Comments welcome

U.S.-Europe Economic Interdependence and Policy Transmission*

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Abstract

This paper proposes a microfounded general equilibrium model of the U.S. and European economies suitable for analyzing the transmission of monetary and fiscal policy shocks between the U.S. and Europe. The focus is on understanding the determinants of transatlantic economic interdependence. A positive analysis of the consequences of policy changes in the U.S. and Europe is made and results about the transmission of such shocks are obtained. In the model, consumer preferences in the U.S. and Europe are biased in favor of goods produced in the continent where agents reside. Hence, PPP does not hold across the Atlantic, except in steady state. However, this is not sufficient to cause overshooting of the dollar exchange rate following policy shocks. U.S. current-account surplus can be achieved by means of a monetary expansion, a persistent increase in government spending, and/or higher long-run distortionary taxes relative to Europe.

Keywords: Europe; Macroeconomic interdependence; Monetary policy; Fiscal policy; United States
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1. Introduction

The advent of the Economic and Monetary Union (EMU) in Europe significantly affects the international monetary system and policy interactions between Europe and the rest of the world. Several papers have been written recently to discuss the impact of EMU.[1] However, most analyses lack the support of a rigorous formal apparatus or rely on models that the recent literature on economic interdependence has made outdated.[2]

The purpose of this paper is to propose a model suitable for analyzing the transmission of monetary and fiscal policy shocks between Europe and the United States that is close to the current state of the art in international macroeconomics. The model provides the foundations for an analytical study of U.S.-European policy interactions in the EMU era that aims at re-examining the pros and cons of transatlantic cooperation—or alternative policy rules in the U.S. and Europe—on the basis of rigorously microfounded normative criteria. Normative questions are not addressed in this paper, though. The focus here is on understanding the determinants of transatlantic economic interdependence. A positive analysis of the consequences of policy shocks in the U.S. and Europe is made, yielding results and intuitions that will guide later analyses of specific policy issues.

I propose a microfounded general equilibrium model that generalizes previous work by Obstfeld and Rogoff (1995, 1996 Ch. 10) while preserving some interesting features of the more traditional framework explored by Eichengreen and Ghironi (1997, 1999) and Ghironi and Giavazzi (1997, 1998).

In the model, the world consists of three regions: the U.S. and two European regions, which are interpreted as the insiders and outsiders in a multi-speed approach to EMU. The totality of Europe and the U.S. are symmetric, whereas the relative size of the two European economies is left free to vary to capture the impact of changes in the size of the monetary union.[3] A region's economic size is captured by the geographic location of production. Following Obstfeld and Rogoff, goods markets are assumed to be imperfectly competitive and the current account plays an important role in the transmission of policy shocks. This differs from Corsetti and Pesenti's (1998) framework, in which workers are assumed to have monopolistic power, goods markets are competitive, and the role of the current account is de-emphasized.[4] The assumptions of nominal rather than real bonds and of asymmetric preferences for consumption goods across the Atlantic allow me to give interesting insights about the effects of unanticipated policy shocks. The structure of the model makes it relatively easy to understand the determinants of policy multipliers and to determine the sign of policy externalities based on a small number of structural parameters.

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[1] See, for example, the papers collected in Masson, Krueger, and Turtelboom (1997), Begg, Giavazzi, and Wyplosz (1997), Eichengreen and Ghironi (1997, 1999), Ghironi and Giavazzi (1997, 1998).

[2] The traditional literature on macroeconomic interdependence is surveyed in Canzoneri and Henderson (1991) and Persson and Tabellini (1995). Recent contributions mentioned in this paper are Benigno G. (1999), Benigno P. (1999), Betts and Devereux (1996), Corsetti and Pesenti (1998), Devereux and Engel (1998), Ghironi (1999*a*, *b*, *c*), Obstfeld and Rogoff (1995, 1996 Ch. 10), Tille (1998*a*, *b*), Warnock (1998). For a more comprehensive survey, see Lane (1999).

[3] Indeed, the model is suitable for analyzing interactions between any three regions such that the aggregate of two of them is equal in size to the third. There is no *a priori* need of viewing the two European regions as *ins* and *outs* in EMU. They could be interpreted as any two European economies in the pre-EMU era or as two economies that join to form EMU itself.

[4] The recent behavior of the current accounts across the Atlantic and policymakers' interest in the consequences of changes in the U.S. current account suggested focusing on a model in which the latter does react to shocks.

This is an important element of value added relative to extensions of the traditional framework used by Canzoneri and Henderson (1991) and others to explore the issue of transatlantic policy interactions. The fully intertemporal nature of the model makes it possible to account for effects of policy that are not featured in the old-style framework.

Consumer preferences in the U.S. and Europe are assumed to be biased in favor of goods produced in the continent where agents reside. Hence, PPP does not hold across the Atlantic, except in steady state. However, this is not sufficient to cause overshooting of the dollar exchange rate following policy shocks. Adjustment in real variables removes the need for nominal exchange rate overshooting to re-equilibrate markets.

Starting from a zero-asset holding position, unexpected monetary expansions at home cause domestic consumption to rise unambiguously relative to foreign. However, if the initial position is characterized by non-zero-asset holdings, the monetary shock redistributes wealth abroad by lowering the real value of the initial stock of nominal assets. This unfavorable wealth effect can cause domestic consumption to decline relative to foreign if substitutability across goods is not sufficiently high.

The size of transatlantic trade matters for intra-European externalities, because policy changes in Europe affect European economies also through their impact on the relative positions of Europe and the U.S. For example, a temporary increase in government spending outside the European monetary union has an expansionary impact on GDP in the union that is larger the smaller transatlantic trade: smaller trade across the Atlantic reduces the unfavorable effect of an appreciated euro.[5]

Short-run changes in distortionary taxation have no effect on GDP, because output is demand-determined in the short run and taxes distort labor supply decisions. Differently from the more traditional model in Eichengreen and Ghironi (1997, 1998) and Ghironi and Giavazzi (1997), where taxes affect labor demand, an increase in steady-state taxation raises domestic GDP in the short run and lowers foreign by causing the dollar to depreciate.[6]

Movements in the U.S. current account are now receiving increasing attention from policymakers in the U.S. and Europe. In the model, U.S. current-account surplus can be achieved by means of a monetary expansion, a persistent increase in government spending, and/or higher long-run distortionary taxes relative to Europe.

The structure of the paper is as follows. The model is presented in Section 2. The long-run flexible-price solution is discussed in Section 3, while Section 4 is devoted to the analysis of the consequences of short-run price rigidities. Section 5 discusses the model's strengths and weaknesses. Section 6 concludes.

2. The Model

This section describes the structure of the model. To facilitate the comparison with the existing literature, I use the same notation as Obstfeld and Rogoff (1995, 1996 Ch. 10) whenever possible.

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[5] In the traditional Mundell-Fleming framework, larger government spending is normally associated with an appreciation of the domestic currency. Here, government spending causes less output to be available for consumption and the latter to fall. Hence, money demand is lower, and the currency depreciates.

[6] Again, the dollar depreciates because lower consumption causes money demand to fall.

2.a. The Setup

The model is a perfect-foresight three-region general equilibrium monetary model with preset prices. The world is assumed to consist of two large symmetric areas: the U.S. and Europe. Europe, in turn, is split in two regions. I leave the relative size of the two European regions free to vary and call them *ins* and *outs*. A continuum of differentiated goods $z \in [0, 1]$ is produced in the world by monopolistically competitive firms. Each good z is produced both in the U.S. and in Europe. Monopolistic competition between European and U.S. producers of good z is ensured by geographical distance. While the U.S. produces the whole range of goods that are available for consumption, the *ins* economy produces only goods in the interval $[0, a]$, whereas the *outs* produce goods in the range $(a, 1]$.

Individuals in all regions have identical preferences over a consumption index, real money balances, and effort expended in production. The representative individual i in region j maximizes the following intertemporal utility function:

$$U_t^{j^i} = \sum_{s=t}^{\infty} \beta^{s-t} \left[\log C_s^{j^i} + \chi \log \frac{M_s^{j^i}}{P_s^j} - \frac{\kappa}{2} y_s^j(i)^2 \right], \qquad j = US, I, O.$$

The variable C is a real consumption index. The consumption index for the representative U.S. agent (C^{US^i}) is defined as:

$$C^{US^i} = \left\{ (1-b)^{\frac{1}{\theta}} \left[\int_0^1 \left(c_{US}^{US^i}(z) \right)^{\frac{\theta-1}{\theta}} dz \right] + b^{\frac{1}{\theta}} \left[\int_0^a \left(c_{US}^{I^i}(z) \right)^{\frac{\theta-1}{\theta}} dz + \int_a^1 \left(c_{US}^{O^i}(z) \right)^{\frac{\theta-1}{\theta}} dz \right] \right\}^{\frac{\theta}{\theta-1}}, \tag{2.1}$$

with $\theta > 1$.[7] $c_{US}^{j^i}(z)$ is consumption by the ith U.S. resident of good z produced in region j. The parameter $b \in [0, 1]$ captures the weight of U.S. versus European goods in the U.S. consumption basket. The assumption $b < 1/2$ is warranted. As the *ins* economy becomes larger—*i.e.*, as a increases—the impact of consumption goods produced by the *outs* on the U.S. consumption basket shrinks, and it is zero when $a = 1$.

The consumption indexes for the representative individuals in the European economies are:

$$C^{I^i} = \left\{ b^{\frac{1}{\theta}} \left[\int_0^1 \left(c_I^{US^i}(z) \right)^{\frac{\theta-1}{\theta}} dz \right] + (1-b)^{\frac{1}{\theta}} \left[\int_0^a \left(c_I^{I^i}(z) \right)^{\frac{\theta-1}{\theta}} dz + \int_a^1 \left(c_I^{O^i}(z) \right)^{\frac{\theta-1}{\theta}} dz \right] \right\}^{\frac{\theta}{\theta-1}},$$

$$C^{O^i} = \left\{ b^{\frac{1}{\theta}} \left[\int_0^1 \left(c_O^{US^i}(z) \right)^{\frac{\theta-1}{\theta}} dz \right] + (1-b)^{\frac{1}{\theta}} \left[\int_0^a \left(c_O^{I^i}(z) \right)^{\frac{\theta-1}{\theta}} dz + \int_a^1 \left(c_O^{O^i}(z) \right)^{\frac{\theta-1}{\theta}} dz \right] \right\}^{\frac{\theta}{\theta-1}}. \tag{2.2}$$

In these expressions, b measures the weight of U.S. goods in the European consumption basket. As a approaches 1, the European currency union becomes symmetric to the United States and the impact of the goods produced by the *outs* on European consumption vanishes. Expressions (2.1) and (2.2) show that the U.S. consumption index is asymmetric relative to the European ones.

[7] θ will turn out to be the price elasticity of demand faced by each producer. $\theta > 1$ is required to ensure an interior equilibrium with a positive level of output.

Consumers on both sides of the Atlantic spend more of their income on goods produced in the continent where they reside.[8]

The price deflator for nominal money balances is the consumption-based money price index. Letting $p^j(z)$ be the domestic currency price of good z in region j, the money price level is:

$$P^j = \left[\int_0^1 \left(p^j(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

I assume that there are no impediments to trade, so that the law of one price holds for each individual good. Letting ε^I and ε^O denote the dollar price of the euro and of the *outs*' currency, respectively, this implies $p^{US}(z) = \varepsilon^I p^I(z)$, $p^{US}(z) = \varepsilon^O p^O(z)$, $p^O(z) = \frac{\varepsilon^I}{\varepsilon^O} p^I(z)$, where $\varepsilon^I/\varepsilon^O$ is the *outs*' currency price of one euro.[9] [10]

Using the law of one price and recalling that the *ins* economy produces goods in the range between 0 and a while the *outs* produce goods between a and 1, the CPIs can be rewritten as:

$$P^{US} = \left[(1-b)\int_0^1 \left(p^{US}(z) \right)^{1-\theta} dz + b\int_0^a \left(\varepsilon^I p^I(z) \right)^{1-\theta} dz + b\int_a^1 \left(\varepsilon^O p^O(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}},$$

$$P^I = \left[(1-b)\int_0^a \left(p^I(z) \right)^{1-\theta} dz + (1-b)\int_a^1 \left(\frac{\varepsilon^O}{\varepsilon^I} p^O(z) \right)^{1-\theta} dz + b\int_0^1 \left(\frac{1}{\varepsilon^I} p^{US}(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}, \tag{2.3}$$

$$P^O = \left[(1-b)\int_0^a \left(\frac{\varepsilon^I}{\varepsilon^O} p^I(z) \right)^{1-\theta} dz + (1-b)\int_a^1 \left(p^O(z) \right)^{1-\theta} dz + b\int_0^1 \left(\frac{1}{\varepsilon^O} p^{US}(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

These expressions make it possible to show that $P^O = \frac{\varepsilon^I}{\varepsilon^O} P^I$. Consumption-based purchasing power parity (PPP) holds between the two European regions because preferences are identical across them and there are no departures from the law of one price. However, consumption-based PPP does not hold between the U.S. and either European region, even if the law of one price

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[8] My assumptions about consumer preferences are consistent with those in Eichengreen and Ghironi (1997, 1999)—where $a = 1/2$—and Ghironi and Giavazzi (1997, 1998). Warnock (1998) develops a two-country model with idiosyncratic preferences for consumption goods.

[9] This assumption is admittedly strong, given the evidence in favor of deviations from the law of one price. Costs of transportation aside, deviations from the law of one price could be caused by trade policy and/or by firms adopting pricing-to-market strategies. I abstract from trade policy here. G. Benigno (1999), Betts and Devereux (1996), Devereux and Engel (1998), and Tille (1998*a*) develop models of interdependence in the presence of pricing to market. I do not consider the possibility for two reasons. On one side, integration in European markets is likely to reduce incentives for pricing to market in Europe. On the other side, as far as transatlantic trade goes, I want to focus on the effect of deviations from purchasing power parity caused by asymmetry in consumer preferences as opposed to firms' behavior (see below).

[10] Formally, the price index solves the problem of minimizing total private spending evaluated in units of the domestic currency subject to the constraint that the domestic real consumption index be equal to 1. Imposing the law of one price, it is easy to derive the result. Notice that, given consumption indexes in which baskets of goods produced in different continents have different weights, for the expression of the price index to be correct, it is important that each good z be produced in both continents.

applies at the individual good level, as it is easy to show. This is a consequence of the asymmetry between the U.S. and European real consumption indexes.[11]

Private agents are not the only consumers of goods. Governments also consume goods. To keep things simple, I assume that the government's real consumption index takes the same form as the private sector's in each region and with the same elasticity of substitution θ.[12] [13]

Each producer in the model faces demand coming from Europe and the U.S. Given the constant-elasticity of substitution consumption index defined above, U.S. consumers' demands of goods produced in the three regions are: [14]

$$c_{US}^{US}(z) = (1-b)\left(\frac{p^{US}(z)}{P^{US}}\right)^{-\theta} C^{US}, \; c_{US}^{I}(z) = b\left(\frac{p^{US}(z)}{P^{US}}\right)^{-\theta} C^{US}, \; c_{US}^{O}(z) = b\left(\frac{p^{US}(z)}{P^{US}}\right)^{-\theta} C^{US}.$$

Analogous expressions can be found for European consumers' demands. For consumers in the *ins* economy:

$$c_{I}^{US}(z) = b\left(\frac{p^{I}(z)}{P^{I}}\right)^{-\theta} C^{I}, \; c_{I}^{I}(z) = (1-b)\left(\frac{p^{I}(z)}{P^{I}}\right)^{-\theta} C^{I}, \; c_{I}^{O}(z) = (1-b)\left(\frac{p^{I}(z)}{P^{I}}\right)^{-\theta} C^{I}.$$

Given identity of preferences across European regions, expressions for the *outs* consumers' demands are analogous to those of *ins* consumers'.

Assuming that governments act as price takers, their demand functions for individual goods have the same form as the private sector's, with $g_l^j(z)$ and G^l replacing $c_l^j(z)$ and C^l, respectively (j, l = US, I, O).[15]

Total demand for good z produced in the U.S. is obtained by integrating across consumers the demands for that good originating in the various regions:

$$y^{US^d}(z) = (1-b)\left(\frac{p^{US}(z)}{P^{US}}\right)^{-\theta}\left(C^{US} + G^{US}\right) + b\left(\frac{p^{I}(z)}{P^{I}}\right)^{-\theta}\left(C^{EU} + G^{EU}\right),$$

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[11] As it is pointed out by Obstfeld and Rogoff (1996 Ch. 10), even when PPP holds, relative prices of various individual goods need not remain constant in the model.

[12] The definitions of the government's real consumption indexes—G—can be recovered from equations (2.1) and (2.2) letting $g_l^j(z)$ denote demand by region l's government of good z produced in region j (j, l = US, I, O). the presence of government consumption does not affect the expressions for the consumption-based price indexes obtained by minimizing total private spending.

[13] Government investment spending would have different effects from government consumption. Also, one may think that government spending affects utility. Corsetti and Pesenti (1998) assume that government spending enters the period utility function in an additively separable fashion. Following Obstfeld and Rogoff (1995, 1996 Ch. 10), I focus on the simplest possible case, in which government spending is purely dissipative and has no effect on productivity or private utility. This is consistent with the models in Eichengreen and Ghironi (1997, 1999) and Ghironi and Giavazzi (1997).

[14] Remember that $c_l^j(z)$ denotes demand by region l's representative consumer of good z produced in region j (j, l = US, I, O). Demand functions are obtained by maximizing C subject to a spending constraint.

[15] As observed by Obstfeld and Rogoff (1995, 1996 Ch. 10), governments may have incentives to act as strategic monopsonists in the model, preferring to buy home rather than foreign goods to bid up their price. I follow Obstfeld and Rogoff in abstracting from this possibility. At least for European economies, my assumption is consistent with the provision of the Maastricht Treaty that prohibits discrimination in public procurement.

where I have made use of the facts that consumption-based PPP and the law of one price imply $\frac{p^I(z)}{P^I} = \frac{p^O(z)}{P^O}$ for each good z and that symmetric agents make identical choices in equilibrium, and I have defined:

$$C^{EU} \equiv \int_0^a C^{I^j} dj + \int_a^1 C^{O^j} dj = aC^I + (1-a)C^O, \ \ G^{EU} \equiv \int_0^a G^I dj + \int_a^1 G^O dj = aG^I + (1-a)G^O.$$

Because consumption-based PPP does not hold between the U.S. and either European economy, in general, $\frac{p^{US}(z)}{P^{US}} \neq \frac{p^I(z)}{P^I}$. As a consequence, the expression of total demand of good z produced in the U.S. is not as compact as in the two-country world of Obstfeld and Rogoff (1995, 1996 Ch. 10), in which consumption-based PPP holds. Due to the absence of purchasing power parity across the Atlantic, total demand of the representative good produced in the U.S. depends on the behavior of the price of the good relative to the aggregate price index both in the U.S. and in Europe. Since the law of one price holds, $p^{US}(z) = \varepsilon^I p^I(z)$ and the demand for the representative U.S. good can be rewritten as:

$$y^{US^d}(z) = \left(p^{US}(z)\right)^{-\theta}\left[(1-b)\left(\frac{1}{P^{US}}\right)^{-\theta}\left(C^{US} + G^{US}\right) + b\left(\frac{1}{\varepsilon^I P^I}\right)^{-\theta}\left(C^{EU} + G^{EU}\right)\right]. \quad (2.4)$$

Total demands for goods produced in the *ins* and *outs* economies are:

$$y^{I^d}(z) = \left(p^I(z)\right)^{-\theta}\left[b\left(\frac{\varepsilon^I}{P^{US}}\right)^{-\theta}\left(C^{US} + G^{US}\right) + (1-b)\left(\frac{1}{P^I}\right)^{-\theta}\left(C^{EU} + G^{EU}\right)\right],$$

$$y^{O^d}(z) = \left(p^O(z)\right)^{-\theta}\left[b\left(\frac{\varepsilon^O}{P^{US}}\right)^{-\theta}\left(C^{US} + G^{US}\right) + (1-b)\left(\frac{1}{P^O}\right)^{-\theta}\left(C^{EU} + G^{EU}\right)\right].$$

I assume that the only internationally traded assets are riskless bonds issued by the three regions. Each region issues bonds denominated in units of the domestic currency. These assets are regarded as perfect substitutes and arbitrage conditions—uncovered interest parities (UIP)—hold in equilibrium:[16]

$$1 + i_{t+1}^{US} = \left(1 + i_{t+1}^I\right)\frac{\varepsilon_{t+1}^I}{\varepsilon_t^I} = \left(1 + i_{t+1}^O\right)\frac{\varepsilon_{t+1}^O}{\varepsilon_t^O}.$$

i_{t+1}^j is the date t interest rate on bonds denominated in region j's currency. Letting r_{t+1}^j denote region j's consumption-based real interest rate between t and $t + 1$, it is:

$$1 + i_{t+1}^j = \frac{P_{t+1}^j}{P_t^j}\left(1 + r_{t+1}^j\right).$$

Perfect capital mobility and consumption-based PPP imply real interest rate equalization in Europe, so that $r_{t+1}^I = r_{t+1}^O = r_{t+1}^{EU}$. However, because PPP does not hold across the Atlantic, U.S.

[16] These conditions can be obtained from the first-order conditions governing consumers' optimal choice of bond holdings once indifference on the margin between domestic and foreign bonds has been imposed. UIP equations may be violated *ex post* when unexpected shocks happen.

and European real interest rates are not equalized, and the differential depends on the behavior of the real exchange rate of the dollar vis-à-vis the euro or the *outs*' currency:

$$1+r_{t+1}^{US}=\left(1+r_{t+1}^{EU}\right)\frac{\varepsilon_{t+1}^{J}P_{t+1}^{J}/P_{t+1}^{US}}{\varepsilon_{t}^{J}P_{t}^{J}/P_{t}^{US}}=\left(1+r_{t+1}^{EU}\right)\frac{\psi_{t+1}^{J}}{\psi_{t}^{J}}, \qquad (2.5)$$

where ψ^{J} denotes the real exchange rate between the dollar and region J's currency, $J = I, O$.

