold in a stochastic economy if the government has access to a sufficiently large set of financial instruments. It turns out that very simple and realistic securities (in the sense that we can easily observe their counterparts in the actual world) are sufficient to ensure that the composition of the government debt is irrelevant. Thus, an important contribution of this paper is to show that these author's findings are consistent with simpler securities than those they considered.

Duffie and Huang [16] established that a set of long-lived securities could replicate the returns of state contingent assets. Later, Angeletos [5] and Buera and Nicolini [9] also showed that noncontingent public debt of several maturities can complete the markets. For this to happen two conditions have to be satisfied. First, at any given date the number of distinct maturities must be equal to or greater than the number of possible states of nature at the next date. Second, at any given date the term structure of the price of the government bonds must be linearly independent across the states of nature.

We build on these authors' findings to extend our indeterminacy result to a stochastic setup. We assume that the government issues bonds of all maturities. These securities are risk free and pay one unit of the domestic currency when redeemed. We show that it is irrelevant whether the exchange rate floats whenever the term structure of the discount rates is linearly independent across the states of nature. We also show that if this last condition is not observed, then the associated competitive equilibrium will be barely distinguishable from one in which the condition in question holds.

The usefulness and relevance of the Modigliani-Miller Theorem come from the fact it establishes a set of sufficient assumptions for a firm's financing choices not to matter. Therefore, anyone who wants to understand why the composition of a firm's capital is significant has to consider models in which some of the assumptions of that classic theorem do not hold. In similar fashion, our indeterminacy results are important because they provide sufficient conditions for the implementation of a floating exchange rate regime to be irrelevant. Comprehending why such a policy can indeed have any impact on economic outcomes requires the adoption of models with features not present in ours here, and most important, in other macroeconomic models as well.

A reader who goes through our proofs will verify that two features of the competitive equilibrium concept are crucial for our results. First, in a purely competitive environment the government is not an active player. Second, in a competitive equilibrium people have no arbitrage opportunities in the securities market. Thus, we could introduce many frictions in our model economy and still obtain our indeterminacy results. Particularly, our findings would survive the introduction of features such as monopolistic competition, price stickiness, price discrimination and so on.

We wish to emphasize that our findings are also robust to different assumptions on the functioning of the international financial markets. The finding that it is irrelevant whether the net public debt is composed of domestic or foreign securities has a corollary: the composition of a country's external debt between private and public debt is irrelevant. Only its total value matters. Hence, we could let the rate at which the country borrows abroad be a function of its total external debt without affecting our conclusions. Likewise, we could relax the postulate that people and government face the same foreign interest rate.

The above discussion suggests that sovereign debt may be important to our understanding of exchange rate policies. The larger the share a government carries of its country's external debt, the larger its motivation to default is. This may cause the interest rate at which the country borrows at to be an increasing function of the government's share of the external debt.

After Modigliani and Miller's [33] seminal essay, many papers addressed the relevance of firms' capital structure. Myers [35] competently surveyed this literature. He pointed out that there are several reasons for capital structure to be relevant. Given the close relation between our results and the Modigliani-Miller Theorem, it is natural that we check whether any of those reasons can also help us to understand why the implementation of a floating exchange rate regime should matter. Among the factors that Myers listed, asymmetric information has been considered in many international finance papers, as in Herrendorf [24], Herrendorf [25] and Atkeson and Kehoe [3].

An important feature of the competitive environment that we used without comment is the absence of optimizing behavior by the government. For this reason the structure of government debt is undetermined in a competitive equilibrium. However, Lucas and Stokey [32], Alvarez, Kehoe and Neumeyer [2] and Persson, Persson and Svensson [40] pointed out that the composition and maturity of government debt matters for the time consistency of monetary policy. On the other hand, Giavazzi and Pagano [20], Obstfeld [38] and Obstfeld and Rogoff [39] pointed out the relevance of time consistency factors for several exchange rate crises. Backus and Kehoe [4] also mentioned that the set of implementable policies depends on the composition of the government debt. Clearly, if the government optimally selects policies in a sequential fashion, then it will matter whether a floating regime is in place or not.

The findings we present in this paper have consequences for both theoretical and empirical work on exchange rate regimes. We start with its theoretical implications. So far, fixed and floating have been considered polar regimes. However, we show that if a government can commit to a macroeconomic policy, then a floating exchange rate regime can be consistent with many outcomes. As far as we know, this fact has been overlooked in the literature concerning exchange rate regimes. As a consequence of this finding, models in which the government is able to credibly commit to a policy and agents have full information are unlikely to help us understand the connection between the exchange rate and other economic variables.

Exchange rate crises are not the focus of this paper. However, it does shed some light on this subject. Concerning first-generation models, our indeterminacy results show that a currency crisis similar to the ones described in Krugman [28] and Obstfeld [37] can take place under a floating regime. The same conclusion applies to third-generation models. For this reason, Aghion, Bacchetta and Banerjee [1] concluded that a crisis could happen under a floating regime in their model. Only second-generation models can display a link between exchange rate crisis and the composition and maturity of the public debt.