2.b. Remarks on the Specification

An important remark is in order on the geographic allocation of production and the pattern of trade. I assume that both the U.S. and Europe produce *all* goods in the range between 0 and 1. This means that each good z is produced on both sides of the Atlantic by two distinct producers, each of whom has some degree of monopolistic power. The assumption that all goods are produced on both sides of the Atlantic is meant to capture the fact that the U.S. and Europe have the potential for living independently of each other. This seems realistic. But it also reduces the power of product differentiation as motivation of transatlantic trade in goods. If all goods are produced in the U.S. (Europe), why do U.S. (European) consumers want to buy European (U.S.) goods? The point has to do with how one defines the concept of product differentiation. In this paper, I think of the latter as related to (significant) differences in the *physical attributes* of the goods. In this sense, Ford station wagon cars and Volvos are interpreted as the same good z = *station wagon cars* produced both in the U.S. and in Europe by monopolistically competitive firms. However, because of reasons that are not modeled here, U.S. consumers have some preference for European goods and European consumers like goods produced in the U.S. The strength of this preference for goods produced overseas is measured by the parameter b. Consistent with the relatively small size of transatlantic trade in goods, one can expect b to be significantly smaller than 1/2. Overall, my assumptions allow me to capture both the possibility for the U.S. and Europe to live as entirely independent blocs and the fact that some trade in goods does happen across the two areas.

As in Obstfeld and Rogoff (1995, 1996 Ch. 10), the same parameter ($\theta > 1$) measures the elasticity of intratemporal substitution across goods and the degree of monopolistic distortion that characterizes the economies. This parameter is assumed to be identical across regions to keep the model simple. Different elasticities of substitution would induce firms to adopt pricing-to-market strategies—an issue from which this paper abstracts.[17] In Corsetti and Pesenti (1998), the composite consumption basket is a Cobb-Douglas function of the (two) goods produced by the two countries in their model. The elasticity of intratemporal substitution across goods is thus equal to 1. Monopoly power is measured by the elasticity of substitution across factors of production in the labor markets, which is allowed to differ across countries. Most of the enhanced tractability of Corsetti and Pesenti's model hinges on these assumptions. Unitary intratemporal elasticity of substitution is at the core of their result that policy shocks have no impact on the current account and thus of several results in their paper. Instead, as we shall see below, the current account plays an important role in the transmission of policy shocks in my model. Tille (1998*b*) allows the elasticity of substitution between goods produced in each country to differ from the elasticity of substitution between the bundle of domestic goods and that of foreign goods. This yields interesting results on the transmission of monetary shocks.

[17] Recall footnote 9.

Changes in a region's size are captured by changes in the geographic location of production and, consequently, in the relative importance of *ins* versus *outs*' goods in consumption.

The assumptions about market structure, country size, and factor/goods mobility can be related to one another. In Corsetti and Pesenti, labor is immobile across countries. Allowing the relative number of agents in different countries—*i.e.*, the measure of countries' "geographic" size—to vary would amount to allowing labor to be mobile across countries. In the presence of different elasticity of substitution across types of labor in different countries, workers would have incentives to move to the country where their monopolistic power allows them to benefit from the most favorable market conditions. In other words, labor mobility would make a country's size endogenous—at least as long as workers and their services are indivisible. The model thus lends itself naturally to an analysis of the effects of different degrees of labor mobility, migration, and temporary versus permanent barriers to the latter. In an Obstfeld and Rogoff-style framework, in which goods markets are imperfectly competitive, assuming different degrees of monopolistic distortion in different countries would not necessarily imply endogeneity of country size under perfect mobility of goods. As hinted to above, firms would have incentives to adopt pricing-to-market strategies, which do not require producers to move from one country to another. Consequently, analyses of the effects of changes in region size that are exogenous to firms' pricing behavior would remain sensible.

To keep the analysis simple, I maintain Obstfeld and Rogoff's assumption of log-utility from the composite consumption good, whereas Corsetti and Pesenti consider the more general case of CES utility. In their paper, the log-utility case implies that the optimal reaction by the domestic policymaker to a foreign monetary shock would be no reaction at all. Due to this, they argue in favor of the more general specification. Nonetheless, their claim of generality is weakened by the strength of the assumption of unitary intratemporal elasticity of substitution, which leads to the absence of effects of the policy shocks on the current account. The absence of such effects has important implications for the normative results of their model. Besides, we shall see that the difference in assumptions has no impact on the substance of the results about exchange rate overshooting.

The assumption that there is a single fiscal authority in the *ins* region is implicit in the model. This implies the strong assumption that different national governments inside EMU are jointly managing fiscal policy, even if this is not required by the Maastricht Treaty.[18] I am also assuming that the *outs* can be aggregated into a single entity, with a single central bank and a single fiscal authority. I therefore overlook the consequences of interactions between the authorities of the *outs*.

Finally, in Obstfeld and Rogoff, a riskless real bond denominated in the composite consumption good is the only traded asset. Although this assumption simplifies the model significantly, the assumption of nominal bonds denominated in the three currencies increases the realism of the model and allows me to draw some interesting conclusions about the effects of unanticipated monetary policies.

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[18] See Eichengreen and Ghironi (1997, 1999) for analyses of the consequences of non-coordinated fiscal policies in EMU.

2.c. Agents' Behavior

Agents in each region hold only units of the domestic currency. They are subject to two types of taxes: distortionary taxation of individual income at the rate τ^{j} and lump-sum taxation T^{j} (payable in units of the composite consumption good), *j* = *US, I, O*. I focus on the problem facing the representative individual in the U.S. economy. If we let $A_{t+1}^{j\ i}$ denote agent *i*'s nominal holdings of the bonds issued by region *j* entering time *t* + 1, the period budget constraint for the U.S. representative individual expressed in dollars can be written as:

$$A_{t+1}^{US^i} + \varepsilon_t^I A_{t+1}^{I\ i} + \varepsilon_t^O A_{t+1}^{O\ i} + M_t^{US^i} = \left(1+i_t^{US}\right)A_t^{US^i} + \varepsilon_t^I\left(1+i_t^I\right)A_t^{I^i} + \varepsilon_t^O\left(1+i_t^O\right)A_t^{O^i} +$$
$$+ M_{t-1}^{US^i} + \left(1-\tau_t^{US}\right)p_t^{US}(i)y_t^{US}(i) - P_t^{US}C_t^{US^i} - P_t^{US}T_t^{US}.$$

$y_t^{US}(i)$ is output of good *i* produced in the U.S. and $p_t^{US}(i)$ is its dollar price. Due to product differentiation, $p_t^{US}(i)$ need not be the same for all *i*, although in equilibrium symmetric U.S. producers will find it optimal to choose the same prices for their distinct products. $M_{t-1}^{US^i}$ is agent *i*'s holdings of nominal money balances entering period *t*. Period budget constraints for agents in the two European economies can be written similarly.

Equation (2.4) gives total demand for the good produced by this individual. It can be solved to find an expression for $p_t^{US}(i)$:

$$p_t^{US}(i) = \left[\frac{y_t^{US}(i)}{(1-b)\left(C_t^{US}+G_t^{US}\right)\left(P_t^{US}\right)^{\theta} + b\left(C_t^{EU}+G_t^{EU}\right)\left(\varepsilon_t^I P_t^I\right)^{\theta}}\right]^{-\frac{1}{\theta}}. \quad (2.6)$$

This can be substituted into the individual's budget constraint. Solving the resulting equation for $C_t^{US^i}$ and substituting into the intertemporal utility function yields an unconstrained problem in $y^{US}(i)$, M^{US^i}, and the holdings of assets.

The individual takes C^{US}, C^{EU}, and government spending indexes as given. The first-order conditions are intuitive. Dropping the *i*-superscript—because symmetric agents make identical choices in equilibrium—the first-order conditions with respect to $A_{t+1}^{j}\ \left(j = US, I, O\right)$ can be reduced to a single consumption Euler equation for the case where the intertemporal elasticity of substitution is 1:[19]

$$C_{t+1}^{US} = \beta\left(1+r_{t+1}^{US}\right)C_t^{US}. \quad (2.7)$$

Intertemporal consumption smoothing can thus be characterized in terms of the real consumption index *C* and of the consumption-based real interest rate *r*. First-order conditions for M_t^{US} and y_t^{US}, respectively, can be written as:

$$\frac{M_t^{US}}{P_t^{US}} = \chi\ C_t^{US}\left(\frac{1+i_{t+1}^{US}}{i_{t+1}^{US}}\right), \quad (2.8)$$

$$y_t^{US} = \frac{(\theta-1)\left(1-\tau_t^{US}\right)}{\kappa\theta}\frac{p_t^{US}}{P_t^{US}}\frac{1}{C_t^{US}}. \quad (2.9)$$

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[19] See Ghironi (1999*a*).

Equation (2.8) says that, at an optimum, individuals must be indifferent between consuming a unit of the composite consumption good on date *t* or using the same funds to raise cash balances, enjoying the derived transactions utility in period *t*, and then converting the extra cash balances back to consumption in period *t* + 1. Equation (2.9) ensures that, when agents are optimizing, the marginal cost of producing an extra unit of output equals the marginal utility of consuming the increased revenue generated by that extra unit of output.

Consumption Euler equations hold also in Europe. Because of real interest rate equalization across European regions, consumption growth in Europe reacts to the common interest rate r^{EU}. Demands for real money balances and the optimal amount of output in the two European regions obey the analogs to equations (2.8) and (2.9).

The equilibrium also requires transversality conditions to be satisfied. Making use of the uncovered interest parity conditions and letting ${}_{\$}A_{t+1}^{US\,i}$ denote the dollar value of nominal asset holdings by the representative U.S. agent entering period *t* + 1, the transversality condition for the U.S. agent requires that it be (in nominal terms):

$$\lim_{T\to\infty}\left[\prod_{s=t}^{T}\frac{1}{1+i_s^{US}}\right]\left({}_{\$}A_{t+T+1}^{US}+M_{t+T}^{US}\right)=0,$$

where the *i*-superscript has been dropped. Similar conditions hold for the representative agents in the two European economies.

2.d. Governments' Budget Constraints

In order to complete the model, the budget constraints for the three economies' governments need to be specified. Governments are allowed not to balance their budgets in each period. Government spending can be financed only by raising taxes or issuing government debt. Consistent with the fact that seignorage is not a relevant source of revenues for governments in industrialized economies, I assume that all seignorage revenues are rebated to the public in the form of lump-sum transfers. Consider the U.S. government. Letting $\tilde{T}_t^{US}$ denote lump-sum taxes and $TR_t^{US}=\left(M_t^{US}-M_{t-1}^{US}\right)/P_t^{US}$ be the seignorage transfer—so that $P_t^{US}T_t^{US}=P_t^{US}\left(\tilde{T}_t^{US}-TR_t^{US}\right)$—the U.S. government budget constraint can be written as:

$$B_{t+1}^{US}-B_t^{US}=i_t^{US}B_t^{US}+P_t^{US}\left(G_t^{US}-\tilde{T}_t^{US}\right)-\tau_t^{US}\int_0^1 p_t^{US}(z)y_t^{US}(z)dz,$$

where B^{US} denotes dollar denominated bonds issued by the U.S. government. Governments in Europe face similar constraints.[20]

[20] In the *ins* (*outs*) government budget constraint revenues from distortionary taxation need to be divided by *a* (1-*a*) to put aggregate income taxes in the same per capita form as other variables. In order for region *j*'s government's intertemporal budget constraint to be satisfied, the following No-Ponzi-game condition must hold:

2.e. Global Equilibrium

In the aggregate, money demand must equal money supply in each region and demand for bonds denominated in each currency must equal supply. For U.S. bonds, it has to be $A_{t+1}^{US\,US} + aA_{t+1}^{US\,I} + (1-a)A_{t+1}^{US\,O} = B_{t+1}^{US}$, where $A_{t+1}^{US\,j}$ denotes demand for U.S. bonds by the representative agent in region *j*. Similar equilibrium conditions must be satisfied for the European bonds: $A_{t+1}^{I\;\,US} + aA_{t+1}^{I\;\,I} + (1-a)A_{t+1}^{I\;\,O} = aB_{t+1}^{I}$ and $A_{t+1}^{O\;\,US} + aA_{t+1}^{O\;\,I} + (1-a)A_{t+1}^{O\;\,O} = (1-a)B_{t+1}^{O}$. These conditions imply that global net foreign assets (expressed in a common currency) must be zero:

$$ {}_N B_{t+1}^{US} + a\varepsilon_t^I \, {}_N B_{t+1}^{I} + (1-a)\varepsilon_t^O \, {}_N B_{t+1}^{O} = 0, \tag{2.10}$$

where ${}_N B_{t+1}^{US}$, ${}_N B_{t+1}^{I}$, and ${}_N B_{t+1}^{O}$ are net foreign assets of the U.S., *ins*, and *outs* economy, respectively:[21]

$$\begin{aligned} {}_N B_{t+1}^{US} &= A_{t+1}^{US\,US} + \varepsilon_t^I A_{t+1}^{I\;\,US} + \varepsilon_t^O A_{t+1}^{O\;\,US} - B_{t+1}^{US}, \\ {}_N B_{t+1}^{I} &= \frac{A_{t+1}^{US\,I}}{\varepsilon_t^I} + A_{t+1}^{I\;\,I} + \frac{\varepsilon_t^O A_{t+1}^{O\;\,I}}{\varepsilon_t^I} - B_{t+1}^{I}, \\ {}_N B_{t+1}^{O} &= \frac{A_{t+1}^{US\,O}}{\varepsilon_t^O} + \frac{\varepsilon_t^I A_{t+1}^{I\;\,O}}{\varepsilon_t^O} + A_{t+1}^{O\;\,O} - B_{t+1}^{O}. \end{aligned} \tag{2.11}$$

Given these asset-market-clearing conditions, it is possible to derive an aggregate goods' market equilibrium condition according to which nominal world income must equal nominal world consumption of goods by governments and private sectors when all variables are measured in a common currency:[22]

$$ {}_\$\widehat{Y}_t^W = {}_\$\widehat{C}_t^W + {}_\$\widehat{G}_t^W, \tag{2.12}$$

where the following variables have been defined (all of them expressed in dollars):

${}_\$\widehat{Y}_t^W \equiv p_t^{US}(us)y_t^{US}(us) + a\varepsilon_t^I p_t^I(i)y_t^I(i) + (1-a)\varepsilon_t^O p_t^O(o)y_t^O(o)$ = nominal world income;

${}_\$\widehat{G}_t^W \equiv P_t^{US}G_t^{US} + a\varepsilon_t^I P_t^I G_t^I + (1-a)\varepsilon_t^O P_t^O G_t^O$ = nominal world government spending;

${}_\$\widehat{C}_t^W \equiv P_t^{US}C_t^{US} + a\varepsilon_t^I P_t^I C_t^I + (1-a)\varepsilon_t^O P_t^O C_t^O$ = nominal world consumption.

2.f. A Symmetric Steady State

The presence of monopoly pricing and the endogeneity of output make it hard to analyze the behavior of the model for general time paths of the exogenous variables. Hence, I will follow Obstfeld and Rogoff (1995, 1996 Ch. 10) and consider a log-linearized version in the neighborhood of the flexible-price steady state of the economy. This is a disadvantage of my model relative to Corsetti and Pesenti's (1998), which can be solved in closed form without having to use log-linear approximations. A closed-form solution makes it possible to analyze the

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$$\lim_{T\to\infty}\left(\prod_{s=t}^{T}\frac{1}{1+i_s^j}\right)B_{t+T+1}^{j} = 0.$$

[21] A region's net foreign assets are equal to the difference between the domestic currency value of the region's private sector's holdings of assets and government debt.

[22] See Ghironi (1999*a*) for details.

impact of large policy shocks, whereas the formal analysis in this paper is forcefully limited to small perturbations around the steady state.[23] Nonetheless, the enhanced tractability of Corsetti and Pesenti's model follows from the result that unanticipated permanent shocks have no impact on the current account, which instead plays a key role in my model. Whether or not the current account is important to the transmission of policy shocks is a question that only careful empirical investigation can answer. My analysis, though limited to small shocks, provides a benchmark study of the impact of changes in economic policies in a world in which current accounts matter.[24]

Because consumption and output are constant in steady state, real interest rates in all regions are tied down by the consumption Euler equation and are equal to the rate of time preference δ, where $\delta \equiv (1-\beta)/\beta$. Because the rate of time preference is assumed to be identical in all regions, in steady state, the U.S. real interest rate is equal to the European real rates, which are equal to one another also out of the steady state. Using overbars to denote steady-state values of variables, it is: $\bar{r}^{US} = \bar{r}^{I} = \bar{r}^{O} = \bar{r}^{EU} = \delta$.[25]

Steady-state private consumption must equal steady-state real income minus government spending in all regions. Making use of the consumers' and governments' period budget constraints, observing that nominal and real interest rates are equal in steady state, and recalling the definition of a region's net foreign assets, we find:[26]

$$\bar{C}^{J} = \delta \frac{{}_{N}\bar{B}^{J}}{\bar{P}^{J}} + \frac{\bar{p}^{J}(j)\bar{y}^{J}(j)}{\bar{P}^{J}} - \bar{G}^{J}, \qquad (2.13)$$

where $J = US, I, O$, $j = us, i, o$, and both upper and lower case indexes refer to the same region.

Setting consumption to be constant does not pin down a unique steady-state international distribution of asset holdings in the model. The framework I develop in this paper shares the indeterminacy of the steady state that characterizes most contributions to the "new open economy macroeconomics." Determinacy of the steady state fails for an open economy whenever the equilibrium rate of aggregate per capita consumption growth is independent of the economy's aggregate per capita net foreign assets. In that case, the requirement that consumption be constant in steady state does not determine a unique steady state for net foreign assets, and one is forced to pick an "arbitrary" distribution of asset holdings as initial steady state around which to log-linearize the model. As we shall see below, failure to determine a steady state comes with a failure of stationarity: starting from the initial "arbitrary" distribution of asset holdings, all shocks have permanent consequences by generating a new steady-state distribution of asset holdings. I will discuss below the problems caused by this feature of the model, along with a possible solution.

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[23] Large shocks could be studied with the aid of simulation techniques.

[24] On empirical grounds, it could be observed that policymakers' discipline in the U.S. and Europe—whether due to constraints to policymaking or to the authorities' preferences—will probably reduce the likelihood of large policy shocks in the EMU era.

[25] Transatlantic equalization of real interest rates in steady state could have been motivated also by recalling equation (2.5): because the real exchange rate of the dollar vis-à-vis any European currency is constant in steady state, it must be the case that real interest rates are equalized across the Atlantic. The real exchange rate between the dollar and European currencies being constant implies that $\varepsilon_t^J P_t^J / P_t^{US} = \varepsilon_{t+1}^J P_{t+1}^J / P_{t+1}^{US} = \bar{\varepsilon}^J \bar{P}^J / \bar{P}^{US}$, $J = I, O$: although *absolute* consumption-based purchasing power parity does not hold between the U.S. and European regions, *relative* consumption-based PPP holds in steady state. This result seems consistent with the findings of the empirical literature on purchasing power parity between the U.S. and Europe. (See Froot and Rogoff, 1994, for a detailed discussion of these issues.)

[26] The assumption that a steady-state version of (2.10) is satisfied is implicit.

For the purposes of this paper, a simple closed-form solution for the steady state of the world economy exists when initial net foreign assets in each region are zero. In this case, the equilibrium is such that $\bar{p}_0^{US}(us)/\bar{P}_0^{US} = \bar{p}_0^{I}(i)/\bar{P}_0^{I} = \bar{p}_0^{O}(o)/\bar{P}_0^{O} = 1$ and $\bar{C}_0^{US} + \bar{G}_0^{US} = \bar{y}_0^{US}$, $\bar{C}_0^{I} + \bar{G}_0^{I} = \bar{y}_0^{I}$, $\bar{C}_0^{O} + \bar{G}_0^{O} = \bar{y}_0^{O}$, where 0 subscripts on barred variables denote the initial steady state in which net foreign assets are zero in all regions. The first set of equalities follows from the fact that producers are symmetric in all regions and prices of goods in each region are equal to one another in steady state. Assuming that government spending is zero in all regions in the initial steady state, the second set of equalities reduces to $\bar{C}_0^{US} = \bar{y}_0^{US}$, $\bar{C}_0^{I} = \bar{y}_0^{I}$, $\bar{C}_0^{O} = \bar{y}_0^{O}$.

Making use of these equalities and of the first-order conditions governing individual choices of output, and assuming that initial steady-state rates of distortionary taxation are equal across regions, we have:

$$\bar{y}_0^{US} = \bar{y}_0^{I} = \bar{y}_0^{O} = \bar{y}_0 = \left\{ \frac{(1-\bar{\tau}_0)(\theta - 1)}{\kappa\theta} \right\}^{\frac{1}{2}}.$$

Steady-state output in each region reflects the impact of distortionary taxation of agents' income: the higher the rate of distortionary taxation, the lower steady-state output, because of the negative effect on agents' incentives to supply more effort in production.[27]

The previous results can be used together with the money-demand equations to solve for steady state real balances in the U.S. and Europe:

$$\frac{\bar{M}_0^{US}}{\bar{P}_0^{US}} = \frac{\bar{M}_0^{I}}{\bar{P}_0^{I}} = \frac{\bar{M}_0^{O}}{\bar{P}_0^{O}} = \frac{\chi(1+\delta)}{\delta} \bar{y}_0,$$

where a no-speculative-bubbles condition has been assumed.