To the extent that empirical research should provide guidance to theory, papers aimed at classifying exchange rate regimes and documenting the stylized facts associated with them should, whenever possible, also consider variables related at some level with the degree of information asymmetry and government incentives. For instance, the ratio of short- to long-term public debt could be used as a control for time consistency issues in an empirical analysis of exchange rate regimes and economic growth. In other words, observations of just standard variables such as exchange rate devaluation, nominal interest rate, GDP growth rate and so on are unlikely to provide an accurate picture of the relation between exchange rate policy and economic performance. It is necessary to obtain some information on the underlying game played by governments and other agents that generated the sample being studied.

This paper is organized as follows. In Section 2 we obtain our competitive equilibrium indeterminacy results in a deterministic model. In Section 3 we obtain equivalent conclusions in a stochastic model. In Section 4 we present our concluding remarks.

2 A deterministic economy

Consider a small country populated by a single infinitely lived household and a government. The household is composed of a shopper and a worker. The latter is endowed with one unit of time.

This country produces a single good. The household and the government consume that good. The respective amounts they consume are denoted by c and g. The country also exports or imports this good; x denotes the amount exported. A negative value for x means that the country is importing the good.

Markets operate in a particular way. At a first stage of each date t, a spot market for the consumption good and labor services operates. At a second stage, after that market closes, a securities and currency market operates.[1]

A domestic currency M circulates in this economy. Two types of securities are traded: a claim B, with maturity of one period, to one unit of M and a claim A, with the same maturity, to one unit of some foreign currency. Foreigners do not sell or buy claims to the domestic currency. The government and household can purchase and/or sell the claims A at a price of q_t^* units of the foreign currency.

The worker cannot sell her services outside the country. The shopper faces a cash-in-advance constraint. A fraction of his purchases of the consumption good must be paid for with the domestic currency. Except for these cash purchases, all other transactions

[1] See Nicolini [36] and Svensson [45] for further details on this timing convention. The results presented in this paper do not depend on that particular assumption.

are settled during the securities and currency trading session. The date t price, in terms of the foreign currency, of the tradable good is constant and equal to 1.

A single competitive firm produces the consumption good. Technology is described by $0 \leq y \leq l$, where y is the output and l is the amount of time allocated to production. Feasibility requires

$$c_{1t} + c_{2t} + g_t + x_t = l_t \ , \tag{1}$$

where t denotes time, c_{1t} denotes the consumer's purchases of the consumption good that is paid in cash and c_{2t} denotes the remaining purchases of the consumption good.

The government finances the sequence $\{g_t\}_{t=0}^{\infty}$ by issuing and withdrawing domestic currency; by issuing and redeeming claims B; by purchasing and selling A; and by taxing labor income at a proportional tax τ. The sequence $\{g_t, \tau_t, q_t^*\}_{t=0}^{\infty}$ is exogenous. For each t, the vector (g_t, τ_t, q_t^*) belongs to a finite set contained in $[0,1)^2 \times (0,1)$.

The government budget constraint is

$$S_t g_t + M_t + B_t + S_t q_t^* A_{G,t+1} = \tau_t w_t l_t + M_{t+1} + q_t B_{t+1} + S_t A_{G,t} \ , \tag{2}$$

where w_t and q_t are the respective date t monetary prices (in terms of the domestic currency) of labor services and the domestic claim; S_t is the nominal exchange rate; $A_{G,t+1}$ stands for the foreign assets the government holds at the end of date t; and M_{t+1} and B_{t+1} are the amounts of domestic currency and public debt that people hold at the end of date t. A negative value for $A_{G,t+1}$ means that the government is borrowing abroad, while a negative value for B_{t+1} means that the government is lending to the household. At $t = 0$ the government holds an initial amount $\bar{A}_G$ of foreign assets.

Let $A_{H,t+1}$ stand for the foreign assets the household carries at the end of date t. To avoid Ponzi schemes, we impose the borrowing constraints

$$\left| \frac{B_{t+1}}{S_{t+1}} \right|, |A_{H,t+1}|, |A_{G,t+1}| \leq K < \infty \tag{3}$$

on asset holdings. As usual, K is some real number large enough so that these constraints never bind in equilibrium.

The function $u : \mathbb{R}_+^2 \times [0,1] \to \mathbb{R} \cup \{-\infty\}$, $u = u(c_1, c_2, 1 - l)$ is the household period utility function. This function displays local non-satiability and satisfies standard differentiability and Inada conditions. Intertemporal preferences are described by

$$\sum_{t=0}^{\infty} \beta^t u(c_{1t}, c_{2t}, 1 - l_t) \ , \tag{4}$$

where $\beta \in (0,1)$. The household's date t budget constraint is

$$S_t(c_{1t}+c_{2t})+M_{t+1}+q_tB_{t+1}+S_tq_t^*A_{H,t+1}\leq(1-\tau_t)w_tl_t+M_t+B_t+S_tA_{H,t}\ , \qquad (5)$$

while the cash-in-advance constraint is

$$S_tc_{1t}\leq M_t\ . \qquad (6)$$

At date zero, given initial asset holdings $(\bar{M},\bar{B},\bar{A}_H)$, the household chooses a sequence $\{c_{1t},c_{2t},l_t,M_{t+1},B_{t+1},A_{H,t+1}\}_{t=0}^{\infty}$ to maximize (4) subject to the constraints (3), (5), (6), and $l_t\leq 1$. Except for B_{t+1} and $A_{H,t+1}$, all these variables must be non-negative. Additionally, the sequences $\{c_{1t}\}_{t=0}^{\infty}$, $\{c_{2t}\}_{t=0}^{\infty}$ and $\{M_{t+1}/S_{t+1}\}_{t=0}^{\infty}$ have to be bounded. At each period t, the firm chooses l_t to maximize $S_tl_t-w_tl_t$.