2.g. Log-Linearizing around the Steady State

Log-linear versions of the main equations of the model are obtained following the approach of Obstfeld and Rogoff (1995, 1996 Ch. 10). Given symmetry among producers in each region, the price index equations (2.3) reduce to:

$$P^{US} = \left\{ (1-b)\left(p^{US}(us)\right)^{1-\theta} + b\left[a\left(\varepsilon^I p^I(i)\right)^{1-\theta} + (1-a)\left(\varepsilon^O p^O(o)\right)^{1-\theta} \right] \right\}^{\frac{1}{1-\theta}},$$

$$P^{I} = \left\{ b\left(\frac{p^{US}(us)}{\varepsilon^I} \right)^{1-\theta} + (1-b)\left[a\left(p^I(i)\right)^{1-\theta} + (1-a)\left(\frac{\varepsilon^O p^O(o)}{\varepsilon^I} \right)^{1-\theta} \right] \right\}^{\frac{1}{1-\theta}},$$

[27] The assumption that rates of distortionary taxation are equal in the initial steady state does not seem unrealistic for industrialized economies. Monopoly power in the market for each single good makes global output suboptimally low in the decentralized equilibrium. The marginal value of an additional unit of composite consumption exceeds the cost of forgone leisure. Monopolistic individual producers have no incentive to increase output of their individual goods unilaterally, since the benefits accrue mainly to other agents through a lower relative price. Although the distortions caused by monopoly abate if the various goods are close substitutes (if θ is large), a planner could coordinate jointly higher production.

$$P^O = \left\{ b\left(\frac{p^{US}(us)}{\varepsilon^O}\right)^{1-\theta} + (1-b)\left[a\left(\frac{\varepsilon^I p^I(i)}{\varepsilon^O}\right)^{1-\theta} + (1-a)\left(p^O(o)\right)^{1-\theta} \right] \right\}^{\frac{1}{1-\theta}}.$$

Linearizing these equations around the steady state where $\overline{p}_0^{US}(us) = \varepsilon_0^I \overline{p}_0^I(i)$ and $\overline{p}_0^{US}(us) = \varepsilon_0^O \overline{p}_0^O(o)$ yields:

$$\begin{aligned}
\mathsf{p}_t^{US} &= (1-b)\mathsf{p}_t^{US}(us) + b\left[a\left(\mathsf{e}_t^I + \mathsf{p}_t^I(i)\right) + (1-a)\left(\mathsf{e}_t^O + \mathsf{p}_t^O(o)\right)\right], \\
\mathsf{p}_t^I &= b\left(\mathsf{p}_t^{US}(us) - \mathsf{e}_t^I\right) + (1-b)\left[a\mathsf{p}_t^I(i) + (1-a)\left(\mathsf{e}_t^O + \mathsf{p}_t^O(o) - \mathsf{e}_t^I\right)\right], \\
\mathsf{p}_t^O &= b\left(\mathsf{p}_t^{US}(us) - \mathsf{e}_t^O\right) + (1-b)\left[a\left(\mathsf{e}_t^I + \mathsf{p}_t^I(i) - \mathsf{e}_t^O\right) + (1-a)\mathsf{p}_t^O(o)\right],
\end{aligned} \tag{2.14}$$

where, omitting the region-superscripts, I have defined: $\mathsf{p}_t \equiv dP_t / \overline{P}_0$, $\mathsf{e}_t \equiv d\varepsilon_t / \overline{\varepsilon}_0$, and $\mathsf{p}_t(z) \equiv dp_t(z) / \overline{p}_0(z)$.

The purchasing power parity relation between the two European regions becomes:

$$\mathsf{p}_t^O - \mathsf{p}_t^I = \mathsf{e}_t^I - \mathsf{e}_t^O. \tag{2.15}$$

The log-linearized version of the demand schedule for the representative U.S. good—equation (2.4)—is:

$$\mathsf{y}_t^{US} = (1-b)\left[\theta\left(\mathsf{p}_t^{US} - \mathsf{p}_t^{US}(us)\right) + \mathsf{c}_t^{US} + \mathsf{g}_t^{US}\right] + b\left[\theta\left(\mathsf{p}_t^I - \mathsf{p}_t^I(us)\right) + \mathsf{c}_t^{EU} + \mathsf{g}_t^{EU}\right]. \tag{2.16}$$

Since government spending is zero in the initial steady state, I define $\mathsf{g}_t^j \equiv dG_t^j / \overline{y}_0^j = dG_t^j / \overline{C}_0^j$ in each region.

Log-linear versions of the demand equations for the representative European goods are:

$$\begin{aligned}
\mathsf{y}_t^I &= b\left[\theta\left(\mathsf{p}_t^{US} - \mathsf{p}_t^{US}(i)\right) + \mathsf{c}_t^{US} + \mathsf{g}_t^{US}\right] + (1-b)\left[\theta\left(\mathsf{p}_t^I - \mathsf{p}_t^I(i)\right) + \mathsf{c}_t^{EU} + \mathsf{g}_t^{EU}\right], \\
\mathsf{y}_t^O &= b\left[\theta\left(\mathsf{p}_t^{US} - \mathsf{p}_t^{US}(o)\right) + \mathsf{c}_t^{US} + \mathsf{g}_t^{US}\right] + (1-b)\left[\theta\left(\mathsf{p}_t^O - \mathsf{p}_t^O(o)\right) + \mathsf{c}_t^{EU} + \mathsf{g}_t^{EU}\right].
\end{aligned} \tag{2.17}$$

Taking a population-weighted average of equations (2.16)-(2.17) and making use of (2.14) yields the equilibrium condition: [28]

$$\mathsf{y}_t^W \equiv \mathsf{y}_t^{US} + a\mathsf{y}_t^I + (1-a)\mathsf{y}_t^O = \mathsf{c}_t^{US} + \mathsf{g}_t^{US} + \mathsf{c}_t^{EU} + \mathsf{g}_t^{EU} \equiv \mathsf{c}_t^W + \mathsf{g}_t^W. \tag{2.18}$$

In contrast to Obstfeld and Rogoff (1995, 1996 Ch. 10), I allow for shocks to the rates of distortionary taxation. Thus, log-linearized supply equations for each individual good are: [29]

$$\mathsf{y}_t^J = -\mathsf{t}_t^J + \mathsf{p}_t^J(j) - \mathsf{p}_t^J - \mathsf{c}_t^J, \tag{2.19}$$

where *J = US, I, O*, *j = us, i, o*, and both upper and lower case indexes refer to the same region.

The consumption Euler equation (2.7) takes the log-linear form:

$$\mathsf{c}_{t+1}^J = \mathsf{c}_t^J + \frac{\delta}{1+\delta}\mathsf{r}_{t+1}^J, \qquad J = US, I, O, \tag{2.20}$$

where $\mathsf{r}_{t+1}^j \equiv dr_{t+1}^j / \overline{r} = dr_{t+1}^j / \delta$ and $\mathsf{r}_{t+1}^I = \mathsf{r}_{t+1}^O = \mathsf{r}_{t+1}^{EU}$.

Log-linear money-demand equations are:

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[28] (2.18) is the log-linear real counterpart to the nominal equilibrium condition (2.12).

[29] In these equations, the following approximation has been used: $\ln(1-\tau) \cong -\tau$ for τ sufficiently small.

Hence: $d\ln(1-\tau) = \dfrac{-d\tau}{1-\overline{\tau}_0} \cong -d\tau \equiv -\mathsf{t}$.

$$\mathsf{m}_t^J - \mathsf{p}_t^J = \mathsf{c}_t^J - \frac{\mathsf{r}_{t+1}^J}{1+\delta} - \frac{\mathsf{p}_{t+1}^J - \mathsf{p}_t^J}{\delta}, \qquad J = US, I, O. \tag{2.21}$$

Subtracting the *outs*' money-demand equation from the *ins*', recalling the purchasing power parity equation (2.15), and rearranging gives:

$$\mathsf{e}_t^O - \mathsf{e}_t^I = \mathsf{m}_t^I - \mathsf{m}_t^O - \left(\mathsf{c}_t^I - \mathsf{c}_t^O\right) + \frac{1}{\delta}\left[\left(\mathsf{e}_{t+1}^O - \mathsf{e}_{t+1}^I\right) - \left(\mathsf{e}_t^O - \mathsf{e}_t^I\right)\right]. \tag{2.22}$$

This equation relates the current exchange rate between the euro and the *outs*' currency to fundamentals (relative money supply and consumption) and to the expected change in the exchange rate.

Because purchasing power parity does not hold between the U.S. and Europe, the difference between the U.S. money-demand equation and the *ins*'—or the *outs*'—does not yield an equation like (2.22). However, log-linearizing (2.5) gives:

$$\mathsf{r}_{t+1}^{US} - \mathsf{r}_{t+1}^{EU} = \frac{1+\delta}{\delta}\left(\varphi_{t+1}^J - \varphi_t^J\right) = \frac{1+\delta}{\delta}\left(\mathsf{e}_{t+1}^J + \mathsf{p}_{t+1}^J - \mathsf{p}_{t+1}^{US} - \mathsf{e}_t^J - \mathsf{p}_t^J + \mathsf{p}_t^{US}\right), \tag{2.23}$$

where $\varphi_{t+1}^J \equiv d\psi_{t+1}^J / \overline{\psi}_0^J$, $J = I, O$. Taking the difference between the U.S. money-demand equation and the *ins*'—or the *outs*'—and using (2.23) makes it possible to find an expression for the expected depreciation of the dollar vis-à-vis the European currencies:

$$\mathsf{e}_{t+1}^J - \mathsf{e}_t^J = \delta\left[\mathsf{p}_t^{US} - \mathsf{p}_t^J - \left(\mathsf{m}_t^{US} - \mathsf{m}_t^J\right) + \mathsf{c}_t^{US} - \mathsf{c}_t^J\right], \qquad J = I, O. \tag{2.24}$$

3. The Flexible-Price Equilibrium

I solve the model treating all exchange rates as endogenous variables. This is consistent with the assumption of a *flexible* exchange rate regime between the *ins* and the *outs*, whereas it has been decided that an EMS-style arrangement will link the euro to the *outs*' currencies. Because I consider small perturbations around the initial steady state of the world economy, I interpret the flexible exchange rate solution as a description of the daily behavior of variables under the regime that will govern interactions in Europe.[30]

As in Obstfeld and Rogoff (1995, 1996 Ch. 10), analyzing the steady-state effects of changes in economic policies and shifts in the distribution of wealth across regions is useful to understand the consequences of unanticipated policy shocks in different regions. If prices are perfectly flexible and all shocks are permanent, the world economy jumps instantly to the steady state governed by the existing distribution of wealth. By taking each region's long-run nominal asset holdings as exogenous and assuming that the economy jumps immediately to the steady state, the analysis in this section overlooks the effects due to the endogeneity of asset holdings with respect to policy shocks. These effects—which need to be taken into account to fully describe the long-run behavior of variables—are explored in the next section, in which short-run price-rigidities are introduced and steady-state holdings of assets become endogenous.[31]

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[30] Small perturbations are consistent with small fluctuations of intra-European exchange rates within the limits of sufficiently wide EMS bands. Some consequences of EMS realignments, when the intra-European exchange rate becomes a choice variable and the *outs*' money supply is determined endogenously, are discussed in Ghironi (1999*a*).

[31] Once (temporary) rigidities in nominal prices are introduced, the economy converges to the steady-state equilibrium only in the long run. As in Obstfeld and Rogoff (1995, 1996 Ch. 10), once such rigidities are introduced, unanticipated monetary policies have long-run real effects through the world distribution of wealth.

To find closed-form solutions for the new steady state to which the world economy is moved by permanent policy changes or changes in the distribution of asset holdings, I log-linearize equations (2.13), which equate steady-state income and expenditure in each region. The log-linear versions are:

$$\overline{c}^J = \delta\ \overline{b}^J + \overline{p}^J(j) + \overline{y}^J - \overline{p}^J - \overline{g}^J,\ J = US, I, O;\ j = us, i, o. \tag{3.1}$$

In these equations, a bar on a lowercase arial variable denotes the (approximate) log change in its steady-state value, for example, $\overline{c} = d\overline{C}/\overline{C}_0 = (\overline{C} - \overline{C}_0)/\overline{C}_0$. $\overline{P}_0$ has been normalized to 1. Since regions' net foreign asset positions are zero in the initial steady state, I define $\overline{b} \equiv d\,{}_N\overline{B}/\overline{C}_0$. (Analogously, because government spending is zero in the initial steady state, $\overline{g} \equiv d\overline{G}/\overline{C}_0$.) Time subscripts do not appear in equations (3.1) because they are valid only for steady-state changes. Steady-state government consumption reduces income available for private consumption in all regions.[32]

Equations (2.14)-(2.24) hold at all points. Hence, they must hold also when the world economy is in steady state. The linear system that characterizes the steady state is thus governed by equations (3.1) and barred versions of equations (2.14)-(2.24). Solving the system is easier if we make use of Aoki's (1981) technique of solving for differences between variables and for population-weighted world aggregates.

3.a. Solving for *Ins-Outs* Differences

I begin by considering differences in per capita variables between the two European economies. Subtracting equation (2.17) for the *outs* from the corresponding equation for the *ins* yields:

$$y_t^I - y_t^O = -\theta\left[p_t^I(i) - p_t^O(o) - \left(e_t^O - e_t^I\right)\right]. \tag{3.2}$$

The difference in demands for the representative European goods depends on the terms of trade between them. Subtracting (2.19) for the *outs* from the supply equation for the *ins* gives:

$$y_t^I - y_t^O = -\left(t_t^I - t_t^O\right) - \left[e_t^O - e_t^I + p_t^O(o) - p_t^I(i)\right] - \left(c_t^I - c_t^O\right).$$

Taking (3.2) into account,

$$y_t^I - y_t^O = -\frac{\theta}{\theta+1}\left(c_t^I - c_t^O + t_t^I - t_t^O\right). \tag{3.3}$$

Recalling that consumption-based PPP holds between the two European economies, the difference between (3.1) for the *ins* and the *outs* is:

This long-run *non*-neutrality of money must not be overstated, though. The real effects of money shocks would eventually disappear in an overlapping generations version of the model (see Ghironi, 1999*b*). Also, long-run real effects of monetary policy are likely to be much smaller empirically than short-run effects.

[32] If it were ${}_N\overline{B}_0 \neq 0$, equation (3.1) would be replaced by:

$$\overline{c}^J = \delta\ \frac{{}_N\overline{B}_0^J}{\overline{C}_0^J}\left(\overline{b}^J - \overline{p}^J\right) + \overline{p}^J(j) + \overline{y}^J - \overline{p}^J - \overline{g}^J,$$

with $\overline{b} \equiv d\,{}_N\overline{B}/{}_N\overline{B}_0$. In this case, given agents' holdings of nominal assets, unexpected price changes would have real effects by redistributing real wealth also in a flexible price world. The flexible-price solution for real variables could no longer be obtained without taking the role of money into account. Because agents have no assets in the initial steady state, unexpected price changes have no redistribution effect.

$$\bar{c}^I - \bar{c}^O = \delta\left(\bar{b}^I - \bar{b}^O\right) - \left[\bar{e}^O - \bar{e}^I + \bar{p}^O(o) - \bar{p}^I(i)\right] + \bar{y}^I - \bar{y}^O - \left(\bar{g}^I - \bar{g}^O\right).$$

Substituting barred versions of equations (3.2) and (3.3) into the previous equation yields the following reduced forms for the steady-state consumption differential and terms of trade between the *ins* and the *outs*:

$$\bar{c}^I - \bar{c}^O = \left(\frac{1+\theta}{2\theta}\right)\delta\left(\bar{b}^I - \bar{b}^O\right) - \left(\frac{1+\theta}{2\theta}\right)\left(\bar{g}^I - \bar{g}^O\right) - \left(\frac{\theta-1}{2\theta}\right)\left(\bar{t}^I - \bar{t}^O\right), \tag{3.4}$$

$$\bar{p}^I(i) - \left(\bar{e}^O - \bar{e}^I\right) - \bar{p}^O(o) = \frac{\delta}{2\theta}\left(\bar{b}^I - \bar{b}^O\right) - \frac{1}{2\theta}\left(\bar{g}^I - \bar{g}^O\right) + \frac{1}{2\theta}\left(\bar{t}^I - \bar{t}^O\right). \tag{3.5}$$

An increase in *ins*' asset holdings relative to *outs*' causes the *ins*-*outs* consumption differential to widen. It improves the *ins*' terms of trade relative to the *outs* because higher interest income induces *ins* agents to shift out of work into leisure. Because a region's net foreign asset holdings depend on the amount of debt issued by the government, if debt increases, the region's relative foreign asset holdings position worsens unless all the extra government debt is held by domestic agents: steady-state consumption will decline relative to the counterpart's and the terms of trade will worsen.

A rise in steady-state *ins*' government consumption reduces the *ins*' steady-state private consumption relative to the *outs*' by leaving less income available for private consumption in the *ins* economy. At the same time, a relative rise in steady-state *ins*' government consumption induces a rise in *ins*' output relative to *outs*'. Hence, it leads to a deterioration in the *ins*' terms of trade vis-à-vis the *outs*.[33] Higher distortionary taxes in the *ins* economy lower *ins*' consumption relative to *outs*' by reducing disposable income. They induce a decrease in *ins*' output relative to *outs*', which tends to improve the terms of trade.

3.b. Solving for Differences between Aggregate U.S. and European Variables

In what follows, for each variable x_t^J ($J = I, O$), I define the corresponding aggregate European variable as $\mathsf{x}_t^{EU} \equiv a\mathsf{x}_t^I + (1-a)\mathsf{x}_t^O$. Because all goods in the range [0, 1] are produced in the U.S., symmetry of U.S. producers in equilibrium implies that aggregate U.S. variables coincide with per capita variables. The real effective exchange rate between the U.S. and Europe is $\varphi_t \equiv \mathsf{p}_t^{EU} + \mathsf{e}_t^{EU} - \mathsf{p}_t^{US}$, whereas the effective terms of trade of the U.S. are given by $\eta_t \equiv \mathsf{p}_t^{US}(us) - \mathsf{p}_t^{EU}(eu) - \mathsf{e}_t^{EU}$, where $\mathsf{p}_t^{EU}(eu) \equiv a\mathsf{p}_t^I(i) + (1-a)\mathsf{p}_t^O(o)$. Using these definitions, equations (2.16), (2.17), and the law of one price yield:

$$\mathsf{y}_t^{US} - \mathsf{y}_t^{EU} = (1-2b)\left[\mathsf{c}_t^{US} - \mathsf{c}_t^{EU} + \mathsf{g}_t^{US} - \mathsf{g}_t^{EU} - \theta\varphi_t\right] - \theta\eta_t. \tag{3.6}$$

Consistent with the intuition, there is an inverse relation between the U.S. effective terms of trade and aggregate demand for U.S. goods relative to European. If $b < 1/2$, a real effective depreciation of the dollar induces *lower* relative demand for U.S. goods. The intuition has to do with consumers' intertemporal behavior and is better understood if we recall equation (2.23). The time-t real effective exchange rate of the dollar can be written as:

[33] When considering fiscal policy shocks, I leave implicit the assumption that governments' budget constraints are always satisfied—if needed, by making use of lump-sum taxes and transfers. I also leave issues related to the Stability and Growth Pact aside. Again, the idea is that small fiscal policy shocks are consistent with the limits imposed by the Pact.

$$\varphi_t = \varphi_{t+1} - \frac{\delta}{1+\delta}\left(\mathrm{r}_{t+1}^{US} - \mathrm{r}_{t+1}^{EU}\right).$$

A higher value of φ_t must be accompanied by either a higher value of φ_{t+1} or a lower value of $\mathrm{r}_{t+1}^{US} - \mathrm{r}_{t+1}^{EU}$ or both. Thus, when consumers see a higher φ_t, they anticipate that either the U.S. consumption basket is going to be relatively cheaper in the future or U.S. consumers' real interest income is going to be relatively lower or both. But a cheaper U.S. consumption basket in the future tends to shift demand for U.S. goods from today to tomorrow. Similarly, relatively lower interest income reduces the demand for U.S. goods today because of optimal consumption smoothing.

From the supply equations (2.19),

$$\mathrm{y}_t^{US} - \mathrm{y}_t^{EU} = -\left(\mathrm{t}_t^{US} - \mathrm{t}_t^{EU}\right) + \eta_t + \varphi_t - \left(\mathrm{c}_t^{US} - \mathrm{c}_t^{EU}\right). \tag{3.7}$$

An improvement in the U.S. effective terms of trade induces U.S. producers to supply more output relative to Europeans. The same is true of a real effective depreciation of the dollar. Both changes face U.S. producers with more favorable relative price conditions and cause them to put more effort in production.

Solving (3.7) for the effective terms of trade of the U.S. and substituting into (3.6) gives:

$$\mathrm{y}_t^{US} - \mathrm{y}_t^{EU} = -\frac{\theta-1+2b}{1+\theta}\left(\mathrm{c}_t^{US} - \mathrm{c}_t^{EU}\right) + \frac{1-2b}{1+\theta}\left(\mathrm{g}_t^{US} - \mathrm{g}_t^{EU}\right) - \frac{\theta}{1+\theta}\left(\mathrm{t}_t^{US} - \mathrm{t}_t^{EU}\right) + \frac{2b\theta}{1+\theta}\varphi_t. \tag{3.8}$$

When demand and supply effects are combined, a real effective depreciation of the dollar has an expansionary effect on aggregate U.S. output relative to European.