Let us establish some notation. We denote a date t price vector (S_t,w_t,q_t) by ψ_t and a date t bundle (c_{1t},c_{2t},l_t) by χ_t, while φ_{t+1} stands for the household's end-of-period t asset holdings $(M_{t+1},B_{t+1},A_{Ht+1})$. Additionally, $(\psi,\chi,\varphi)=\{\psi_t,\chi_t,\varphi_{t+1}\}_{t=0}^{\infty}$.

Definition 1 *A* competitive equilibrium *is an object* $[\psi,\chi,\varphi,\{A_{G,t+1}\}_{t=0}^{\infty},\{x_t\}_{t=0}^{\infty}]$ *that satisfies: (i) given* ψ*,* (χ,φ) *provides a solution for the household problem; (ii)* $w_t=S_t$*; (iii) (1) and (2) hold.*

A balance-of-payment condition was not spelled out in definition 1. It is not necessary to do so. Observe that by adding the zero-profit condition $w_tl_t=S_t(c_{1t}+c_{2t}+g_t+x_t)$ to (2) and (5), taken as equality, one obtains

$$x_t+A_{G,t}+A_{H,t}-q_t^*(A_{G,t+1}+A_{H,t+1})=0\ , \qquad (7)$$

which is the balance-of-payments identity of this model economy.

As usual in small open-economy models, a competitive equilibrium must satisfy a condition that rules out arbitrage between domestic and foreign assets. That is, the nominal exchange rate and domestic and foreign bond prices must satisfy the parity condition

$$S_tq_t^*=S_{t+1}q_t\ . \qquad (8)$$

We are now in a position to establish that the composition of government debt between domestic and foreign bonds is irrelevant in a competitive equilibrium.

Proposition 2 *Let* $[\psi,\chi,\varphi,\{A_{G,t+1}\}_{t=0}^{\infty},\{x_t\}_{t=0}^{\infty}]$ *be a competitive equilibrium. If the sequence of foreign assets* $\{A'_{G,t+1}\}_{t=0}^{\infty}$ *is bounded, then there exists a portfolio* φ' *such that* $[\psi,\chi,\varphi',\{A'_{G,t+1}\}_{t=0}^{\infty},\{x_t\}_{t=0}^{\infty}]$ *is a competitive equilibrium.*

Proof. We start by constructing the sequence φ'. For each t, set $M'_{t+1} = M_{t+1}$ and $A'_{H,t+1} = A_{H,t+1} + A_{G,t+1} - A'_{G,t+1}$. Define $\{B'_{t+1}\}_{t=0}^{\infty}$ to satisfy

$$B'_{t+1} + S_{t+1}A'_{H,t+1} = B_{t+1} + S_{t+1}A_{H,t+1} \ . \tag{9}$$

We now show that $[\psi, \chi, \varphi', \{A'_{G,t+1}\}_{t=0}^{\infty}, \{x_t\}_{t=0}^{\infty}]$ is a competitive equilibrium. The first step in this process consists of showing that φ' satisfies the borrowing bounds in (3). The sequence $\{A'_{G,t+1}\}_{t=0}^{\infty}$ respects that constraint by assumption. The boundedness of $\{A'_{H,t+1}\}_{t=0}^{\infty}$ and $\{B'_{t+1}/S_{t+1}\}_{t=0}^{\infty}$ follows from the inequalities $|A'_{H,t+1}| \leq |A_{H,t+1}| + |A_{G,t+1}| + |A'_{G,t+1}|$ and $|B'_{t+1}/S_{t+1}| \leq |B_{t+1}/S_{t+1}| + |A_{H,t+1}| + |A'_{H,t+1}|$.

Let us now show that (χ, φ') satisfies the budget constraint (5) of a typical household. Combine (9) with (8) to obtain

$$q_t B'_{t+1} + S_t q_t^* A'_{H,t+1} = q_t B_{t+1} + S_t q_t^* A_{H,t+1} \ . \tag{10}$$

Since the household can afford (χ, φ), (9) lagged by one period and (10) imply that the same is true for (χ, φ').

We are now able to conclude the proof. Concerning item (i) of Definition 1, the pair (χ, φ') yields the same lifetime utility as (χ, φ). So, the former is an optimal choice for the household when the prevailing price system is ψ. Clearly, ψ satisfies (ii). With respect to item (iii), χ and $\{x_t\}_{t=0}^{\infty}$ obviously satisfy (1). Moreover, we constructed φ' so that $A'_{H,t+1} + A'_{G,t+1} = A_{H,t+1} + A_{G,t+1}$. Thus, $\{x_t\}_{t=0}^{\infty}$ and φ' satisfy (7). We combine that condition with (1) and (5) with equality to conclude that (2) holds. □

We now turn to the task of providing some intuition to the above result. As we have previously argued, Proposition 2 has a Modigliani-Miller like flavor. In a perfectly competitive environment with full information, whether a firm finances its investment projects with equity or debt is irrelevant. In similar fashion, it does not matter whether the government finances its transitory deficits by issuing domestic or foreign bonds.

There is a second way to view Proposition 2. Lucas and Stokey [32] studied optimal fiscal policies in a one-sector closed economy. They allowed the government to issue debt of all maturities. They showed that any competitive equilibrium pins down only the present value of the public debt, but not its composition. Chari and Kehoe [14] reached the same conclusion. Proposition 2 shows that only the total value of the public debt matters. Its composition between domestic and foreign bonds is irrelevant.

Arbitrage opportunities are ruled out in a competitive equilibrium. This fact provides an alternative interpretation of Proposition 2. Equation (8) ensures that people are indifferent between domestic and foreign bonds. This allows the government to change the composition of its debt $B_t - S_t A_{Gt}$ without affecting its value. For instance, the government can sell abroad Δ units of foreign currency denominated bonds. Simultaneously, people sell to the government $S_t q_t^* \Delta / q_t$ units of domestic debt and use the proceeds to buy exactly Δ units of foreign bonds. This operation does not change the wealth of the government, people or foreigners.

Kareken and Wallace [26] showed, in a two-country model, that if the two currencies are perfect substitutes, then the exchange rate path is undetermined. Clearly, the indeterminacy in Proposition 2 is of a different type.

Usually the exchange rate is said to float if the government does not intervene in the foreign exchange market. That is, the government carries a constant amount of foreign assets. The next definition follows this tradition.

Definition 3 *Given a competitive equilibrium, the exchange rate* floats at t *if* $A_{G,t+1} = A_{G,t}$, *it* never floats *if* $A_{G,t+1} \neq A_{G,t}$ *for every date* t *and it* permanently floats *if* $A_{G,t+1} = \bar{A}_G$ *for all* t.

A permanent float is a stronger requirement than a transitory one. This poses an additional challenge to the study of floating regimes. If the adoption of this type of policy is to have some real effects, those effects are unlikely to be the same for both transitory and permanent floats. However, for any finite sample we obtain from an actual economy, we will not be able to distinguish with certainty between a transitory and a permanent float. Therefore, we may be compelled to treat in a homogenous way data generated by distinct government policies.

Corollary 4 *Suppose that* (ψ, χ, φ), $\{A_{G,t+1}\}_{t=0}^{\infty}$ *and* $\{x_t\}_{t=0}^{\infty}$ *constitute a competitive equilibrium. Then, there exist sequences* $\{A_{G,t+1}^F\}_{t=0}^{\infty}$, φ^F, $\{A_{G,t+1}^N\}_{t=0}^{\infty}$ *and* φ^N *that satisfy: (1)* $[\psi, \chi, \varphi^F, \{A_{G,t+1}^F\}_{t=0}^{\infty}, \{x_t\}_{t=0}^{\infty}]$ *is a competitive equilibrium in which the exchange rate permanently floats; and (2)* $[\psi, \chi, \varphi^N, \{A_{G,t+1}^N\}_{t=0}^{\infty}, \{x_t\}_{t=0}^{\infty}]$ *is a competitive equilibrium in which the exchange rate never floats.*

Proof. Set $A_{G,t+1}^F = \bar{A}_G$ and $A_{G,t+1}^N = \bar{A}_G + (-1)^{t+1}\delta$, where δ is any real number. Then, apply Proposition 2 to obtain the desired conclusions. □

We now apply our findings in two examples that discuss some classic issues in international finance.

Example 5 (Speculative Attack) Suppose that the government of our artificial economy fixes the exchange rate at some level $\bar{S}$. Suppose that the fiscal variables are given by $\tau_t = 0$ and $g_t = g > 0$ for every date t, while $\bar{A}_G > 0$. Suppose that the government finances its fiscal deficit by gradually selling its foreign assets. Clearly, that combination of fiscal deficit and fixed exchange rate cannot last indefinitely. Moreover, as in Krugman [28] and Obstfeld [37], the collapse of the pegging policy and the ensuing devaluation will entail a speculative attack at some date $T < \infty$. We can apply Corollary 4 to conclude that this outcome is fully consistent with a permanent float.

In a such an alternative competitive equilibrium the government will finance its deficit by gradually issuing domestic debt. After date T the government will fail to place any newly issued debt. Hence, the exchange rate depreciation will appear to be a side effect of a confidence crisis that worsened the government's ability to manage the public debt. Observe that we deliberately used the expressions 'devaluation' for the first competitive equilibrium and 'depreciation' for the second one. Recall that the former concept is usually associated to an increase in the nominal exchange rate induced by government actions, while the latter is used to denote a similar increment in a floating regime. Of course, there is hardly any distinction between the two concepts in this context.

Example 6 (Currency Board) Assume now that the government of our artificial economy successfully implements a currency board at date zero and permanently pegs its currency to the US dollar. Needless to say, to avoid a speculative attack the fiscal policy must be consistent with the pegging. Suppose that the government often purchases or sells foreign currency to its nationals, so that $A_{G,t}$ is never constant. We can apply Corollary 4 to conclude that the same exchange rate path is fully consistent with a permanent float. In this alternative equilibrium, open market operations induce the currency stability. Under the currency board arrangement, the pegged exchange rate seems to be mostly a consequence of direct government interventions in the exchange market. Under the alternative policy, the currency stability appears to be a natural consequence of sound monetary and fiscal fundamentals. However, the two policy regimes are virtually equivalent.