I now explore the consequences of a change in the steady-state asset holdings of the U.S. relative to Europe. From (3.1),

$$\overline{c}^{EU} = \delta\overline{b}^{EU} + \overline{p}^{EU}(eu) + \overline{y}^{EU} - \overline{p}^{EU} - \overline{g}^{EU}.$$

Subtracting this equation from the corresponding equation for the U.S. yields:

$$\overline{c}^{US} - \overline{c}^{EU} = \delta\left(\overline{b}^{US} - \overline{b}^{EU}\right) + \overline{\eta} + \overline{\varphi} + \overline{y}^{US} - \overline{y}^{EU} - \left(\overline{g}^{US} - \overline{g}^{EU}\right). \tag{3.9}$$

Although this point had been left implicit in the previous subsection, changes in holdings of nominal assets are subject to the constraint that net foreign assets expressed in a common currency must be zero on a world scale—equation (2.10). Because I have assumed that initial net foreign assets are zero in each region, totally differentiating a barred version of (2.10) and normalizing by $\overline{C}_0^W$ yields:

$$\overline{\mathrm{b}}^{US} + a\overline{\varepsilon}_0^I\overline{\mathrm{b}}^I + (1-a)\overline{\varepsilon}_0^O\overline{\mathrm{b}}^O = 0.$$

Assuming that the exchange rate between the dollar and the European currencies is 1 in the initial steady state, this condition simplifies to:

$$\overline{\mathrm{b}}^{US} + a\overline{\mathrm{b}}^I + (1-a)\overline{\mathrm{b}}^O = 0. \tag{3.10}$$

Making use of this condition, (3.9) can be rewritten as:

$$\overline{c}^{US} - \overline{c}^{EU} = 2\delta\overline{b}^{US} + \overline{\eta} + \overline{\varphi} + \overline{y}^{US} - \overline{y}^{EU} - \left(\overline{g}^{US} - \overline{g}^{EU}\right).$$

Combining this equation with barred versions of (3.6) and (3.7), we have:

$$\overline{c}^{US} - \overline{c}^{EU} = \frac{1+\theta}{\theta-1+2b}\delta\overline{b}^{US} - \frac{\theta-1}{2(\theta-1+2b)}\left(\overline{t}^{US} - \overline{t}^{EU}\right) - \frac{\theta-1+4b}{2(\theta-1+2b)}\left(\overline{g}^{US} - \overline{g}^{EU}\right) + \frac{2b\theta}{\theta-1+2b}\overline{\varphi}, \tag{3.11}$$

$$\overline{\eta} = \frac{2(1-b)}{\theta-1+2b}\delta\overline{b}^{US} + \frac{b}{\theta-1+2b}\left[\left(\overline{t}^{US} - \overline{t}^{EU}\right) - \left(\overline{g}^{US} - \overline{g}^{EU}\right)\right] - \frac{(1-2b)(\theta-1)}{\theta-1+2b}\overline{\varphi}. \tag{3.12}$$

Because purchasing power parity does not hold across the Atlantic, the steady-state consumption differential between the U.S. and Europe, as well as the U.S. effective terms of trade, depend also on the effective real exchange rate of the dollar. An effective real depreciation of the U.S. currency increases U.S. output available for consumption, and thus raises U.S. aggregate consumption relative to European. However, by making more output available, it worsens the effective terms of trade of the U.S. A redistribution of net foreign assets from Europe to the U.S. widens the differential between U.S. and European aggregate consumption and improves the U.S. effective terms of trade. Because I am considering the difference between aggregate variables, the relative size of the *ins* versus the *outs* does not affect the impact of a change in the distribution of asset holdings between Europe and the U.S.

In order to find a reduced form for the aggregate consumption differential across the Atlantic, it is necessary to derive an expression for the dollar effective real exchange rate. This can be done by making use of equations (2.14), (2.19), (3.11), and of the definition of the transatlantic real effective exchange rate. The resulting equation is:

$$\varphi_t = -\frac{(1-b)(1-2b)}{b[1+2\theta(1-b)]}\left(\mathrm{c}_t^{US}-\mathrm{c}_t^{EU}\right)-\frac{(1-2b)^2}{2b[1+2\theta(1-b)]}\left(\mathrm{g}_t^{US}-\mathrm{g}_t^{EU}\right)-\frac{1-2b}{2b[1+2\theta(1-b)]}\left(\mathrm{t}_t^{US}-\mathrm{t}_t^{EU}\right). \tag{3.13}$$

An increase in aggregate U.S. consumption relative to European causes an effective real appreciation of the dollar by inducing an increase in the demand for the U.S. currency. An increase in U.S. government consumption makes a real appreciation of the dollar necessary in order to re-equilibrate the goods markets by increasing relative demands for U.S. goods. If U.S. producers face higher taxes, the relative supply of U.S. goods declines, and a real appreciation is required to restore equilibrium.

Equation (3.11) can be combined with a barred version of (3.13) to take the endogeneity of the effective real exchange rate of the dollar into account. When the aggregate consumption differential between the U.S. and Europe widens, the dollar appreciates in effective real terms. This tends to reduce the expansionary impact of a redistribution of wealth from Europe to the U.S. on relative U.S. consumption. Nonetheless, the impact of the real appreciation is more than offset by the expansionary effect of $\overline{b}^{US} > 0$, so that a wealth transfer from Europe to the U.S. does expand U.S. aggregate consumption relative to European.

More U.S. government consumption reduces U.S. private aggregate consumption relative to European both by diminishing the amount of goods available for private consumption and by causing a real appreciation. The initial reduction in relative U.S. consumption tends to depreciate the dollar in real terms, so that the overall impact of a change in government consumption on aggregate private consumption appears ambiguous. Again, combining (3.11) with a barred version of (3.13) shows that the depreciation effect is more than offset by the others, so that increases in U.S. government consumption do reduce steady-state aggregate private consumption in the U.S. relative to Europe. The same conclusion can be reached about the impact of an increase in U.S. distortionary taxes. This tends to reduce the supply of goods in the U.S. and hence to reduce U.S. aggregate consumption directly and indirectly via real effective appreciation of the dollar. The initial decrease in U.S. consumption relative to European tends to depreciate the dollar in effective real terms by reducing the demand for U.S. currency, which would increase relative U.S. consumption. When all effects are considered jointly, higher distortionary taxes contract U.S. steady-state aggregate consumption relative to European.

A wealth transfer improves the effective terms of trade of the U.S. directly and indirectly by increasing the aggregate consumption differential and by the real effective appreciation that follows. An increase in U.S. distortionary taxes tends to improve the effective terms of trade of the U.S. by diminishing the supply of U.S. goods and appreciating the dollar in effective real terms. However, U.S. aggregate consumption decreases relative to European. Hence, the real effective exchange rate tends to depreciate. It is possible to verify that the supply-side effect is strong enough to induce an improvement in the U.S. terms of trade when all effects are considered together. An increase in $\overline{g}^{US}$ tends to worsen the terms of trade directly by increasing U.S. output. In addition, the aggregate U.S.-Europe consumption differential shrinks, which means that the dollar effective real exchange rate tends to depreciate. This effect tends to worsen the terms of trade even further. This notwithstanding, more government spending directly induces an effective real appreciation of the dollar, which tends to improve the terms of trade. Again, once can show that, when all effects are combined, the effective terms of trade of the U.S. worsen as a consequence of higher government consumption.[34]

3.c. Solving for Population-Weighted World Aggregates

Taking a population-weighted average of the supply equations (2.19) and making use of the price equations (2.14) yields:

$$y_t^W = -t_t^W - c_t^W,$$

where $t_t^W \equiv t_t^{US} + a t_t^I + (1-a) t_t^O$. Combining the steady-state version of this equation with a barred version of (2.18) gives:

$$\overline{y}^W = \frac{\overline{g}^W - \overline{t}^W}{2},$$

$$\overline{c}^W = -\frac{\overline{g}^W + \overline{t}^W}{2}.$$

A permanent rise in government spending raises steady-state world output: it increases demand of the representative good and, consequently, its price. Agents respond by substituting into work and out of leisure and this induces an increase in output. For this reason, world consumption falls by less than the rise in government spending. A permanent rise in distortionary taxation reduces steady-state world output by inducing agents to substitute into leisure and out of work. However, less supply of goods means that prices have to increase in order to re-equilibrate the markets. This dampens the incentive to reduce the work effort and implies that steady-state world output (and consumption) decrease by less than the rise in distortionary taxation.[35] Because of the symmetry across agents in the world economy, small changes in the international distribution of net foreign asset holdings have no first-order effect on world consumption or income.

[34] Note that, by construction, the U.S. and Europe have identical economic size: both regions produce all goods in the range between 0 and 1 and changes in *b* have mirror effects on trade. If *b* increases, the share of European goods in the U.S. consumption basket increases, but so does the share of U.S. goods in the European consumption baskets, thus leaving the relative positions of the U.S. and Europe in world trade unchanged.

[35] In the case of an increase in government spending, more supply of goods made lower prices necessary to re-equilibrate the markets, thus dampening the incentive to put more effort in production. Consequently, steady-state world output increased by less than the increase in government spending.

3.d. Solving for the Levels of Individual Variables

Having derived reduced forms for differences and world aggregates, it is easy to solve for the levels of the individual variables.[36] We know that, for any variable x_t, $x_t^W \equiv x_t^{US} + a x_t^I + (1-a) x_t^O$. In addition, by definition of aggregate European variables, $x_t^W = x_t^{US} + x_t^{EU}$. Given the solutions for differences and world variables, individual variables are thus given by:

$$
\begin{aligned}
x_t^{US} &= \frac{x_t^W}{2} + \frac{\left(x_t^{US} - x_t^{EU}\right)}{2}, \\
x_t^I &= x_t^W - x_t^{US} + (1-a)\left(x_t^I - x_t^O\right) = x_t^{EU} + (1-a)\left(x_t^I - x_t^O\right), \\
x_t^O &= x_t^W - x_t^{US} - a\left(x_t^I - x_t^O\right) = x_t^{EU} - a\left(x_t^I - x_t^O\right).
\end{aligned}
\tag{3.14}
$$

Using these formulas and the results obtained above, it is possible to check that, for example, steady-state consumption in the U.S. depends on the overall stance of fiscal policy on a world scale and on shocks that affect the aggregate position of the U.S. vis-à-vis Europe. Quite intuitively, intra-European developments that leave the aggregate world stance of fiscal policy and the relative position of the U.S. unaffected do not have any impact on U.S. consumption. Instead, consumption in the *ins* (*outs*) economy is affected also by purely intra-European shocks. When the size of the *ins* approaches the whole of Europe ($a \to 1$), the impact of differences vis-à-vis the *outs* tends to vanish and $\bar{c}^I \to \bar{c}^{EU}$. Analogously, when a is very small, $\bar{c}^O$ approaches $\bar{c}^{EU}$.

4. Short-Run Dynamics with Sticky Prices

As in Obstfeld and Rogoff (1995, 1996 Ch. 10), I assume that the domestic-currency price of domestic goods—$p^{US}(us),\ p^I(i),\ p^O(o)$—is set one period in advance, but it adjusts to the flexible-price level after one period. More formally, in the short run (at time 1) domestic currency prices of domestic goods are fixed at their initial steady-state levels: $p_1^{US}(us) = \bar{p}_0^{US}(us),\ p_1^I(i) = \bar{p}_0^I(i),\ p_1^O(o) = \bar{p}_0^O(o)$.[37] Output becomes demand determined and the labor-leisure trade-off equations (2.19) do not bind. However, the other equilibrium equations (2.14)-(2.18) and (2.20)-(2.24) hold also in the sticky-price short run.[38]

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[36] The solutions for differences between U.S. and *ins* (*outs*) per capita variables are not necessary to solve for the levels of individual variables.

[37] Even with domestic currency prices of domestic goods set a period in advance, domestic currency prices of foreign goods—for example, $p^{US}(i)$ and $p^{US}(o)$—must be able to fluctuate with the exchange rates in order for the law of one price to hold. In the absence of impediments to trade, it is not possible for all goods to have fixed nominal prices in all regions.

[38] Obstfeld and Rogoff suggest the menu cost approach of Akerlof and Yellen (1985) and Mankiw (1985) as a justification for the assumption of sticky prices. This hypothesis allows the model to explain *why* output becomes demand determined in the short run if prices are rigid. If markets were competitive, there would be no strong reason for arguing that output responds to movements in demand rather than supply. Under monopoly, prices are set above marginal cost. Hence, producers will adjust quantities as a reaction to changes in demand even if they cannot change their prices.

Another difference between the short and long run is that in the short run, income need not equal expenditure.[39] Regions may run current account surpluses according to:

$$ {}_N B_{t+1} - {}_N B_t = i_t \, {}_N B_t + p_t(j) y_t(j) - P_t(C_t + G_t), \qquad (4.1) $$

where region-superscripts have been omitted. Normalizing $\overline{P}_0 = 1$, linearized short-run (period 1) current account equations for the U.S. and the two European economies can be written as:

$$ \begin{aligned} \overline{\mathrm{b}}^{US} &= \mathrm{y}^{US} - \mathrm{c}^{US} - \mathrm{g}^{US} - b\mathrm{e}^{EU}, \\ \overline{\mathrm{b}}^{I} &= \mathrm{y}^{I} - \mathrm{c}^{I} - \mathrm{g}^{I} + b\mathrm{e}^{EU} + (1-a)(\mathrm{e}^{I} - \mathrm{e}^{O}), \qquad (4.2) \\ \overline{\mathrm{b}}^{O} &= \mathrm{y}^{O} - \mathrm{c}^{O} - \mathrm{g}^{O} + b\mathrm{e}^{EU} - a(\mathrm{e}^{I} - \mathrm{e}^{O}). \end{aligned} $$

Time subscripts are dropped because nominal prices adjust in one period, and this implies that the world economy reaches its long-run equilibrium in just one period. Hence, barred variables denote the long run (period 2 and beyond) and variables without time subscripts or bars denote period 1 variables. As a approaches 1, the *outs* region reduces to a small open economy whose actions have a negligible impact on the U.S. and the *ins*' current accounts but whose current account becomes increasingly sensitive to changes in the exchange rates with these economies. If the financial markets equilibrium condition (3.10) is taken into account, equations (4.2) imply the goods markets equilibrium condition $\mathrm{y}^W = \mathrm{c}^W + \mathrm{g}^W$, as expected.[40]

As Obstfeld and Rogoff (1995, 1996 Ch. 10) point out, it is important to stress that $\overline{\mathrm{b}}^j$ ($j = US, I, O$) appears in equations (4.2). This is because, with one-period price setting, whatever net foreign asset holdings arise at the end of the first period become the new steady-state levels from period 2 on. That is, $\mathrm{b}_t^j = \overline{\mathrm{b}}^j$, $\forall t \geq 2$, because all agents have equal discount rates and outputs are constant. This provides a crucial link between short- and long-run equilibrium. Steady-state variables are functions of $\overline{\mathrm{b}}^j$, but $\overline{\mathrm{b}}^j$ is affected by short-run current-account imbalances. In Corsetti and Pesenti (1998), the assumption of unitary intratemporal elasticity of substitution across goods ensures that policy shocks have no effect on the current account and *de facto* removes this link between short- and long-run equilibrium.

4.a. Solving for *Ins-Outs* Differences

As for the flexible-price steady state, I focus initially on intra-European differences. Subtracting the log-linearized Euler equations for the two European regions yields:

$$ \overline{\mathrm{c}}^I - \overline{\mathrm{c}}^O = \mathrm{c}^I - \mathrm{c}^O, \qquad (4.3) $$

where the left-hand side is the difference in long-run consumption changes and the right-hand side is the difference in short-run (period 1) changes. Equation (4.3) shows that changes in relative *ins* and *outs* consumption levels are permanent, even though short-run real interest rate changes can tilt individual-region consumption profiles.[41] The fact that the *ins-outs* consumption differential follows a random walk has important consequences for the properties of the model. All shocks that cause the short-run differential to change end up affecting long-run asset accumulation by changing also the long-run consumption differential. Thus, all shocks that cause a change in the

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[39] This is in contrast with long-run equations (3.1).

[40] In deriving equations (4.2), I have made use of equations (2.14) and of the fact that domestic currency prices of domestic goods are preset in the short run.

[41] The reason is that agents in both European regions face the same real interest rate. Therefore, interest rate changes tilt consumption profiles proportionately.

short-run consumption differential end up having permanent consequences for other real variables as well by generating a new steady-state distribution of international asset holdings. In particular, as we shall see shortly, this non-stationarity of the model—anticipated in Section 2.f—implies that monetary shocks have permanent real consequences regardless of whether agents are holding nominal or real bonds.[42]

To keep things simple, I focus on permanent shocks to monetary policy. In the case of a permanent change in relative money supply in Europe, it is:

$$\overline{m}^I - \overline{m}^O = m^I - m^O, \tag{4.4}$$

where m is the percentage deviation of the time 1 money supply from the initial steady state: $m \equiv (M_1 - \overline{M}_0) / \overline{M}_0$.[43]

Because prices are sticky only in the short run, all variables adjust to their steady-state values by the end of period 2. Hence, $e_t^J = \overline{e}^J \;\forall t > 2$ ($J = I, O$) and equation (2.22) can be rewritten as:

$$m^I - m^O - \left(e^O - e^I\right) = c^I - c^O - \frac{1}{\delta}\left[\left(\overline{e}^O - \overline{e}^I\right) - \left(e^O - e^I\right)\right]. \tag{4.5}$$

Equations (3.6) and (4.3) imply:

$$\overline{e}^O - \overline{e}^I = \left(\overline{m}^I - \overline{m}^O\right) - \left(c^I - c^O\right). \tag{4.6}$$

Substituting (4.6) into (4.5) and taking (4.4) into account, we obtain:

$$e^O - e^I = \left(m^I - m^O\right) - \left(c^I - c^O\right). \tag{4.7}$$

Comparing (4.6) and (4.7)—and recalling (4.4)—we see that $e^O - e^I = \overline{e}^O - \overline{e}^I$: the exchange rate between the two European currencies jumps immediately to its new long-run equilibrium following a permanent relative money shock. The intuition is apparent from (4.5): if money-supply and consumption differentials are both expected to be constant, then the exchange rate must be expected to be constant as well. This is the same result that is obtained by Obstfeld and Rogoff (1995, 1996 Ch. 10) and Corsetti and Pesenti (1998).[44]

Figure 1 shows equation (4.7) as the downward-sloping **MM** schedule; its slope is -1. The schedule is downward sloping because an increase in relative *ins*' consumption raises *ins*' money demand. Therefore, the *ins*' relative price level must fall, implying an appreciation of the exchange rate between the euro and the *outs*' currency. The schedule intersects the vertical $e^O - e^I$ axis at $m^I - m^O$, which would be the equilibrium exchange rate response in the absence of changes in the consumption differential.

A second schedule relating $e^O - e^I$ to the *ins-outs* consumption differential can be obtained as follows. From (4.2),

$$\overline{b}^I - \overline{b}^O = y^I - y^O - \left(c^I - c^O\right) - \left(g^I - g^O\right) + e^I - e^O. \tag{4.8}$$

Equation (3.2), together with short-run price rigidity, implies:

$$y^I - y^O = -\theta\left(e^I - e^O\right). \tag{4.9}$$

[42] See Obstfeld and Rogoff (1995, 1996 Ch. 10) and recall footnote 32.

[43] Solving the model for the more general case in which $\overline{m}^I - \overline{m}^O \neq m^I - m^O$ is slightly more complicated.

[44] Corsetti and Pesenti obtain the no-overshooting result assuming a general CES utility of composite consumption rather than log-utility. Their result shows the robustness of the finding to alternative specifications of the utility function.

Equation (3.4) gives the *ins-outs* steady-state consumption differential as a function of steady-state relative asset holdings. Taking (4.3) and (4.4) into account and rearranging yields:

$$\bar{b}^I - \bar{b}^O = \frac{2\theta}{(1+\theta)\delta}\left(c^I - c^O\right) + \frac{1}{\delta}\left(\bar{g}^I - \bar{g}^O\right) + \frac{\theta - 1}{(1+\theta)\delta}\left(\bar{t}^I - \bar{t}^O\right). \tag{4.10}$$

Combining (4.8) and (4.10) and taking (4.9) into account, we have:

$$e^O - e^I = \frac{2\theta + (1+\theta)\delta}{\delta(\theta^2 - 1)}\left(c^I - c^O\right) + \frac{1}{\theta - 1}\left[g^I - g^O + \frac{1}{\delta}\left(\bar{g}^I - \bar{g}^O\right)\right] + \frac{1}{(\theta+1)\delta}\left(\bar{t}^I - \bar{t}^O\right),$$

which is the upward-sloping **GG** schedule in Figure 1. This schedule slopes upward because *ins*' consumption can rise relative to *outs*' only if the euro depreciates in the short run and permits *ins*' output to rise relative to *outs*'. The steady-state component of the government spending differential is multiplied by $1/\delta \; (= 1/\bar{r})$, reflecting that current consumption behavior depends on the present discounted value of government spending in all future periods. Purely temporary changes in distortionary taxes have no effect on the exchange rate. This is because output is demand-determined in the short run and distortionary taxes do not appear in equation (4.1) which combines both the individuals' and the government's budget constraints. Taxes redistribute income available for consumption between the government and the private sector. For given total consumption of the economy a temporary change in taxation does not alter the region's aggregate demand, which determines output in the short run, and therefore cannot affect the exchange rate. Instead, a change in steady-state taxation does affect the long-run (and short-run) consumption differential through its impact on the supply equations—which are binding in the long run—and hence alters the current exchange rate.