The implications of adopting an exchange rate regime are the basis of an old debate in international finance. Relatively recent contributions on this topic are the papers of Calvo [10] and Lahiri, Singh and Végh [29]. Those two essays evaluate the implications of adopting either a fixed or floating regime and concluded that each regime would lead to distinct outcomes. However, we showed in Corollary 4 that a floating regime is consistent with any outcome. Our results differ from those of Calvo and Lahiri, Singh and Végh because those authors assumed that the floating regime was combined with a monetary policy that kept the money supply constant. Hence, the implications they attributed to the floating regime were, at least partially, induced by other features of the macroeconomic policy.

As we have already mentioned, Backus and Kehoe [4] obtained results similar to our Proposition 2 in a many-country model. They then argued that regressing the exchange rate or interest rate differentials on some proxy for the currency denomination of the public debt was not a very informative exercise, since this last variable was undetermined in a competitive equilibrium. We take their reasoning a little further to conclude that unless we have data on variables that shed light on informational issues or the strategic interaction between government and private agents, an empirical analysis of exchange rate policies is likely to miss some crucial feature of the possible relation between these policies and other macroeconomic variables.

3 A stochastic economy

In this section we show that if the government can issue risk-free bonds of different maturities, then a result similar to Proposition 2 holds in a stochastic model. For simplicity, we assume that government consumption is the only source of uncertainty.

Let $\{g_t\}_{t=1}^{\infty}$ be a random sequence on some probability space. Each g_t has a finite support $\mathbb{G} = \{\gamma_1, \gamma_2, ..., \gamma_n\} \subset [0, 1)$. We denote the t-fold Cartesian product of $\mathbb{G}$ by $\mathbb{G}^t$. The realization of g_t is known at the beginning of date t. This formulation implicitly assumes that at $t = 0$ all agents already know g_0. The variable g^t denotes the history of realizations $(g_1, g_2, ..., g_t)$. By convention, $g^0 = g_0$ and $\mathbb{G}^0 = \{g^0\}$. For a given g^t, $\mu(g^t)$ denotes the probability that the particular history g^t will happen.

Let us now show that if, as in the previous section, the government can issue only bonds denominated in the domestic currency with maturity of one period, then Proposition 2 does not hold in a stochastic setup. Let $A_H(g^t)$ and $B(g^t)$ denote, respectively, the amounts of foreign and domestic bonds the household holds at the end of date t, contingent on history g^t. Other variables indexed by g^t have similar meanings.

As the proof of Proposition 2 makes clear, the portfolios φ and φ' should leave the household with the same wealth at every period t. That is, φ' must satisfy (9). In a stochastic environment, a similar condition must hold at every node g^t of the event tree. Hence, the equality

$$B'(g^t) = B(g^t) + S(g^t, g_{t+1})[A_H(g^t) - A'_H(g^t)] \tag{11}$$

should hold for all g^t and g_{t+1}.

Recall that given $A'_G(g^t)$, a balance-of-payments constraint determines the value of $A'_H(g^t)$. Thus, it will not be possible to select a single value for $B'(g^t)$ that satisfies (11) for all possible realizations of g_{t+1} unless $S(g^t, g_{t+1})$ does not depend on g_{t+1}. Of course, there is no reason for this last condition to hold.

An obvious way of circumventing the above problem consists of indexing the returns of the domestic bonds to the nominal exchange rate S.[2] However, most macroeconomists would agree that a government that is selling foreign-currency denominated debt to its nationals is intervening in the exchange market. Therefore, allowing the government to issue this type of bond would not be consistent with the spirit of Proposition 2 and

[2] Of course, allowing the government to sell state contingent bonds would also be a solution. However, since S depends on g_t, for the purposes of this paper such a solution would be equivalent to indexing the domestic debt to the nominal exchange rate.

Corollary 4.

Summarizing the above discussion, we want to generalize Proposition 2 and Corollary 4 without introducing an assumption that violates the spirit of these results or is inconsistent with the usual policy instruments observed in the actual world. It turns out that all that is required is to allow for public debt with varied maturities. As Duffie and Huang [16], Angeletos [5] and Buera and Nicolini [9] pointed out, government bonds with distinct maturities can act as substitutes for state contingent assets.