The two schedules can be combined to solve for $e^O - e^I$ and $c^I - c^O$. Solid lines in Figure 2 correspond to the equilibrium in the absence of any policy shock. Solutions for exchange rate and consumption differential are, respectively:

$$e^O - e^I = \frac{2\theta + \delta(\theta+1)}{2\theta + \theta\delta(\theta+1)}\left(m^I - m^O\right) + \frac{\delta(\theta+1)}{2\theta + \theta\delta(\theta+1)}\left[g^I - g^O + \frac{1}{\delta}\left(\bar{g}^I - \bar{g}^O\right)\right] + \frac{\theta - 1}{2\theta + \theta\delta(\theta+1)}\left(\bar{t}^I - \bar{t}^O\right). \tag{4.11}$$

$$c^I - c^O = \frac{\delta(\theta^2 - 1)}{2\theta + \theta\delta(\theta+1)}\left(m^I - m^O\right) - \frac{\delta(\theta+1)}{2\theta + \theta\delta(\theta+1)}\left[g^I - g^O + \frac{1}{\delta}\left(\bar{g}^I - \bar{g}^O\right)\right] - \frac{\theta - 1}{2\theta + \theta\delta(\theta+1)}\left(\bar{t}^I - \bar{t}^O\right). \tag{4.12}$$

Because domestic currency prices of domestic goods are rigid in the short run, equation (4.11) also gives the short-run change in the terms of trade between the representative European goods.

Combining (4.11) and (4.9) yields the short-run output differential:

$$y^I - y^O = \theta \left\{ \begin{array}{l} \frac{2\theta + \delta(\theta+1)}{2\theta + \theta\delta(\theta+1)}\left(m^I - m^O\right) + \frac{\delta(\theta+1)}{2\theta + \theta\delta(\theta+1)}\left[g^I - g^O + \frac{1}{\delta}\left(\bar{g}^I - \bar{g}^O\right)\right] + \\ + \frac{\theta - 1}{2\theta + \theta\delta(\theta+1)}\left(\bar{t}^I - \bar{t}^O\right) \end{array} \right\}.$$

Substituting (4.12) into (4.10) yields the short-run relative current account (which equals the long-run change in relative net foreign assets $\bar{b}^I - \bar{b}^O$): [45]

[45] Global asset markets equilibrium has not been imposed in (4.10) and in the derivation of the following equations. However, it is possible to show that taking condition (3.10)—and the reduced form for $\bar{b}^{US}$ —into

$$\bar{b}^I - \bar{b}^O = \frac{2(\theta-1)}{2+\delta(1+\theta)}(m^I - m^O) - \frac{2}{2+\delta(1+\theta)}(g^I - g^O) + \frac{1+\theta}{2+\delta(1+\theta)}(\bar{g}^I - \bar{g}^O) + \frac{\theta-1}{2+\delta(1+\theta)}(\bar{t}^I - \bar{t}^O). \tag{4.13}$$

4.a.1. Monetary Policy Shocks

Consider a permanent shock to relative money supply such that $\mathrm{m}^I - \mathrm{m}^O > 0$ in the absence of any other policy shock. In Figure 2, the **MM** schedule shifts to **MM'**, whereas the **GG** schedule remains unchanged. The impact of $\mathrm{m}^I - \mathrm{m}^O > 0$ on the exchange rate is an unambiguous depreciation of the euro against the *outs*' currency. The depreciation has an expansionary impact on the *ins* economy that raises *ins*' consumption relative to *outs*'. Because $\theta > 1$, the impact of $\mathrm{m}^I - \mathrm{m}^O$ on the *ins-outs* exchange rate is less than 1:1 and the euro depreciates less than proportionately in response to a monetary surprise *even in the long run*. (Recall that $\mathrm{e}^O - \mathrm{e}^I = \bar{\mathrm{e}}^O - \bar{\mathrm{e}}^I$ for a permanent money shock.) The short-run depreciation temporarily raises *ins*' real income relative to *outs*' so that the *ins* economy runs a current-account surplus, via the usual intertemporal consumption-smoothing channel. Higher long-run wealth leads to substitution into leisure in the *ins* economy (vice versa for the *outs*), a fall in the supply of *ins* goods, and therefore an improvement in the long-run terms of trade of the *ins* vis-à-vis the *outs*. Because *ins*' real income and consumption rise in the long run, the nominal exchange rate does not need to depreciate 1:1 to re-equilibrate markets.

4.a.1.b. The Role of the Initial Position

If the initial steady state had been characterized by non-zero asset holdings, the **GG** schedule would have reacted to a monetary shock, because equation (3.4) would have incorporated the redistribution effect of an unexpected change in prices on existing wealth. A monetary expansion in the *ins* economy would have shifted the **GG** schedule to the left, and the effect on the consumption differential would have been ambiguous. On one side the expansionary effect of the depreciation of the euro on the *ins* economy would have tended to raise *ins*' consumption relative to *outs*'. On the other side, the monetary shock would have redistributed real wealth in favor of the *outs* economy, which tends to decrease the consumption differential. The former effect prevails only if θ is sufficiently high, *i.e.*, only if goods produced in the two European regions are sufficiently close substitutes. Both the solutions for the short- and long-run levels of variables would have been affected by a different initial asset holding position (recall footnote 32).

4.a.2. Fiscal Policy Shocks

Consider now the impact of a purely temporary government spending shock in the *outs* economy, such that $\mathrm{g}^I - \mathrm{g}^O < 0$ and $\bar{\mathrm{g}}^I - \bar{\mathrm{g}}^O = 0$, all other policy instruments being held constant. The effect is shown in Figure 3. The **MM** schedule does not shift, whereas the **GG** schedule shifts to **GG'**. A rise in *outs*' government spending induces the euro to appreciate against the *outs*'

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account does not affect the expression for $\bar{\mathrm{b}}^I - \bar{\mathrm{b}}^O$. Consequently, the intra-European exchange rate $\mathrm{e}^O - \mathrm{e}^I$ is determined independently of transatlantic phenomena, namely of e^{EU}, and of the relative size of the two European economies. See Ghironi (1999*a*) for more details.

currency. What causes the depreciation of the *outs*' currency? A rise in *outs*' government spending leads to an immediate fall in relative *outs*' consumption. Lower consumption implies lower money demand, thus requiring a rise in the price level and a depreciation of the currency. Because $\theta > 1$, the *ins* economy runs a current-account surplus relative to the *outs* as a consequence of the temporary fiscal expansion by the *outs*' government, whereas the *outs* economy runs a deficit. In the case of a permanent rise in *outs*' government spending relative to *ins*'—$\mathsf{g}^I - \mathsf{g}^O = \overline{\mathsf{g}}^I - \overline{\mathsf{g}}^O < 0$—$\theta > 1$ ensures that the *ins* economy runs a deficit vis-à-vis the *outs*. The reason is that, with preset prices, short-run *outs*' income rises by more than long-run, so *outs* residents adjust current consumption downward by more than the change in government spending and save in the form of a surplus vis-à-vis the *ins*. These results parallel those in Obstfeld and Rogoff (1995, 1996 Ch. 10) but are different from those in Corsetti and Pesenti (1998), where a permanent government spending shock has no short-run effect on consumption.

Figure 4 shows what happens in the case of an unexpected increase in *ins*' steady-state distortionary taxes relative to *outs*'—$\overline{\mathsf{t}}^I - \overline{\mathsf{t}}^O > 0$. The **MM** schedule remains at its original position. The **GG** schedule shifts to **GG'**. The euro depreciates vis-à-vis the *outs*' currency and *ins*' consumption decreases relative to *outs*'. The immediate decrease in *ins*' consumption induced by higher taxes implies lower demand for euros. Hence, the *ins*' price level must rise relative to the *outs*' in order to keep equilibrium in the money market, and the euro depreciates. Because *ins*' income increases relative to *outs*' as a consequence of the depreciation, optimal consumption smoothing by *ins* consumers implies that the *ins* economy runs a current-account surplus vis-à-vis the *outs*.

Having solved for $\overline{\mathsf{b}}^I - \overline{\mathsf{b}}^O$, it is easy to complete the solution for the long-run changes induced by policy shocks in the presence of short-run price rigidities. For example, substituting (4.12) and (4.13) into (3.5) would give the steady-state change in the *ins*-*outs* terms of trade.

4.b. Solving for Differences between Aggregate U.S. and European Variables

As for the flexible-price steady state, the solution for interactions between the U.S. and Europe is complicated by the absence of purchasing power parity across the Atlantic. The consumption Euler equations (2.20) imply:

$$\overline{\mathsf{c}}^{US} - \overline{\mathsf{c}}^{EU} = \mathsf{c}^{US} - \mathsf{c}^{EU} + \frac{\delta}{1+\delta}\left(\mathsf{r}^{US} - \mathsf{r}^{EU}\right), \tag{4.14}$$

where r is the short-run real interest rate (on loans between periods 1 and 2). The long-run consumption differential is affected by the short-run real interest rate differential caused by deviations from PPP.

Recalling that $e_t^{EU} = \overline{e}^{EU}\ \forall t > 2$, equation (2.23) yields:

$$\mathsf{r}^{US} - \mathsf{r}^{EU} = \frac{1+\delta}{\delta}\left[\overline{\mathsf{e}}^{EU} - \mathsf{e}^{EU} + \mathsf{p}^{US} - \mathsf{p}^{EU} - \left(\overline{\mathsf{p}}^{US} - \overline{\mathsf{p}}^{EU}\right)\right]. \tag{4.15}$$

Equations (2.14) and rigidity of prices imply $\mathsf{p}^{US} - \mathsf{p}^{EU} = 2b\mathsf{e}^{EU}$. Also, by definition of effective real exchange rate of the dollar, $\overline{\mathsf{p}}^{US} - \overline{\mathsf{p}}^{EU} = \overline{\mathsf{e}}^{EU} - \overline{\varphi}$. Substituting these results into (4.15) gives:

$$\mathsf{r}^{US} - \mathsf{r}^{EU} = \frac{1+\delta}{\delta}\left[\overline{\varphi} - (1-2b)\mathsf{e}^{EU}\right].$$

This equation can be substituted into (4.14) to obtain:

$$\bar{c}^{US} - \bar{c}^{EU} = c^{US} - c^{EU} + \bar{\varphi} - (1-2b)e^{EU}. \quad (4.16)$$

Equation (2.24) yields:

$$\bar{e}^{EU} - e^{EU} = \delta\left[p^{US} - p^{EU} - \left(m^{US} - m^{EU}\right) + c^{US} - c^{EU}\right]. \quad (4.17)$$

The definition of the dollar real exchange rate and barred versions of equations (2.21) imply:

$$\bar{e}^{EU} = m^{US} - m^{EU} - \left(\bar{c}^{US} - \bar{c}^{EU}\right) + \bar{\varphi}, \quad (4.18)$$

where I have made use of the assumption of unexpected permanent monetary shocks: $\bar{m}^{US} - \bar{m}^{EU} = m^{US} - m^{EU}$.

Substituting $p^{US} - p^{EU} = 2be^{EU}$ and (4.18) into (4.17), and making use of (4.16), yields:

$$e^{EU} = \frac{1}{2b}\left(m^{US} - m^{EU}\right) - \frac{1}{2b}\left(c^{US} - c^{EU}\right). \quad (4.19)$$

Equation (4.19) is shown in Figure 5 as the **MM^** schedule. Its slope is - (1/2*b*): if c^{US} increases relative to c^{EU}, the demand for dollars increases relative to that for European currencies. Hence, the dollar appreciates. Only if *b* = 1/2 the **MM^** schedule has slope -1. In the general case in which *b* < 1/2, **MM^** is steeper than **MM**. Because of the asymmetry in the U.S. and European consumption baskets, the transatlantic nominal exchange rate becomes more sensitive to changes in the consumption differential, the more so the smaller the extent of trade between the U.S. and Europe.[46]

Does the nominal exchange rate of the dollar overshoot or undershoot its long-run equilibrium following shocks? If *b* = 1/2, purchasing power parity between the U.S. and Europe implies $\bar{\varphi} = 0$. As a consequence, equations (4.14), (4.18), and (4.19) immediately yield $\bar{e}^{EU} = e^{EU}$ in the special case *b* = 1/2. It is easy to show that the nominal effective exchange rate of the dollar—as well as the exchange rates against the individual European currencies—does not overshoot (or undershoot) its long-run equilibrium also in the general case in which *b* < 1/2. Substituting (4.16) into (4.18) yields:

$$\bar{e}^{EU} = m^{US} - m^{EU} - \left(c^{US} - c^{EU}\right) + (1-2b)e^{EU}.$$

Solving (4.19) for the consumption differential and substituting into the previous equation yields $\bar{e}^{EU} = e^{EU}$. The asymmetry in consumption patterns across the Atlantic is not sufficient to induce the dollar to overshoot (or undershoot) its long-run equilibrium as a consequence of unanticipated policy shocks. The intuition is simple. In the intra-European context, in which purchasing power parity always holds, no overshooting (or undershooting) happens because constant expected money-supply and consumption differentials require that the expected exchange rate be constant as well.[47] However, the same must be true for the transatlantic exchange rate, notwithstanding short-run deviations from PPP. It is easy to check that:

$$\bar{\varphi} = \varphi + \frac{\delta}{1+\delta}\left(r^{US} - r^{EU}\right)$$

Because the change in the consumption differential between the short and long run is exactly equal to the change in the real exchange rate of the dollar, there is no need for the nominal value

[46] Conversely, $b < 1/2$ ensures that the transatlantic consumption differential is less sensitive to exchange rate movements than the intra-European consumption differential. This lends support to the fact that policymakers in the United States tend to pay relatively little attention to the movements of the dollar.

[47] This can be verified by solving equation (2.22) forward.

of the U.S. currency to overshoot (or undershoot) its long-run position in order to equilibrate markets.[48]

As for the intra-European case, we need a second schedule relating e^{EU} to $c^{US} - c^{EU}$ in order to find the reduced forms for exchange rate and consumption differential. From equations (4.2),

$$\bar{b}^{US} - \bar{b}^{EU} = y^{US} - y^{EU} - \left(c^{US} - c^{EU}\right) - \left(g^{US} - g^{EU}\right) - 2be^{EU}. \tag{4.20}$$

Equation (3.6) gives:

$$y^{US} - y^{EU} = (1-2b)\left(c^{US} - c^{EU} + g^{US} - g^{EU} - \theta\varphi\right) - \theta\eta.$$

However, because domestic prices of domestic goods are fixed in the short run, $\eta = -e^{EU}$ and $\varphi = e^{EU} - \left(p^{US} - p^{EU}\right) = (1-2b)e^{EU}$. Thus:

$$y^{US} - y^{EU} = (1-2b)\left(c^{US} - c^{EU} + g^{US} - g^{EU}\right) + 4b\theta(1-b)e^{EU}. \tag{4.21}$$

Substituting (4.21) into (4.20) and recalling that $\bar{b}^{US} - \bar{b}^{EU} = 2\bar{b}^{US}$, we have:

$$\bar{b}^{US} = -b\left\{\left(c^{US} - c^{EU}\right) + \left(g^{US} - g^{EU}\right) - \left[2\theta(1-b) - 1\right]e^{EU}\right\}, \tag{4.22}$$

where $\theta > 1$ and $b < /2$ ensure $2\theta(1-b) - 1 > 0$.

Combining (4.22) with (3.13), (3.14), and (4.16) yields:[49]

$$e^{EU} = \mathrm{A}\left(c^{US} - c^{EU}\right) + \mathrm{B}\left(g^{US} - g^{EU}\right) + \Phi\left(\bar{g}^{US} - \bar{g}^{EU}\right) + \Gamma\left(\bar{t}^{US} - \bar{t}^{EU}\right), \tag{4.23}$$

where the parameters A, B, Φ, and Γ are defined in the appendix and I assume that the restrictions ensuring that they are all positive are satisfied.

Equation (4.23) is shown in Figure 5 as the positively sloped **GG^** line.[50] This schedule slopes upward because U.S. consumption can rise relative to European only if the dollar is depreciating against European currencies, thus allowing U.S. income to rise above European. Equations (4.19) and (4.23) determine the transatlantic nominal exchange rate—and short-run terms of trade—and the aggregate short-run consumption differential between the U.S. and Europe:

$$e^{EU} = \frac{\mathrm{A}}{1+2b\mathrm{A}}\left(m^{US} - m^{EU}\right) + \frac{1}{1+2b\mathrm{A}}\left[\mathrm{B}\left(g^{US} - g^{EU}\right) + \Phi\left(\bar{g}^{US} - \bar{g}^{EU}\right) + \Gamma\left(\bar{t}^{US} - \bar{t}^{EU}\right)\right] \tag{4.24}$$

$$c^{US} - c^{EU} = \frac{1}{1+2b\mathrm{A}}\left(m^{US} - m^{EU}\right) - \frac{2b}{1+2b\mathrm{A}}\left[\mathrm{B}\left(g^{US} - g^{EU}\right) + \Phi\left(\bar{g}^{US} - \bar{g}^{EU}\right) + \Gamma\left(\bar{t}^{US} - \bar{t}^{EU}\right)\right]. \tag{4.25}$$

Equations (4.19) and (4.20) make it possible to write the following semi-reduced form equation for the short-run (and long-run) current-account balance of the U.S.:

[48] In Obstfeld and Rogoff's (1995, 1996 Ch. 10) two-country framework, exchange-rate overshooting is obtained by introducing non-traded goods and having a general isoelastic utility for real money balances, with elasticity greater than 1. Isoelastic utility of money balances with elasticity larger than 1 would be sufficient to generate overshooting in transatlantic exchange rates in my model. The "continental bias" in consumer preferences would play the same role as the presence of non-traded goods in Obstfeld and Rogoff (see Warnock, 1998).

[49] See the appendix for details.

[50] It is a matter of straightforward algebra to check that equation (4.23) returns the expression of the **GG** schedule for intra-European differences when $b = 1/2$.

$$\overline{\mathsf{b}}^{US} = \frac{2\theta(1-b)-1}{2}\left(\mathsf{m}^{US} - \mathsf{m}^{EU}\right) - b\left(\mathsf{g}^{US} - \mathsf{g}^{EU}\right) - \left[b + \frac{2\theta(1-b)-1}{2}\right]\left(\mathsf{c}^{US} - \mathsf{c}^{EU}\right). \quad (4.26)$$

4.b.1. Monetary Policy Shocks

Consider the consequences of an unanticipated permanent increase in the U.S. money supply relative to European—$\mathsf{m}^{US} - \mathsf{m}^{EU} > 0$. In Figure 6, solid lines are the pre-shock schedules. The **MM^** schedule shifts to **MM^'**, whereas the **GG^** schedule remains fixed. The dollar unambiguously depreciates in effective terms, and the aggregate short-run consumption differential between the U.S. and Europe widens.[51]

What is the impact of the monetary shock on the current account of the U.S.? The depreciation of the dollar drives U.S. short-run income above European, thus intertemporal consumption smoothing suggests that the U.S. should run a current-account surplus. From (4.26):

$$\frac{\partial\ \overline{\mathsf{b}}^{US}}{\partial\left(\mathsf{m}^{US} - \mathsf{m}^{EU}\right)} = \frac{2\theta(1-b)-1}{2} - \left[b + \frac{2\theta(1-b)-1}{2}\right]\frac{\partial\left(\mathsf{c}^{US} - \mathsf{c}^{EU}\right)}{\partial\left(\mathsf{m}^{US} - \mathsf{m}^{EU}\right)}.$$

Assuming that the aggregate consumption differential widens as a consequence of the monetary expansion, two contrasting forces are affecting the current account, so that the overall effect of the shock appears ambiguous. Plotting $\partial\ \overline{\mathsf{b}}^{US} \big/ \partial\left(\mathsf{m}^{US} - \mathsf{m}^{EU}\right)$ as a function of b and δ for several values of θ shows that the consumption-smoothing effect prevails: the U.S. runs a current-account surplus vis-à-vis Europe as a consequence of an unanticipated permanent monetary expansion. When $\theta \geq 2$, the U.S. surplus is larger the larger θ, the closer b to $1/2$, and the smaller δ.

4.b.2. Fiscal Policy Shocks

Suppose now that there is a purely temporary increase in U.S. government spending relative to European—$\mathsf{g}^{US} - \mathsf{g}^{EU} > 0$, $\overline{\mathsf{g}}^{US} - \overline{\mathsf{g}}^{EU} = 0$—in the absence of any other policy shock. In Figure 7, the **MM^** schedule remains at its original position, while the **GG^** schedule shifts to **GG^'**. The dollar depreciates and the short-run aggregate consumption differential decreases. As for intra-European interactions, the increase in U.S. government consumption induces an immediate decrease in U.S. private consumption. This translates into lower demand for dollars and a higher U.S. price level in order to keep equilibrium in the money market. As a consequence, the dollar depreciates.

What is the impact of a temporary fiscal expansion on the U.S. current account? From equation (4.26):

$$\frac{\partial\ \overline{\mathsf{b}}^{US}}{\partial\left(\mathsf{g}^{US} - \mathsf{g}^{EU}\right)} = -b - \left[b + \frac{2\theta(1-b)-1}{2}\right]\frac{\partial\left(\mathsf{c}^{US} - \mathsf{c}^{EU}\right)}{\partial\left(\mathsf{g}^{US} - \mathsf{g}^{EU}\right)}.$$

Because the consumption differential decreases, two contrasting forces are affecting the current account. A smaller consumption differential tends to induce a current-account surplus, but the

[51] As in the intra-European case, if the initial asset holding position were different from zero, **GG^** would move as a consequence of the monetary shock, and the transatlantic consumption differential would rise only if substitutability across goods were sufficiently high.

direct impact of government spending on the current account tends to move it into deficit. Plotting $\partial \bar{b}^{US} / \partial\left(g^{US} - g^{EU}\right)$ as a function of *b* and δ for several values of θ shows that a temporary increase in relative U.S. government spending unambiguously induces the U.S. economy to run a current-account deficit, which is larger the larger *b* and the smaller δ.

If the shock to relative government spending is permanent—$g^{US} - g^{EU} = \bar{g}^{US} - \bar{g}^{EU} > 0$—the depreciation of the dollar is more pronounced and so is the decrease in U.S. consumption relative to European. In this case, the U.S. runs a current-account surplus for all values of *b* smaller than $1/2$ and all δ's between 0 and 1 if θ is sufficiently big.[52]

When distortionary taxes in the U.S. are permanently higher than in Europe—$\bar{t}^{US} - \bar{t}^{EU} > 0$—the dollar depreciates and the aggregate consumption differential shrinks. In Figure 8, the **MM^** schedule remains unchanged, whereas the **GG^** schedule shifts to **GG^'**. The dollar depreciates as a consequence of the lower money demand caused by the decrease in U.S. consumption. Because the latter decreases relative to European consumption, permanently higher distortionary taxes induce the U.S. economy to run a current-account surplus, which is larger the larger θ and b and the smaller δ.

4.b.3. The Long-Run Effects of Transatlantic Shocks

As for intra-European differences, using the results obtained in this sub-section and the findings of Section 3.b., it is possible to complete the solution for the long-run changes induced by unanticipated policy shocks across the Atlantic. Here, I discuss briefly the long-run consequences of a monetary expansion in the U.S.

Because PPP does not hold between the U.S. and Europe, the long-run consumption differential between the two areas does not equal the short-run. The dollar appreciates in real terms in the long run. The nominal depreciation is more than offset by a wider CPI differential with Europe, and the real appreciation is larger if *b* is small. The intuition is simple. In the short-run, exchange-rate movements account for 100% of CPI fluctuations. In the long run, also individual goods' prices move. For any given value of θ, when *b* is small, U.S. consumers cannot substitute European goods for U.S. In addition, U.S. firms have less reason to worry about the consequences of higher prices on their exports. For both reasons, U.S. firms have an incentive to raise prices by more when *b* is small. Given the nominal depreciation, more aggressive price increases make it more likely that CPI movements are such that a real appreciation is observed. If θ is small, the long-run U.S.-Europe consumption differential shrinks (especially when *b* is small) because of the contractionary effect of the real appreciation. As θ rises, the real appreciation becomes smaller for any value of *b*, and the long-run consumption differential tends to widen as a consequence of the monetary shock over an expanding set of combinations of *b* and δ. The latter result is intuitive too: as θ rises, firms' incentives to charge higher prices weaken, and so does the real appreciation.[53]

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[52] $\theta \geq 1.5$ is sufficient.

4.c. Solving for Short-Run World Aggregates

Recalling that world aggregate variables are defined as $\mathrm{x}^W = \mathrm{x}^{US} + a\mathrm{x}^I + (1-a)\mathrm{x}^O$, the consumption Euler equations (2.20) imply:

$$\bar{\mathrm{c}}^W = \mathrm{c}^W + \frac{\delta}{1+\delta}\mathrm{r}^W,$$

where $\mathrm{r}^W \equiv \mathrm{r}^{US} + \mathrm{r}^{EU} = 2\mathrm{r}^{US}$ because of real interest rate equalization in Europe and one-period price rigidity. From Section 3.c., we know that $\bar{\mathrm{c}}^W = -\left(\bar{\mathrm{g}}^W + \bar{\mathrm{t}}^W\right)/2$. Hence:

$$\mathrm{c}^W = -\frac{\delta}{1+\delta}\mathrm{r}^W - \frac{\bar{\mathrm{g}}^W + \bar{\mathrm{t}}^W}{2}. \tag{4.27}$$

From the money demand equations (2.21):

$$\mathrm{m}^W - \mathrm{p}^W = \mathrm{c}^W - \frac{\mathrm{r}^W}{1+\delta} - \frac{\bar{\mathrm{p}}^W - \mathrm{p}^W}{\delta}. \tag{4.28}$$

However, the steady-state world price level is:

$$\bar{\mathrm{p}}^W = \mathrm{m}^W - \bar{\mathrm{c}}^W = \mathrm{m}^W + \frac{\bar{\mathrm{g}}^W + \bar{\mathrm{t}}^W}{2},$$

where I have made use of the assumption of permanent monetary shocks. Also, short-run rigidity of prices implies that equations (2.14) reduce to:

$$\mathrm{p}^{US} = b\mathrm{e}^{EU},$$
$$\mathrm{p}^I = -b\mathrm{e}^{EU} + (1-a)\left(\mathrm{e}^O - \mathrm{e}^I\right), \tag{4.29}$$
$$\mathrm{p}^O = -b\mathrm{e}^{EU} - a\left(\mathrm{e}^O - \mathrm{e}^I\right),$$

from which it is easy to show that $\mathrm{p}^W = 0$. Thus, equation (4.28) yields:

$$\mathrm{m}^W = \mathrm{c}^W - \frac{\mathrm{r}^W}{1+\delta} - \frac{1}{\delta}\left(\mathrm{m}^W + \frac{\bar{\mathrm{g}}^W + \bar{\mathrm{t}}^W}{2}\right). \tag{4.30}$$

Combining (4.27) and (4.30) and solving for the world real interest rate and short-run consumption, we find:

$$\mathrm{r}^W = -\frac{1+\delta}{\delta}\left(\mathrm{m}^W + \frac{\bar{\mathrm{g}}^W + \bar{\mathrm{t}}^W}{2}\right),$$

$$\mathrm{c}^W = \mathrm{m}^W.$$

In addition, taking (2.18) into account,

$$\mathrm{y}^W = \mathrm{m}^W + \mathrm{g}^W. \tag{4.31}$$

A monetary expansion in the U.S. or in Europe temporarily lowers the world real interest rate in proportion to the size of the expanding region; world consumption therefore expands. In the long run, both the world interest rate and consumption return to their pre-shock levels. Although the effects may be asymmetric, global monetary policy is not a zero-sum game. A permanent rise in government spending and/or distortionary taxes lowers the world short-run interest rate. Note that this depends only on the steady-state (future) values of the fiscal policy instruments. Thus, temporary changes in government spending and/or distortionary taxes have no

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[53] At $\theta = 2$, the consumption differential rises for b sufficiently high.

effect on the world interest rate. This is because output is demand determined in the short run with preset prices. An unanticipated temporary rise in world government spending induces an equal temporary rise in world output with no effect on the net output available to the private sector. Hence, there is no tilting of net output profiles, no interest-rate effect, and no impact on consumption. A temporary change in distortionary taxes does not affect short-run world output because the supply equations are not binding in the short run. Therefore, there is no change in output available for private consumption and no impact on the world interest rate. Steady-state changes in fiscal policy do affect the world interest rate, but still leave world short-run consumption unaffected. Recall equation (4.27): an increase in steady-state world government spending and/or distortionary taxes tends to reduce world consumption directly through its negative impact on the amount of output available for private consumption in the long run. However, this effect is translated into a temporary reduction in the world interest rate to keep equilibrium in the money market. In turn, the temporary reduction in the world interest rate induces consumers to raise short-run consumption and the overall effect of interest rate change and optimal consumption smoothing is such that world short-run consumption does not react to permanent fiscal policy shocks.

4.d. Solving for Short-Run Levels of Individual Variables

As in Section 3.d., solutions for levels of individual variables can be found easily by making use of formulas (3.14). In this section I derive semi-reduced form equations for output and consumption levels that allow me to describe the short-run effects of economic policies.

4.d.1. Output

From equations (4.21), (4.31), and the definition of world variables,

$$\mathrm{y}^{US} = \frac{\mathrm{m}^{W} + \mathrm{g}^{W}}{2} + \frac{1-2b}{2}\left(\mathrm{c}^{US} - \mathrm{c}^{EU} + \mathrm{g}^{US} - \mathrm{g}^{EU}\right) + 2b\theta(1-b)\mathrm{e}^{EU}.$$

Making use of formulas (3.14) and of equation (4.9), we have:

$$\mathrm{y}^{I} = \frac{\mathrm{m}^{W} + \mathrm{g}^{W}}{2} - \frac{1-2b}{2}\left(\mathrm{c}^{US} - \mathrm{c}^{EU} + \mathrm{g}^{US} - \mathrm{g}^{EU}\right) - 2b\theta(1-b)\mathrm{e}^{EU} + (1-a)\theta\left(\mathrm{e}^{O} - \mathrm{e}^{I}\right),$$

$$\mathrm{y}^{O} = \frac{\mathrm{m}^{W} + \mathrm{g}^{W}}{2} - \frac{1-2b}{2}\left(\mathrm{c}^{US} - \mathrm{c}^{EU} + \mathrm{g}^{US} - \mathrm{g}^{EU}\right) - 2b\theta(1-b)\mathrm{e}^{EU} - a\theta\left(\mathrm{e}^{O} - \mathrm{e}^{I}\right).$$

A monetary expansion in Europe raises U.S. output by increasing world money supply. However, it causes the dollar to appreciate in effective nominal terms and U.S. consumption to decrease relative to European. Both these effects tend to decrease U.S. output. An increase in the *outs*' money supply tends to increase *ins*' output by raising world money supply, by increasing European consumption relative to U.S., and by appreciating the dollar in effective nominal terms. These effects must be weighed against the contractionary impact of an appreciation of the euro against the *outs*' currency. Similar ambiguities exist in the external effects of fiscal policy shocks. A temporary increase in U.S. government spending tends to raise output in the European economies by increasing world aggregate demand and by lowering U.S. consumption relative to European. However, the increase in U.S. government consumption has a direct contractionary effect on European outputs due to the transatlantic asymmetry in governments' consumption baskets. Also, European outputs tend to decline because of the effective depreciation of the dollar caused by the increase in U.S. government spending.

The previous equations can be simplified by recalling that the transatlantic aggregate consumption differential depends on the effective nominal value of the dollar—equation (4.19): $\mathsf{c}^{US} - \mathsf{c}^{EU} = \mathsf{m}^{US} - \mathsf{m}^{EU} - 2b\mathsf{e}^{EU}$.

Ceteris paribus, a depreciation of the dollar tends to decrease U.S. consumption relative to European via its effect on relative price levels and money market equilibrium. This equation makes it possible to rewrite output levels in the three regions as functions of policy instruments and exchange rates:

$$\mathsf{y}^{US} = \frac{\mathsf{m}^W + \mathsf{g}^W}{2} + \frac{1-2b}{2}\left(\mathsf{m}^{US} - \mathsf{m}^{EU} + \mathsf{g}^{US} - \mathsf{g}^{EU}\right) + b\left[2\theta(1-b) - (1-2b)\right]\mathsf{e}^{EU}, \tag{4.32}$$

$$\mathsf{y}^{I} = \frac{\mathsf{m}^W + \mathsf{g}^W}{2} - \frac{1-2b}{2}\left(\mathsf{m}^{US} - \mathsf{m}^{EU} + \mathsf{g}^{US} - \mathsf{g}^{EU}\right) - b\left[2\theta(1-b) - (1-2b)\right]\mathsf{e}^{EU} + (1-a)\theta\left(\mathsf{e}^{O} - \mathsf{e}^{I}\right), \tag{4.33}$$

$$\mathsf{y}^{O} = \frac{\mathsf{m}^W + \mathsf{g}^W}{2} - \frac{1-2b}{2}\left(\mathsf{m}^{US} - \mathsf{m}^{EU} + \mathsf{g}^{US} - \mathsf{g}^{EU}\right) - b\left[2\theta(1-b) - (1-2b)\right]\mathsf{e}^{EU} - a\theta\left(\mathsf{e}^{O} - \mathsf{e}^{I}\right). \tag{4.34}$$

These equations show how unanticipated policy changes affect output in different regions directly and indirectly via exchange-rate effects. Because $\theta > 1$ ensures $2\theta(1-b) - (1-2b) > 0$, a depreciation of the dollar in effective nominal terms has an expansionary impact on U.S. output, while output in the two European regions shrinks.[54] The size of transatlantic trade in goods—b—affects the size of the externalities imposed by the U.S. to Europe and vice versa, as well as the impact of policies on the domestic economy. As b increases from 0 to 1/2 the direct external and internal effect of differences in aggregate money supplies and government spending tends to vanish due to the increased symmetry in consumption baskets across the Atlantic. However, a higher value of b corresponds also to larger trade in goods between the U.S. and Europe, so that changes in the effective value of the dollar become more effective, as it is possible to verify.[55] Because policies in one European region affect the other—and the domestic economy—also by changing the relative position of Europe vis-à-vis the U.S., the size of transatlantic trade has consequences for the intra-European effects of *ins*' and/or *outs*' policies.

4.d.1.a. Changes in U.S. Policies

A monetary expansion in the U.S. has an unambiguously expansionary impact on U.S. output. The effect on output in the two European regions is apparently ambiguous, because of the expansion in U.S. consumption relative to European and the depreciation of the dollar. It is:

$$\frac{\partial\, \mathsf{y}^J}{\partial\, \mathsf{m}^{US}} = b - b\left[2\theta(1-b) - (1-2b)\right]\frac{\partial\, \mathsf{e}^{EU}}{\partial\, \mathsf{m}^{US}}, \qquad J = I, O.$$

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[54] Aggregate European output is:

$$\mathsf{y}^{EU} = \frac{\mathsf{m}^W + \mathsf{g}^W}{2} - \frac{1-2b}{2}\left(\mathsf{m}^{US} - \mathsf{m}^{EU} + \mathsf{g}^{US} - \mathsf{g}^{EU}\right) - b\left[2\theta(1-b) - (1-2b)\right]\mathsf{e}^{EU}.$$

[55] Consistent with the intuition, the effectiveness of changes in the value of the dollar is also an increasing function of the extent to which goods are substitutes.

Making use of (4.24) and plotting the resulting expression as a function of b and δ for several values of θ shows that a monetary expansion in the U.S. imposes a negative externality to output in the two European regions. The externality is larger the larger b and θ and the smaller δ.

A temporary expansion in U.S. government spending raises U.S. output but its external effect also appears ambiguous. Differentiating (4.33) and (4.34) with respect to g^{US} yields:

$$\frac{\partial y^J}{\partial g^{US}} = b - b\left[2\theta(1-b) - (1-2b)\right]\frac{\partial e^{EU}}{\partial g^{US}}, \qquad J = I, O.$$

Recalling (4.24) makes it possible to show that this effect is positive and larger the larger b and the smaller δ.

If the increase in U.S. government spending is permanent, the effective depreciation of the dollar is larger. As a consequence, the external effect on output in both European economies is negative if θ is sufficiently large.[56]

An increase in U.S. steady-state distortionary taxes affects output in all regions only via its impact on the effective nominal value of the dollar. Because the dollar depreciates, output increases in the U.S. and decreases in the two European regions in the short run. The way distortionary taxes affect the economy in this model is different from the more traditional models of Eichengreen and Ghironi (1997, 1999) and Ghironi and Giavazzi (1997). There, domestic output expansion is achieved by lowering distortionary taxes and this has contractionary effects on output in foreign economies. Here, higher steady-state distortionary taxes cause domestic output to be higher in the short run and foreign output to be lower. The intuition is as follows. In Eichengreen and Ghironi (1997, 1999) and Ghironi and Giavazzi (1997), distortionary taxation of firms' revenues affects labor demand—the demand of production effort—but not its supply, which is inelastic once nominal wages have been set by the unions. Because labor demand determines employment also in the short run even in the presence of wage rigidity, higher distortionary taxes have an immediate negative effect on the supply of output.[57] In this model, distortionary taxation of firms' revenues affects the supply of production effort rather than its demand. Because the labor-leisure tradeoff equations are not binding when prices are rigid, *i.e.*, supply equations are binding only in the long run, short-run changes in taxation have no impact on output. Only changes in steady-state (future) taxes affect output today. Intuitively, if steady-state taxes are higher, consumption declines immediately, consistent with optimal consumption smoothing over time. Lower demand for dollars causes the depreciation, which expands output in the short run. In turn, the short-run output expansion is partly saved in the form of a current account surplus, which helps reduce the negative consequences of higher taxes on long-run consumption.[58]

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[56] $\theta \geq 1.5$ is sufficient.

[57] The supply-side effect prevails on the demand creating effect of higher government spending (assuming that governments' budgets are balanced and distortionary taxes are the only source of revenues) under reasonable assumptions about parameter values.

[58] The models in Eichengreen and Ghironi (1997, 1999) and Ghironi and Giavazzi (1997) are not explicitly intertemporal. The focus is on the short run and there is no room for current effects of shocks to the future values of policy instruments. In those models, changes in distortionary taxation would have no effect on output if the tax base were given by workers' wage incomes rather than by firms' revenues. Because wages are predetermined and static expectations are rational in those models—*i.e.*, the supply of production effort does not play an active role, unexpected shocks to wage-income taxation would have no effect on output.

4.d.1.b. Changes in European Policies

A monetary expansion in the *ins* economy unambiguously raises *ins*' output. It is easy to verify that $\frac{\partial \mathrm{y}^{US}}{\partial \mathrm{m}^{I}} = a\frac{\partial \mathrm{y}^{J}}{\partial \mathrm{m}^{US}} = a\frac{\partial \mathrm{y}^{EU}}{\partial \mathrm{m}^{US}}$, ($J = I, O$). Hence, the results about the external impact of a monetary expansion in the U.S. allow to argue that if the *ins*' money supply increases, U.S. output declines, the more so the larger the size of the *ins* economy.[59] As for the external impact on the *outs* economy, *outs*' output tends to increase because of the expansionary effect of the *ins*' policy on European output, but this effect must be weighed against the contractionary impact of a depreciation of the euro:

$$\frac{\partial \mathrm{y}^{O}}{\partial \mathrm{m}^{I}} = a(1-b) - b\left[2\theta(1-b) - (1-2b)\right]\frac{\partial \mathrm{e}^{EU}}{\partial \mathrm{m}^{I}} - a\theta\frac{\partial\left(\mathrm{e}^{O} - \mathrm{e}^{I}\right)}{\partial \mathrm{m}^{I}}.$$

Making use of equations (4.11) and (4.24) makes it possible to argue that if the degree of substitutability across goods is very low (θ very close to 1), the impact of the depreciation of the euro is more than offset by the expansion in European output for intermediate values of b. In this case, the external effect of the shock on *outs*' output is positive—though small. If θ increases the externality becomes negative.[60] The external effect of the *ins*' monetary expansion on the *outs*' output is proportional to a and is thus larger the larger the size of the *ins* economy.

Consider now the case of a temporary increase in *outs*' government spending. Short-run domestic output unambiguously increases. The impact on U.S. output can be easily determined based on the results obtained above because $\frac{\partial \mathrm{y}^{US}}{\partial \mathrm{g}^{O}} = (1-a)\frac{\partial \mathrm{y}^{J}}{\partial \mathrm{g}^{US}} = (1-a)\frac{\partial \mathrm{y}^{EU}}{\partial \mathrm{g}^{US}}$, ($J = I, O$). Thus, the externality is positive, and its size decreases as the *outs* economy becomes smaller.[61]

Analogously to the case of a monetary expansion, a temporary increase in *outs*' government spending tends to raise *ins*' output via its expansionary effect on aggregate European output. However, this effect must be weighed against the contractionary impact of an appreciation of the euro against the *outs*' currency. The externality is proportional to $1-a$ and is given by:

[59] Analogous conclusions can be reached about the effect on U.S. output of a monetary expansion in the *outs* economy: $\frac{\partial \mathrm{y}^{US}}{\partial \mathrm{m}^{O}} = (1-a)\frac{\partial \mathrm{y}^{J}}{\partial \mathrm{m}^{US}} = (1-a)\frac{\partial \mathrm{y}^{EU}}{\partial \mathrm{m}^{US}}$ ($J = I, O$).

[60] $\theta = 1.2$ is sufficient to ensure the result. In this case the externality is larger if b and δ are small. Conclusions about the external effect on the *ins* economy of a monetary expansion by the *outs* are analogous. It is possible to verify that $\frac{\partial \mathrm{y}^{I}}{\partial \mathrm{m}^{O}} = \frac{1-a}{a}\frac{\partial \mathrm{y}^{O}}{\partial \mathrm{m}^{I}}$.

[61] The external effect on U.S. output of a temporary increase in *ins*' government spending is: $\frac{\partial \mathrm{y}^{US}}{\partial \mathrm{g}^{I}} = a\frac{\partial \mathrm{y}^{J}}{\partial \mathrm{g}^{US}} = a\frac{\partial \mathrm{y}^{EU}}{\partial \mathrm{g}^{US}}$ ($J = I, O$).

$$\frac{\partial\ y^I}{\partial\ g^O} = (1-a)(1-b) - b[2\theta(1-b) - (1-2b)]\frac{\partial\ e^{EU}}{\partial\ g^O} + (1-a)\theta\frac{\partial\ (e^O - e^I)}{\partial\ g^O}.$$

This expression is unambiguously positive—and larger the smaller b and δ. It tends to decrease if θ increases: the expansion in aggregate European output prevails on the redistribution of demand caused by the appreciation of the euro, but the effect of the latter is larger the higher the degree of substitutability across goods.[62]

Suppose now that the fiscal expansion in the *outs* economy is permanent—$g^O = \overline{g}^O > 0$. Domestic output is higher in the short run. Again, the results obtained above make it possible to determine the short-run impact on U.S. output. Since $\frac{\partial\ y^{US}}{\partial\ \overline{g}^O} = (1-a)\frac{\partial\ y^J}{\partial\ \overline{g}^{US}} = (1-a)\frac{\partial\ y^{EU}}{\partial\ \overline{g}^{US}}$, ($J = I, O$), the externality is unambiguously negative if θ is sufficiently large. As for the impact on *ins*' output, a larger effective appreciation of the dollar produces a more significant expansion of demand for European goods, but this effect must be weighed against the unfavorable impact of a larger appreciation of the euro against the *outs*' currency:

$$\frac{\partial\ y^I}{\partial\ \overline{g}^O} = (1-a)(1-b) - b[2\theta(1-b) - (1-2b)]\frac{\partial\ e^{EU}}{\partial\ \overline{g}^O} + (1-a)\theta\frac{\partial\ (e^O - e^I)}{\partial\ \overline{g}^O}.$$

The externality—which is proportional to $1-a$—is unambiguously negative for realistic values of θ. The unfavorable effect of the appreciation of the euro prevails, so that the external effect on *ins*' output of a permanent increase in *outs*' government spending is negative—and larger the smaller b and δ.[63]

A change in *ins*' steady-state distortionary taxes affects short-run output in all regions only via its impact on the exchange rates. If taxes are increased, the dollar appreciates in effective nominal terms and U.S. output is lower. Because the euro depreciates against the *outs*' currency, the domestic effect is unambiguously expansionary.[64] The effect on *outs*' output is apparently ambiguous, the expansionary effect of the appreciation of the dollar contrasting with the adverse consequences of an appreciation of the *outs*' currency vis-à-vis the euro:

$$\frac{\partial\ y^O}{\partial\ \overline{t}^I} = -b[2\theta(1-b) - (1-2b)]\frac{\partial\ e^{EU}}{\partial\ \overline{t}^I} - a\theta\frac{\partial\ (e^O - e^I)}{\partial\ \overline{t}^I}.$$

The externality is unambiguously negative, and more significant the smaller b and δ.