Consider a situation in which $\mathbb{G} = \{\gamma_1, \gamma_2\}$. Suppose now that the government issues debt with maturities of one and two periods. Let $B_k(g^t)$ denote the debt that matures at $k \geq t$ outstanding at the end of period t (conditional on history g^t) and $q_k(g^t)$ the date t price (conditional on g^t) of $B_k(g^t)$. Of course, $q_t(g^t) = 1$. In such a context, the equivalent of (11) is

$$\begin{gathered} B'_{t+1}(g^t) + q_{t+2}(g^t, g_{t+1}) B'_{t+2}(g^t) = \\ B_{t+1}(g^t) + q_{t+2}(g^t, g_{t+1}) B_{t+2}(g^t) + S(g^t, g_{t+1})[A_H(g^t) - A'_H(g^t)] \ . \end{gathered} \tag{12}$$

Define the matrix $\bar{\mathbf{Q}}(g^t)$ according to

$$\bar{\mathbf{Q}}(g^t) = \begin{bmatrix} 1 & q_{t+2}(g^t, \gamma_1) \\ 1 & q_{t+2}(g^t, \gamma_2) \end{bmatrix} \ .$$

If $\bar{\mathbf{Q}}(g^t)$ has an inverse, then (12) implies that

$$\begin{bmatrix} B'_{t+1}(g^t) \\ B'_{t+2}(g^t) \end{bmatrix} = [\bar{\mathbf{Q}}(g^t)]^{-1} \begin{bmatrix} B_{t+1}(g^t) + q_{t+2}(g^t, \gamma_1) B_{t+2}(g^t) + S(g^t, \gamma_1)[A_H(g^t) - A'_H(g^t)] \\ B_{t+1}(g^t) + q_{t+2}(g^t, \gamma_2) B_{t+2}(g^t) + S(g^t, \gamma_2)[A_H(g^t) - A'_H(g^t)] \end{bmatrix} .$$

Hence, we can find bond holdings $B'_{t+1}(g^t)$ and $B'_{t+2}(g^t)$ so that (12) holds for all g^t and g_{t+1} if and only if $\bar{\mathbf{Q}}(g^t)$ has full rank. This condition is satisfied if and only if $q_{t+2}(g^t, \gamma_1) \neq q_{t+2}(g^t, \gamma_2)$. That is, the government debt is not discounted at the same rate in two different states.

As Angeletos [5] and Buera and Nicolini [9] pointed out, the requirement that $\bar{\mathbf{Q}}(g^t)$ be of full rank has an obvious analogy with the definition of complete markets. These authors also showed that the full rank requirement is not a very restrictive one.

We now turn to the task of describing the environment we consider in this section. The economy is very similar to the one in Section 2. We keep the assumption that $\{\tau_t\}_{t=0}^{\infty}$ and $\{q_t^*\}_{t=0}^{\infty}$ are deterministic sequences. We assume that the government issues bonds of all maturities. The equivalent of (1) is

$$c_1(g^t) + c_2(g^t) + g_t + x(g^t) = l(g^t) \ .$$

The balance-of-payment and government budget constraints are, respectively,

$$x(g^t) + A_G(g^{t-1}) + A_H(g^{t-1}) - q_t^*[A_G(g^t) + A_H(g^t)] = 0$$

and

$$S(g^t)g_t + M(g^{t-1}) + \sum_{k=t}^{\infty} q_k(g^t)B_k(g^{t-1}) + S(g^t)q_t^* A_G(g^t) =$$
$$\tau_t w(g^t)l(g^t) + M(g^t) + \sum_{k=t+1}^{\infty} q_k(g^t)B_k(g^t) + S(g^t)A_G(g^{t-1}) \ .$$

To rule out Ponzi games, asset holdings have to satisfy

$$\left| \frac{\sum_{k=t+1}^{\infty} q_k(g^t)B_k(g^t)}{S(g^t, g_{t+1})} \right|, |A_{H,t+1}|, |A_{G,t+1}| \leq K < \infty \ . \tag{13}$$

The household maximizes

$$\sum_{t=0}^{\infty} \sum_{g^t \in \mathbb{G}^t} \beta^t \mu(g^t) u\left(c_1(g^t), c_2(g^t), 1 - l(g^t)\right)$$

subject to $S(g^t)c_1(g^t) \leq M(g^{t-1})$, $l(g^t) \leq 1$, (13), and

$$S(g^t)[c_1(g^t) + c_2(g^t)] + M(g^t) + \sum_{k=t+1}^{\infty} q_k(g^t)B_k(g^t) + S(g^t)q_t^* A_H(g^t) \leq \tag{14}$$
$$(1 - \tau_t)w(g^t)l(g^t) + M(g^{t-1}) + \sum_{k=t}^{\infty} q_k(g^t)B_k(g^{t-1}) + S(g^t)A_H(g^{t-1}) \ .$$

The firm's problem is to maximize $S(g^t)l(g^t) - w(g^t)l(g^t)$.

As in Section 2, we define $\psi = \{[S(g^t), w(g^t), \{q_k(g^t)\}_{k=t+1}^{\infty}]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ and attach corresponding meanings to χ and φ. We then define a *competitive equilibrium* to be a list of arrays (ψ, χ, φ), $\{[A_G(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ and $\{[x(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ that satisfy conditions equivalent to those of Definition 1.

Recall that $\mathbb{G} = \{\gamma_1, \gamma_2, ..., \gamma_n\}$. For each g^t, define the matrix $\mathbf{Q}(g^t)$ according to

$$\mathbf{Q}(g^t) = \begin{bmatrix} 1 & q_{t+2}(g^t, \gamma_1) & q_{t+3}(g^t, \gamma_1) & \cdots \\ 1 & q_{t+2}(g^t, \gamma_2) & q_{t+3}(g^t, \gamma_2) & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ 1 & q_{t+2}(g^t, \gamma_n) & q_{t+3}(g^t, \gamma_n) & \cdots \end{bmatrix} .$$

To obtain the results we are after, we need $\mathbf{Q}(g^t)$ to have rank n. That is, the term structure of the discount rates must be linearly independent across the histories g^t.

Proposition 7 *Let* (ψ, χ, φ), $\{[A_G(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ *and* $\{[x_t(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ *constitute a competitive equilibrium in which the rank of* $\mathbf{Q}(g^t)$ *equals* n *for all* g^t*. If* $\{[A'_G(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ *is bounded, then there exists a portfolio* φ' *such that* (ψ, χ, φ'), $\{[A'_G(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ *and* $\{[x_t(g^t)]_{g^t \in \mathbb{G}^t}\}_{t=0}^{\infty}$ *constitute a competitive equilibrium.*

Proof. First, observe that since $\mathbf{Q}(g^t)$ has rank n, there exists a set $\mathbb{T}(g^t) = \{t_1, t_2, ..., t_n\}$ of n dates such that the matrix

$$\mathbf{Q}_{\mathbb{T}}(g^t) = \begin{bmatrix} q_{t_1}(g^t, \gamma_1) & ... & q_{t_n}(g^t, \gamma_1) \\ \vdots & \vdots & \vdots \\ q_{t_1}(g^t, \gamma_n) & ... & q_{t_n}(g^t, \gamma_n) \end{bmatrix}$$

has an inverse. From now on, we adopt the same reasoning we used in the proof of Proposition 2. For each g^t, set $M'(g^t) = M(g^t)$ and $A'_H(g^t) = A_H(g^t) + A_G(g^t) - A'_G(g^t)$. We still have to define the debt holdings $\{B'_k(g^t)\}_{k=t+1}^{\infty}$. We proceed as follows. If $k \notin \mathbb{T}(g^t)$, then we set $B'_k(g^t) = 0$. The remaining bond holdings are given by

$$\begin{bmatrix} B'_{t_1}(g^t) \\ \vdots \\ B'_{t_n}(g^t) \end{bmatrix} = \left[\mathbf{Q}_{\mathbb{T}}(g^t)\right]^{-1} \begin{bmatrix} \kappa_1(g^t) \\ \vdots \\ \kappa_n(g^t) \end{bmatrix},$$

where $\kappa_i(g^t) = \sum_{k=t+1}^{\infty} q_k(g^t, \gamma_i) B_k(g^t) + S(g^t, \gamma_i)[A_H(g^t) - A'_H(g^t)]$.

The argument we used in Proposition 2 shows that φ' satisfies (13). To show that (χ, φ') satisfies the budget constraint (14), note that the first-order conditions for $A_H(g^t)$ and $B_k(g^t)$ are

$$\lambda(g^t) q_k(g^t) = \sum_{g_{t+1} \in \mathbb{G}} \lambda(g^t, g_{t+1}) q_k(g^t, g_{t+1}) \tag{15}$$

$$\lambda(g^t) S(g^t) q_t^* = \sum_{g_{t+1} \in \mathbb{G}} \lambda(g^t, g_{t+1}) S(g^t, g_{t+1}), \tag{16}$$

where $\lambda(g^t)$ is a Lagrange multiplier for (14).

We defined φ' so that

$$\sum_{k=t+1}^{\infty} q_k(g^t, g_{t+1}) B'_k(g^t) + S(g^t, g_{t+1}) A'_H(g^t) = \tag{17}$$
$$\sum_{k=t+1}^{\infty} q_k(g^t, g_{t+1}) B_k(g^t) + S(g^t, g_{t+1}) A_H(g^t)$$

holds for all g^t and g_{t+1}. Multiply both sides of this equation by $\lambda(g^t, g_{t+1})$, add over g_{t+1} and combine the resulting equality with (15) and (16) to obtain

$$\sum_{k=t+1}^{\infty} q_k(g^t)B'_k(g^t) + S(g^t)q_t^* A'_H(g^t) = \sum_{k=t+1}^{\infty} q_k(g^t)B_k(g^t) + S(g^t)q_t^* A_H(g^t) \ . \tag{18}$$

On the other hand, (17) lagged by one period yields

$$\sum_{k=t}^{\infty} q_k(g^t)B'_k(g^{t-1}) + S(g^t)A'_H(g^{t-1}) = \sum_{k=t}^{\infty} q_k(g^t)B_k(g^{t-1}) + S(g^t)A_H(g^{t-1}) \ . \tag{19}$$

Since φ' respects both (18) and (19), the pair (χ, φ') is affordable. The remainder of the proof is identical to that of Proposition 2. □

As we have previously mentioned, Proposition 7 is closely related to the results of Sargent and Smith [44] and Backus and Kehoe [4]. Therefore, we must clearly compare our contribution to the findings of those authors.

The key difference between Proposition 7 and Backus and Kehoe's conclusions lies in the assumption on the available debt instruments. They considered a many-country model in which each government would issue state contingent bonds denominated in its own currency and all other currencies, while we only allow the government to issue risk-free bonds denominated on its own currency. As a side comment, our assumptions on debt instruments have the advantage of establishing that irrelevance results such as Backus and Kehoe's and ours do not require a government to issue bonds identical to those traded in the international financial markets.