[62] Conclusions about the external effect on the *outs* economy of a temporary increase in *ins*' government spending are similar. It is: $\frac{\partial\ y^O}{\partial\ g^I} = \frac{a}{1-a}\frac{\partial\ y^I}{\partial\ g^O}$.

[63] As usual, conclusions about the external effect on the *outs* economy of a permanent expansion in *ins*' government spending are analogous: $\frac{\partial\ y^O}{\partial\ \overline{g}^I} = \frac{a}{1-a}\frac{\partial\ y^I}{\partial\ \overline{g}^O}$.

4.d.2. Consumption

Making use of the results obtained above, it is easy to show that semi-reduced form equations for short-run consumption levels in the three regions are given by:

$$\mathrm{c}^{US} = \frac{\mathrm{m}^{W}}{2} + \frac{\mathrm{m}^{US} - \mathrm{m}^{EU}}{2} - b\mathrm{e}^{EU},$$

$$\mathrm{c}^{I} = \frac{\mathrm{m}^{W}}{2} - \frac{\mathrm{m}^{US} - \mathrm{m}^{EU}}{2} + (1-a)\left(\mathrm{m}^{I} - \mathrm{m}^{O}\right) + b\mathrm{e}^{EU} - (1-a)\left(\mathrm{e}^{O} - \mathrm{e}^{I}\right),$$

$$\mathrm{c}^{O} = \frac{\mathrm{m}^{W}}{2} - \frac{\mathrm{m}^{US} - \mathrm{m}^{EU}}{2} - a\left(\mathrm{m}^{I} - \mathrm{m}^{O}\right) + b\mathrm{e}^{EU} + a\left(\mathrm{e}^{O} - \mathrm{e}^{I}\right).$$

These equations can be used to study the impact of changes in economic policies on consumption. Monetary policies act both directly and indirectly via their impact on the exchange rates. Fiscal policy shocks affects consumption only indirectly through changes in the exchange rates. Because the approach should be clear from the previous discussion, I will focus on changes in U.S. policies as an example.

A monetary expansion in the U.S. has a 1:1 direct impact on U.S. consumption. This must be contrasted with the negative effects of the depreciation of the dollar, which worsens the effective terms of trade of the U.S. It is possible to check that the overall impact is unambiguously positive for all values of b and δ—and larger the smaller the size of transatlantic trade. Consumption increases in the two European regions, where agents benefit from improved effective terms of trade with the U.S. However, the effect is smaller the smaller is b. The impact of changes in the effective exchange rate of the dollar on domestic and foreign consumption is proportional to the size of transatlantic trade. Although the effect of fiscal policies on the value of the dollar is also a function of b, a smaller size of this parameter implies a smaller short-run effect of U.S. fiscal policies on consumption for most combinations of parameter values. Because increases in U.S. government spending or steady-state taxation cause the dollar to depreciate (recall Section 4.b.2), these shocks induce consumption to be lower in the U.S. and higher in Europe. Internal and external effects on consumption of shocks to economic policies in Europe can be analyzed similarly.

4.d.3. The Dollar, the Euro, and Exchange-Rate Polarization

Given solutions for e^{EU} and $\mathrm{e}^{O} - \mathrm{e}^{I}$ it is easy to recover reduced forms for the exchange rates between the dollar and the two European currencies. Using a simplified notation, we know that $\mathrm{e}^{O} - \mathrm{e}^{I} = f(I-O)$, where $f(I-O)$ is a function of the differences in policy instruments between the *ins* and the *outs* economies. Also, $\mathrm{e}^{EU} = a\mathrm{e}^{I} + (1-a)\mathrm{e}^{O} = h(US-EU)$, $h(US-EU)$ being a function of the differences in the aggregate stances of economic policies across the Atlantic. Hence, $\mathrm{e}^{I} = h(US-EU) - (1-a)f(I-O)$ and $\mathrm{e}^{O} = h(US-EU) + af(I-O)$.

Intra-European policy changes that induce the euro to depreciate against the *outs*' currency *while leaving the aggregate stance of European economic policy unchanged* will cause the dollar to appreciate vis-à-vis the euro and to depreciate against the *outs*' currency.

[64] The intuition for this result is the same as for the analogous result for an increase in U.S. distortionary taxes.

Conversely, policy changes that cause the euro to appreciate in Europe induce the dollar to depreciate against the euro and to appreciate vis-à-vis the *outs*' currency. The latter will be weak with respect to the dollar in situations in which the U.S. currency is weak with respect to the euro. The model can thus capture instances of dollar-euro polarization that resemble the dollar-deutschmark polarization observed in the early years of the EMS, when it happened frequently that European currencies other than the deutschmark weakened against the dollar when this was losing ground vis-à-vis the German currency rather than closely following the latter.[65] Quite intuitively, the larger the size of the *ins* economy, the less the intra-European exchange rate will affect the exchange rate between the dollar and the euro. If a approaches 1, so that the *outs* economy is very small, a given change of the *ins-outs* exchange rate has a larger impact on the dollar-*outs* rate.

4.d.4. Prices

I have focused my attention on real variables and exchange rates. Equations (4.29) determine the behavior of the consumption-based price indexes in the U.S. and Europe in the short-run. Long-run CPIs can be obtained by recalling that the money demand equations (2.21) imply $\overline{p}^J = \overline{m}^J - \overline{c}^J$ ($J = US, I, O$) and by making use of the solutions for $\overline{c}^J$.

5. Discussion

The structure of the model put forth in this paper makes it relatively easy to understand the determinants of policy multipliers and determine the sign of policy externalities based on a small number of structural parameters. This is an important element of value added relative to extensions of the traditional framework used by Canzoneri and Henderson (1991) and others to explore the issue of transatlantic policy interactions. The fully intertemporal nature of the model makes it possible to account for effects of policy that do not feature in the old-style framework. This notwithstanding, there are several reasons to see this model as an initial step towards the construction of a rigorous framework for understanding transatlantic interdependence as opposed to a point of arrival.

Leaving the question of deviations from the law of one price aside, three aspects of the model appear unsatisfactory. The first has to do with the indeterminacy of the steady state and the stationarity issue mentioned several times throughout the paper. In the model I presented—as in most "new open economy macro" models—determinacy of the steady state fails. The choice of the economy's initial position for the purpose of analyzing the consequences of a shock is arbitrary.[66] As noted several times, the sign and size of several policy multipliers can be affected by the initial distribution of asset holdings. Picking zero-asset holdings as the initial position shuts off the wealth effects caused by unexpected price movements when agents hold nominal assets. This limits the generality of several results. At the same time, any other initial distribution of asset holdings would be just as arbitrary. A model in which the steady-state distribution of asset holdings is well determinate would not suffer from this arbitrariness.

[65] See Giavazzi and Giovannini (1989) for a discussion of the dollar-deutschmark polarization.

[66] Determinacy of the steady state—and stationarity—fails because the average rate of growth of the economies' consumption in the models does not depend on average holdings of net foreign assets. Hence, setting consumption to be constant is not sufficient to pin down a steady-state distribution of asset holdings.

In addition, steady-state indeterminacy comes with a failure of stationarity. The position of the domestic and foreign economies that is taken to be the steady state in the absence of shocks is a point to which the economies never return following a disturbance. The consumption differential between countries follows a random walk. So do an economy's net foreign assets. Whatever level of asset holdings materializes in the period immediately following a shock is going to be the new long-run position of the current account, until a new shock happens. When the model is log-linearized, one is actually approximating its dynamics around a "moving steady state." The results of comparative statics exercises are thus questionable, particularly if one wants to look seriously at the long-run effects of shocks. When variables wander away from the initial steady state, the reliability of the log-linear approximation becomes questionable, along with that of any normative conclusion. A stochastic version of the model, in which several random shocks happen at each point in time, would be basically impossible to analyze. The inherent unit root problem complicates empirical testing. The long-run non-neutrality of money that characterizes the results can be attacked on empirical grounds.

The failure of stationarity is not the only problem of the model though. The assumption of one-period price rigidity that characterizes it—and several other contributions—is not appealing from an empirical perspective. Normative conclusions based on this assumption may have very little bearing on reality. Finally, the absence of investment and capital accumulation seriously limits the appropriateness of the framework for thorough investigations of current-account behavior and the consequences of alternative policy rules for medium- to long-run dynamics.

Corsetti and Pesenti (1998) remove the problems caused by non-stationarity by shutting off the current-account channel assuming a very specific functional form for the consumption basket. So does P. Benigno (1999). G. Benigno (1999) relies on market completeness to take care of the problem. However, this too shuts off the current account channel of transmission of policy shocks. Both G. Benigno (1999) and P. Benigno (1999) have richer price dynamics by adopting Calvo-type price staggering.[67]

In Ghironi (1999*b*), I develop a two-country model that offers alternative solutions to the problems mentioned above. The recent experience of the United States and of several other countries suggests that movements of the current account constitute an important channel of interdependence and do matter for policy considerations. Shutting off current-account effects does not seem appealing. I address the stationarity problem by relying on a demographic structure a la Weil (1989) as opposed to the familiar representative agent framework. I assume that the world economy consists of distinct infinitely lived households that come into being on different dates and are born owning no assets.[68] The demographic structure, combined with the key assumption that newly born agents have no financial wealth, allows the model to be characterized by an endogenously determined steady state to which the world economy returns over time following temporary shocks. I can thus perform analysis of one-time impulses and stochastic simulations in a framework in which the current account channel is not removed.
I assume that firms face costs of adjusting the price of their outputs. I choose a quadratic specification for these costs, as in Rotemberg (1982). This specification produces aggregate dynamics that are similar to those induced by staggered price setting a la Calvo (1983). It also generates a markup that is endogenous to the conditions of the economy as long as the latter is

[67] See Calvo (1983).
[68] Financial markets remain incomplete, which seems more consistent with the presence of real effects of monetary policy in a world characterized by nominal rigidity.

not in steady state. The dynamics of the markup play an important role in business cycle fluctuations, consistent with the analysis in Rotemberg and Woodford (1990). Firms produce output using labor and physical capital. Capital is accumulated via investment, and new capital is costly to install as in a familiar Tobin's *q* model. The presence of monopoly power has consequences for the dynamics of employment, by introducing a wedge between the real wage index and the real marginal revenue product of labor. I identify the two economies in the model with Canada and the U.S., thus focusing on the interaction between a small open economy and a large relatively closed one. I estimate the structural parameters of the Canadian economy using the log-linear equations that govern the dynamics of the aggregate economy, non-linear least squares at the single-equation level, and full information maximum likelihood for system-wide regressions. In Ghironi (1999*c*), I use the parameter estimates and the model to perform a normative analysis of the performance of alternative monetary rules for the Canadian economy based on a rigorously microfounded welfare criterion. The exercise yields interesting conclusions, different from results of papers that rely on traditional non-microfounded models. It supports the idea that normative analyses based on more explicitly dynamic models than those used in much of the literature and founded in empirical work are likely to yield more relevant conclusions than theoretical exercises based on hyper-simplified models.

Because of the limitations discussed above, I see this paper as the initial step in a broader project. The understanding of U.S.-European interdependence and the transmission of policy actions developed here will provide the basic intuitions against which to compare the results of a more dynamic and empirically appealing model, developed by incorporating some of the assumptions in Ghironi (1999*b*).

6. Conclusions

This paper has laid the foundations for a rigorous analysis of transatlantic economic interdependence and policy interactions by presenting a microfounded general equilibrium model of the U.S. and European economies. The model is close to the current state of the art in international macroeconomics. It generalizes work by Obstfeld and Rogoff (1995, 1996 Ch. 10). Reduced or semi-reduced form equations for the most relevant endogenous variables have been derived, and the domestic and external impact of unexpected policy shocks in Europe and the U.S. has been analyzed from a purely positive perspective. The focus has been on understanding the determinants of transatlantic economic interdependence and the channels through which policy changes are transmitted in Europe and across the Atlantic in the context of a formal framework that proponents of the so-called "new open economy macroeconomics" argue should supplant the time-honored Mundell-Fleming-Dornbusch model.

In the model, consumer preferences in the U.S. and Europe are biased in favor of goods produced in the continent where agents reside. Hence, PPP does not hold across the Atlantic, except in steady state. However, this is not sufficient to cause overshooting of the dollar exchange rate following policy shocks. Adjustment in real variables removes the need for nominal exchange rate overshooting to re-equilibrate markets.

Starting from a zero-asset holding position, an unexpected monetary expansion raises domestic consumption relative to foreign, as in Obstfeld and Rogoff (1995, 1996 Ch. 10). However, if agents hold non-zero asset balances in the initial position, unfavorable wealth effects may cause consumption to decline if substitutability across goods is not sufficiently high.

The size of transatlantic trade matters for intra-European externalities, because policy changes in Europe affect European economies also through their impact on the relative positions of Europe and the U.S. For example, a temporary increase in government spending outside the European monetary union has an expansionary impact on GDP in the union that is larger the smaller transatlantic trade: smaller trade across the Atlantic reduces the unfavorable effect of an appreciated euro.

Short-run changes in distortionary taxation have no effect on GDP, because output is demand-determined in the short run and taxes distort labor supply decisions. Differently from the more traditional model in Eichengreen and Ghironi (1997, 1998) and Ghironi and Giavazzi (1997), where taxes affect labor demand, an increase in steady-state taxation raises domestic GDP in the short run and lowers foreign by causing the dollar to depreciate.

Movements in the U.S. current account are now receiving increasing attention from policymakers in the U.S. and Europe. In the model, U.S. current-account surplus can be achieved by means of a monetary expansion, a persistent increase in government spending, and/or higher long-run distortionary taxes relative to Europe.

No normative analysis has been performed in the paper. This has been left out of the scene, together with a study of strategic interactions among policymakers and, say, the pros and cons of policy coordination or alternative policy rules. No such policy question has been raised. The reason is that, although the model is rich and flexible enough to address several different normative questions, for the reasons discussed in the previous section, I see it as an initial step towards the construction of a formal framework for normative analysis of transatlantic issues. Understanding the mechanisms through which policy shocks are transmitted in Europe and across the Atlantic in the context of a state-of-the-art yet relatively simple macro model was the purpose of this paper. This understanding came with the consciousness of some important weaknesses of the framework, besides the absence of deviations from the law of one price: indeterminacy of the steady state and non-stationarity, a hyper-simplified approach to nominal rigidity, and the omission of investment and capital accumulation from the analysis. The next order of business will be taking care of those weaknesses. The model will then be used to perform normative analysis of policy issues along the lines of Ghironi (1999*c*), for example, addressing the welfare implications for the United States and Europe of alternative policy rules followed by the European Central Bank.

Appendix. Derivation of Equation (4.23)

This appendix illustrates the derivation of equation (4.23) and allows the reader to investigate the dependence of the semi-reduced form parameters A, B, Φ, and Γ on the structural parameters.

Equation (3.14) can be solved for $\overline{\mathrm{b}}^{US}$:

$$\overline{\mathrm{b}}^{US} = \frac{\theta - 1 + 2b}{\delta(1+\theta)}\left(\overline{\mathrm{c}}^{US} - \overline{\mathrm{c}}^{EU}\right) + \frac{\theta - 1}{2\delta(1+\theta)}\left(\overline{\mathrm{t}}^{US} - \overline{\mathrm{t}}^{EU}\right) + \frac{\theta - 1 + 4b}{2\delta(1+\theta)}\left(\overline{\mathrm{g}}^{US} - \overline{\mathrm{g}}^{EU}\right) - \frac{2b\theta}{\delta(1+\theta)}\overline{\varphi}.$$

Making use of (4.16), this yields:

$$\overline{\mathrm{b}}^{US} = \frac{\theta - 1 + 2b}{\delta(1+\theta)}\left(\mathrm{c}^{US} - \mathrm{c}^{EU}\right) + \frac{\theta - 1}{2\delta(1+\theta)}\left(\overline{\mathrm{t}}^{US} - \overline{\mathrm{t}}^{EU}\right) + \frac{\theta - 1 + 4b}{2\delta(1+\theta)}\left(\overline{\mathrm{g}}^{US} - \overline{\mathrm{g}}^{EU}\right) + \frac{(\theta - 1)(1-2b)}{\delta(1+\theta)}\overline{\varphi} - \frac{(\theta - 1 + 2b)(1-2b)}{\delta(1+\theta)}\mathrm{e}^{EU}. \tag{A.1}$$

Equations (3.13) and (4.16) give:

$$\overline{\varphi} = -\frac{(1-b)(1-2b)}{(1-b)[1+2b(\theta-1)]+b}\left(\mathrm{c}^{US}-\mathrm{c}^{EU}\right)+\frac{(1-b)(1-2b)^2}{(1-b)[1+2b(\theta-1)]+b}\mathrm{e}^{EU}+$$
$$-\frac{(1-2b)^2}{2\{(1-b)[1+2b(\theta-1)]+b\}}\left(\overline{\mathrm{g}}^{US}-\overline{\mathrm{g}}^{EU}\right)-\frac{1-2b}{2\{(1-b)[1+2b(\theta-1)]+b\}}\left(\bar{\mathrm{t}}^{US}-\bar{\mathrm{t}}^{EU}\right). \tag{A.2}$$

Substitution of (A.2) into (A.1) returns an expression for $\overline{\mathrm{b}}^{US}$ as a function of e^{EU}, $\mathrm{c}^{US}-\mathrm{c}^{EU}$, and fiscal policy instruments. Equating this expression to (4.22) and solving for e^{EU} yields (4.22). The parameters A, B, Φ, and Γ are defined as follows, and I assume that the restrictions ensuring that they are all positive are satisfied:

$$A \equiv \frac{2(1-b)\theta+(1-2b)+\delta[1+2b(1-b)(\theta-1)]}{2(1-b)[\theta-2b(\theta-1)]+\delta[1+2b(1-b)(\theta-1)][2\theta(1-b)-1]-1};$$

$$\mathrm{B} \equiv \frac{\delta[1+2b(1-b)(\theta-1)]}{2(1-b)[\theta-2b(\theta-1)]+\delta[1+2b(1-b)(\theta-1)][2\theta(1-b)-1]-1};$$

$$\Phi \equiv \frac{b+\theta(1-b)}{2(1-b)[\theta-2b(\theta-1)]+\delta[1+2b(1-b)(\theta-1)][2\theta(1-b)-1]-1};$$

$$\Gamma \equiv \frac{(1-b)(\theta-1)}{2(1-b)[\theta-2b(\theta-1)]+\delta[1+2b(1-b)(\theta-1)][2\theta(1-b)-1]-1}.$$

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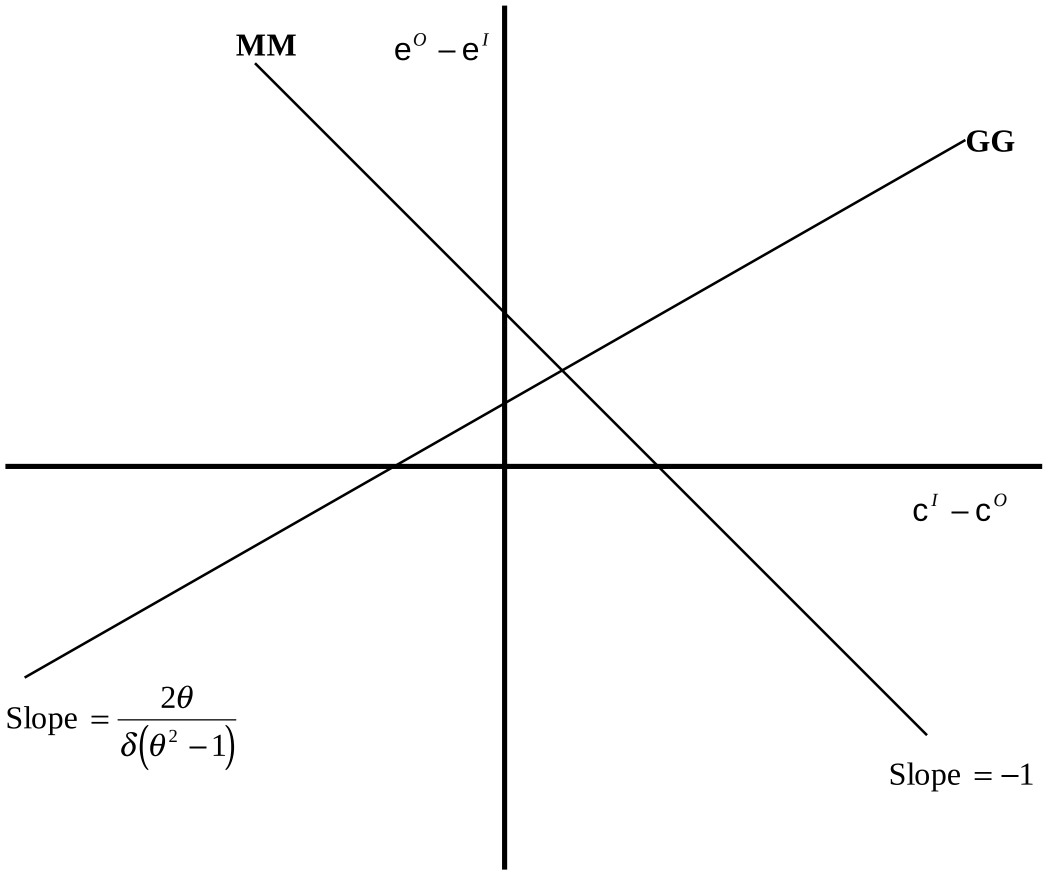