Let us now compare our findings with those of Sargent and Smith. We can interpret equation (18) as a constraint that an open market operation has to fulfill so that it does not impact equilibrium prices and real variables. Observe that the traders in such an operation are the government and its nationals. As we detail next, this is an important departure from Sargent and Smith's conclusions.

These authors considered a two-country overlapping generation model with two moneys. They only studied equilibria in which at least one currency was dominated in rate of return. A subtle consequence of their assumptions on traders, assets and markets is that an open market operation as described in the previous paragraph could not take place. If both currencies were dominated in rate of return, an open market operation that did not affect equilibrium prices and allocation would require the two governments to cooperate. If just one currency was dominated in rate of return, such an open market operation would require some fiscal intervention to compensate for earnings resulting from changes in agents' portfolios.

Definition 8 *Given a competitive equilibrium and a history* g^∞*, the exchange rate* floats at t *if* $A_G(g^{t-1}) = A_G(g^t)$*, it* permanently floats *if* $A_G(g^t) = \bar{A}_G$ *for all* t *and it* never floats *if* $A_G(g^{t-1}) \neq A_G(g^t)$ *for all* t*. Given a competitive equilibrium, the exchange rate* uniformly floats *if it permanently floats for all histories* g^∞*.*

The first three concepts in the above definition are the natural extension of their counterparts in the deterministic model. The last one is a stronger notion. Notice that we would not be able to distinguish a permanent from a uniform float with certainty even if we had a sample of infinite size of the foreign assets A_G. This fact magnifies the regime identification problem we discussed right after Definition 3.

Corollary 9 *Let* $[\psi, \chi, \varphi, \{[A_G(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty, \{[x_t(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty]$ *be a competitive equilibrium in which* $\mathbf{Q}(g^t)$ *is of full rank for all* g^t*. Then, there are arrays* $\{[A_G^F(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$*,* φ^F*,* $\{[A_G^N(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ *and* φ^N *that satisfy: (1)* ψ*,* χ*,* φ^F*,* $\{[A_G^F(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ *and* $\{[x_t(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ *constitute a competitive equilibrium in which the exchange rate uniformly floats; and (2)* ψ*,* χ*,* φ^N*,* $\{[A_G^N(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ *and* $\{[x_t(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ *constitute a competitive equilibrium in which the exchange rate never floats for every history* g^∞*.*

Proof. Set $A_G^F(g^t) = \bar{A}_G$ and $A_G^N(g^t) = \bar{A}_G + (-1)^{t+1}\delta$, where $\delta \in \mathbb{R}$. An appeal to Proposition 7 finishes the proof. □

Let (ψ, χ, φ), $\{[A_G(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ and $\{[x_t(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ constitute a competitive equilibrium. We say that the array $\{[A_G(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ is the *unique inducer* of the outcome $(\psi, \chi, \varphi, \{[x_t(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty)$ if there is a history g^t such that the rank of $\mathbf{Q}(g^t)$ is smaller than n.

When an array $\{[A_G(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ is the unique inducer of an outcome, the indeterminacy results of Proposition 7 and Corollary 9 do not hold. So, if $\{[A_G(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ specifies some type of float, then there is an obvious sense in which the adoption of a floating exchange rate regime has clear-cut implications on prices and real variables. However, the concept of unique implementation is not easily falsifiable.

To show that an array $\{[A_G(g^t)]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$ is the unique inducer, we need to find a history g^t such that the rank of $\mathbf{Q}(g^t)$ is smaller than n. Since any sample we collect from an actual economy will contain just part of a single row of each member of that family of matrices, we could at the very best test whether the government's foreign assets constitute the unique inducer of some outcome. Of course, estimating the rank of an infinite dimension matrix based on an observation of some components of just one of its rows is not a trivial task.

There is another obstacle that makes the task of inferring whether a floating policy uniquely implements an outcome a difficult one. Angeletos [5] and Buera and Nicolini [9] pointed out that small changes in the tax rates may have small effects on the discount factors $\{[\{q_k(g^t)\}_{k=t+1}^\infty]_{g^t\in\mathbb{G}^t}\}_{t=0}^\infty$. Hence, for each competitive equilibrium in which some matrix $\mathbf{Q}(g^t)$ has rank smaller than n, there may exist an arbitrarily close equilibrium in which the same matrix has full rank. Again, to distinguish between the two equilibria is not a trivial problem.

4 Conclusion

Many papers have applied the reasoning of the Modigliani-Miller Theorem to analyze macroeconomic questions. Following this line of research, in this paper we investigated the possible implications of that classic proposition to the study of exchange rate policies.

We obtained similar results to the Modigliani-Miller Theorem for the composition of the public debt between domestic and foreign bonds. In a deterministic model, the structure of government liabilities is undetermined in any competitive equilibrium. Thus, every implementable allocation and price sequence can be decentralized by a floating regime, as well as by a regime in which the exchange rate never floats. If the government can issue nominal bonds of several maturities, then the same results can hold in a stochastic economy.

The link between exchange rate policy and the Modigliani-Miller Theorem implies that a standard macroeconomic model with complete information and a passive government is ill suited to the study of exchange rate regimes. Therefore, characterizing a mapping from exchange rate policies to other economic variables can be more difficult than formerly expected. The research on the relevance of floating and alternative policies should place greater emphasis on issues such as asymmetric information, reputation and time consistency.

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