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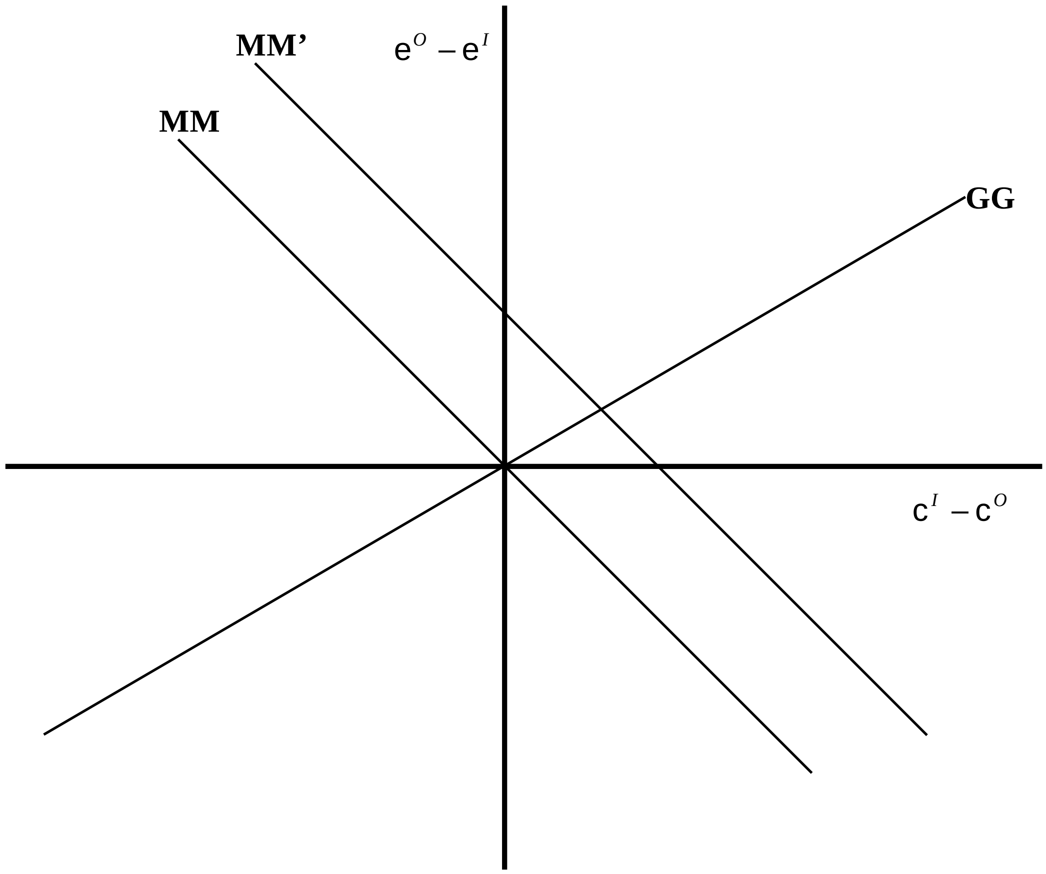

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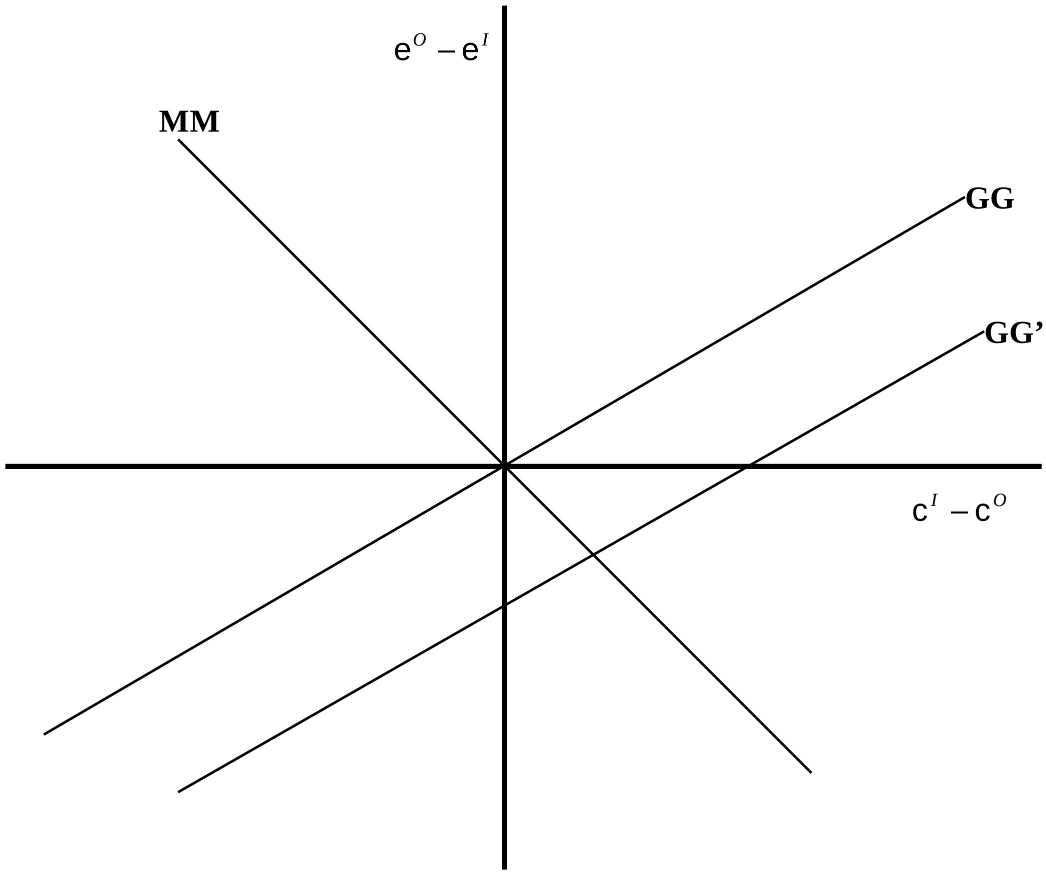

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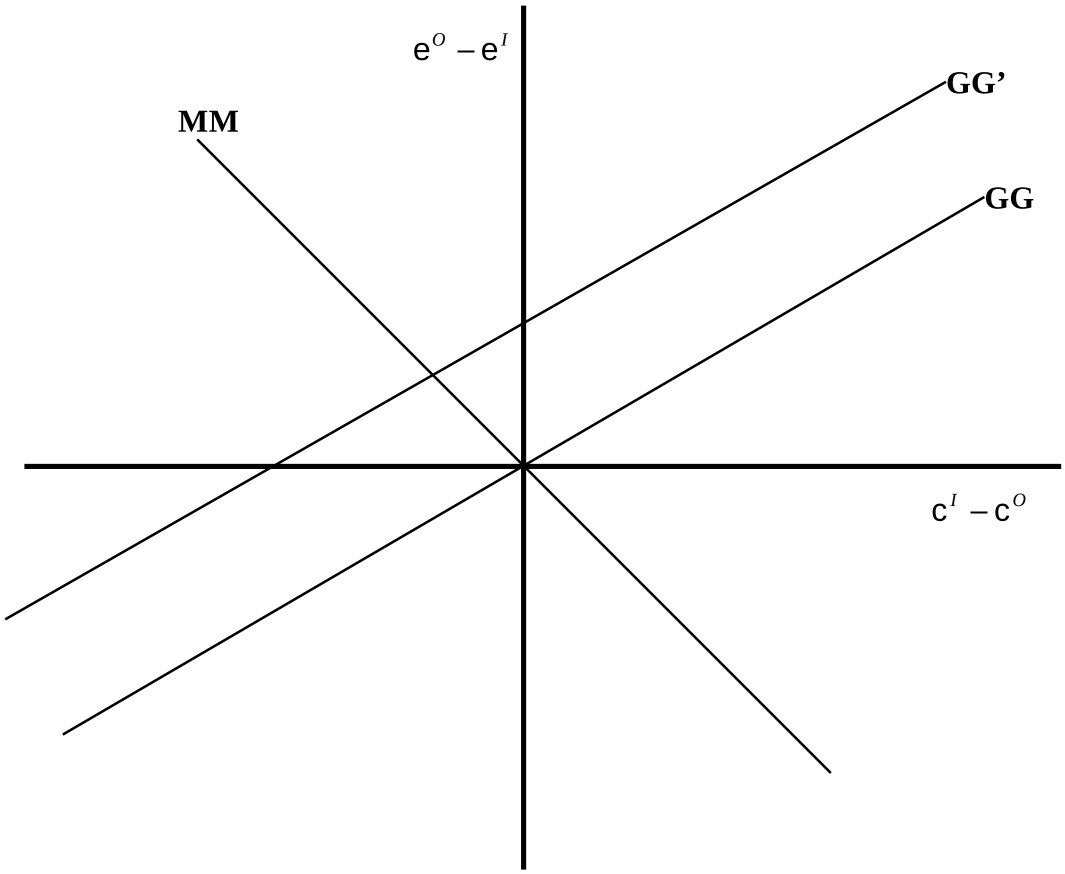
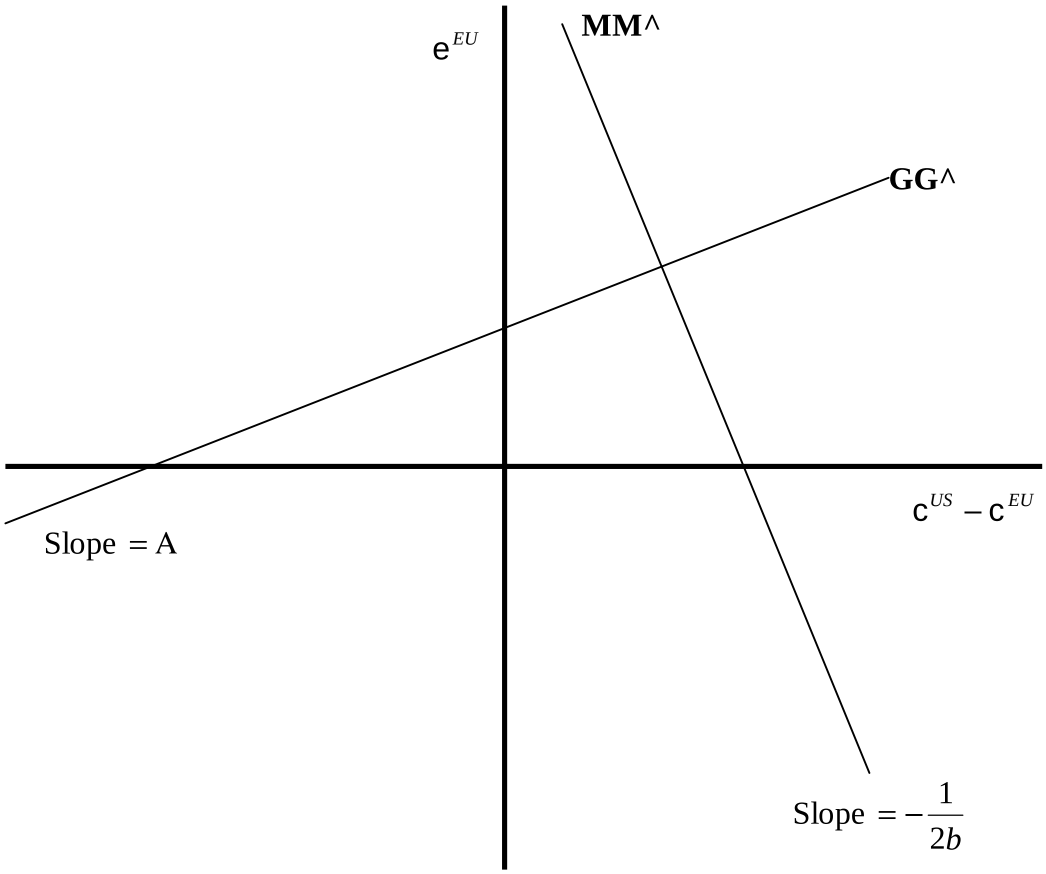


Figure 4



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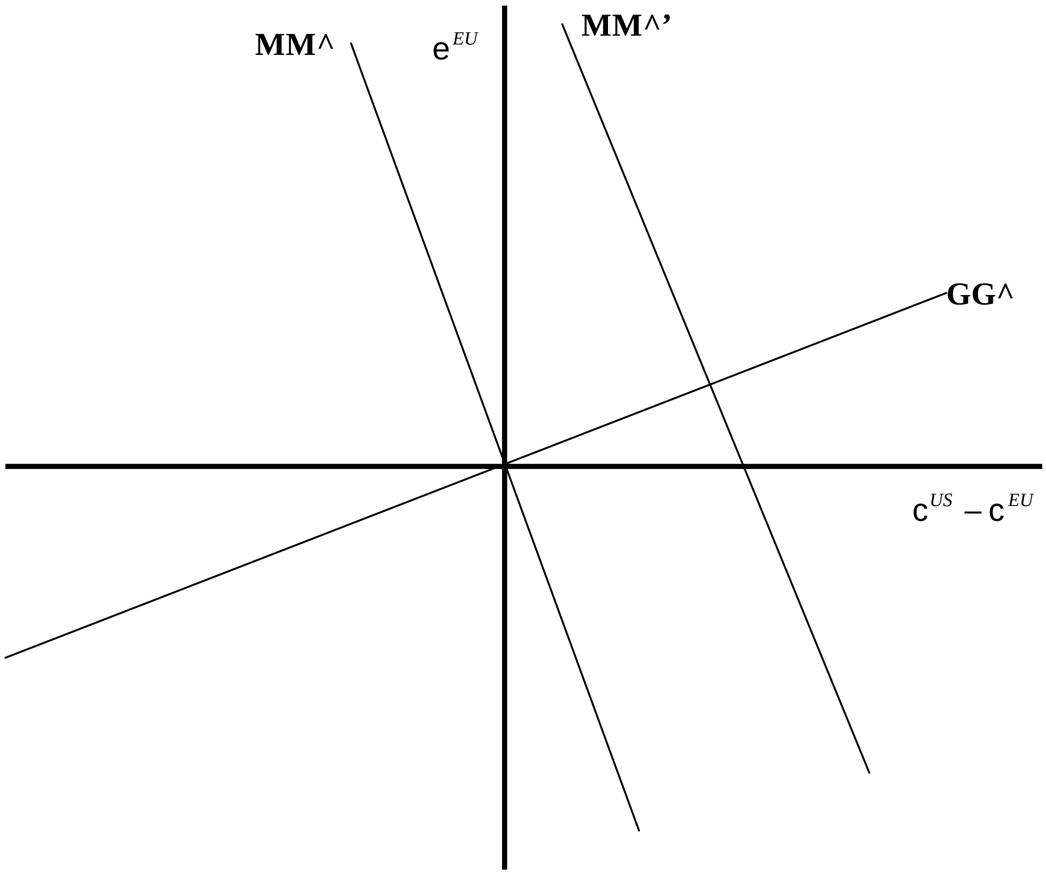

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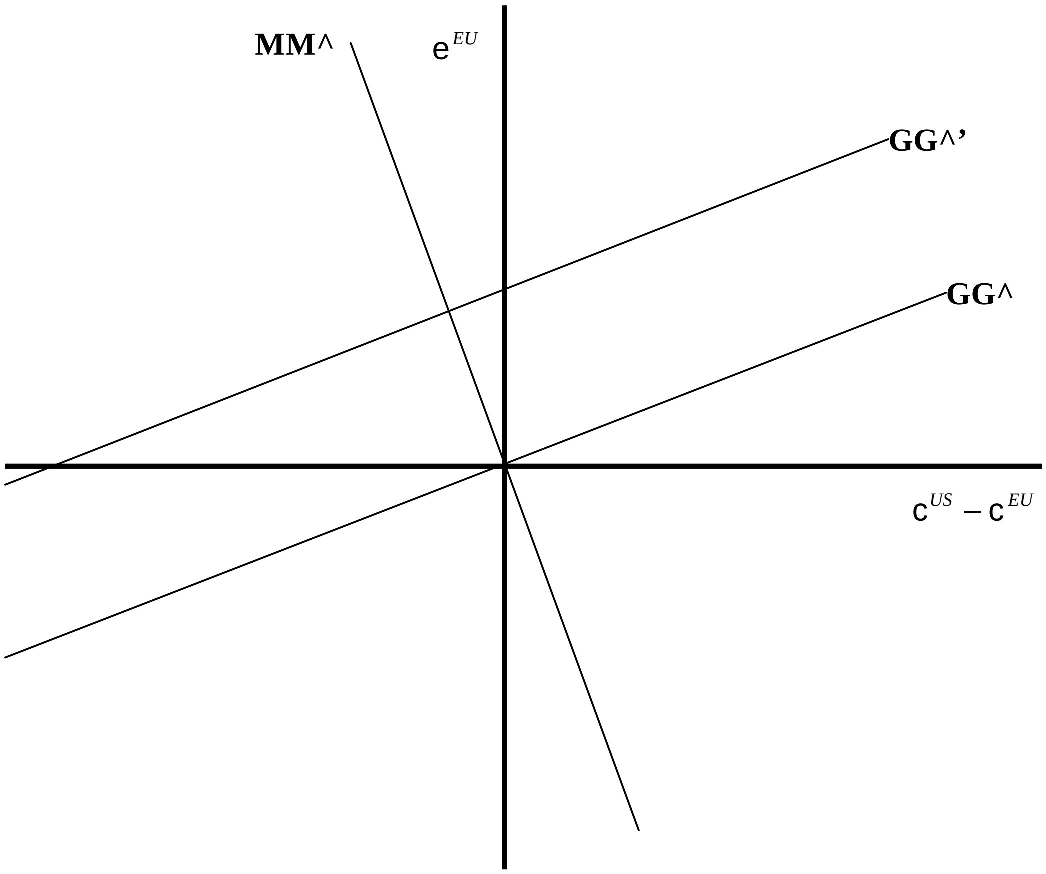

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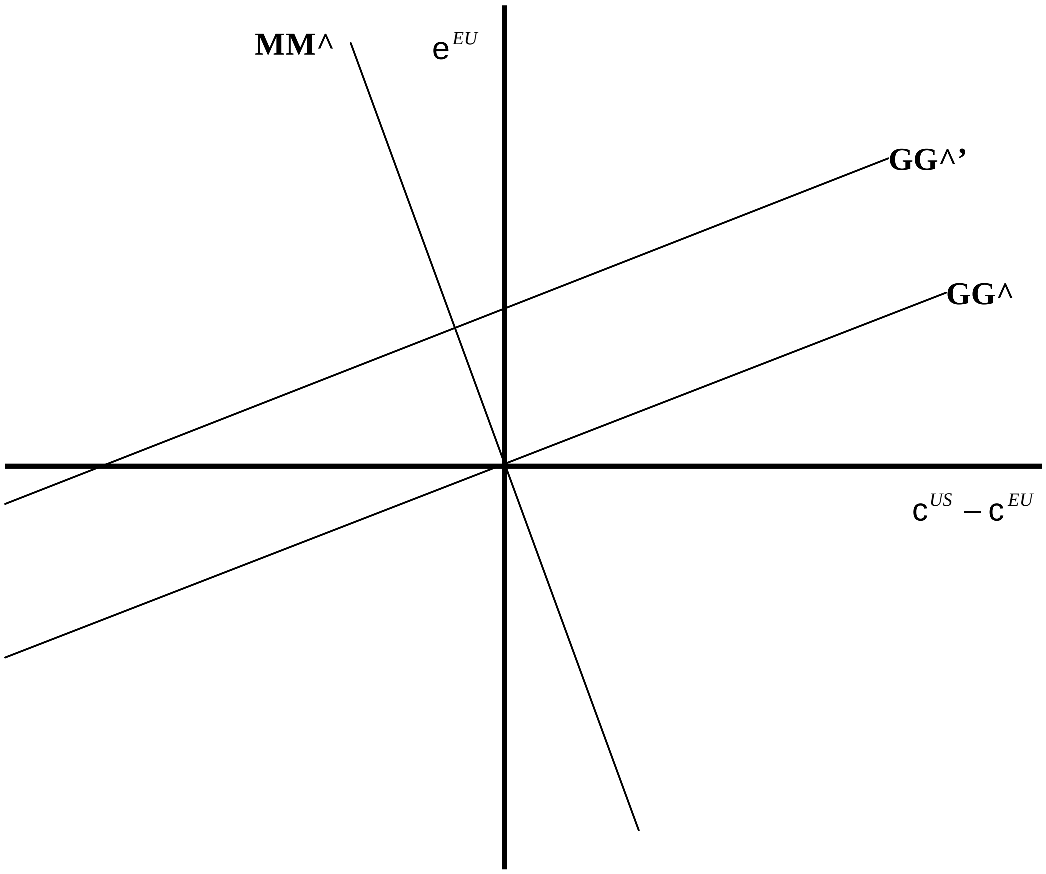

Figure 8