Bonn Econ Discussion Papers

Discussion Paper 10/2007

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July 2007

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Optimal Monetary Policy in an Interdependent World*

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July 20, 2007

Abstract

In the literature on international monetary policy, the paradigm is that gains from coordination are fairly small. Monetary policy is conducted to stabilize macroeconomic fluctuations and gains from policy coordination arise from preventing national monetary authorities from strategically manipulating the terms of trade by means of these stabilization policy instruments. However, as it has been emphasized by Lucas (2003), welfare gains from stabilizing fluctuations are generically small since they are of second order. In this paper, I develop a dynamic stochastic two-country model with sticky wages and a cash-in-advance restriction which is in the spirit of the New Open Economy Macroeconomics framework. In this environment, monetary authorities can manipulate the terms of trade by conducting a general short-run monetary policy using both the nominal interest rate and the money supply. The money supply affects the terms of trade by altering the nominal exchange rate ex post and it is used in the traditional way so as to stabilize macroeconomic fluctuations. The nominal interest rate affects the terms of trade by changing expected inflation ex ante. Self-oriented national policymakers use the nominal interest rates to raise the terms of trade ex ante. This leads to an inefficient inflation tax whose welfare effects are of first order. Consequently, gains from monetary policy coordination are of first order.

Keywords: International Policy Coordination; General Short-Run Monetary Policy; New Open Economy Macroeconomics

JEL classification: F41; F42

*I thank Jürgen von Hagen, Martin Uribe, and Ludger Linnemann for helpful discussions and valuable comments. Financial support of the Deutsche Forschungsgemeinschaft (German Research Foundation) through SPP 1142 is gratefully acknowledged.

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1 Introduction

In the literature on the international dimension of monetary policy, the consensus is that gains from policy coordination are fairly small. Monetary policy is considered to be concerned with the stabilization of macroeconomic fluctuations only. Gains from policy coordination arise then from preventing strategic considerations regarding the use of these stabilization policies from unilaterally manipulating the terms of trade. However, as it has been emphasized by Lucas (2003), the gains from stabilizing macroeconomic fluctuations per se are generically quite limited. Instead, he argues that

> "...there remain important gains in welfare ... from providing people with better incentives to work and to save, not from better fine tuning of spending flows."

In this paper, I take up his proposition and translate it into the context of an open economy. I demonstrate that gains from international monetary policy cooperation can be substantial when policymakers coordinate on the stimulation of labor and hence production rather than on the stabilization of exogenously driven fluctuations. To this end, I develop a simple dynamic stochastic two-country model with preset wages and cash-in-advance restrictions. National monetary authorities can affect the equilibrium allocation in this environment by conducting a general short-run monetary policy using both the nominal interest rate as well as the money supply. On the one hand, the money supply policy affects the allocation by altering the nominal spending and thereby the nominal exchange rate ex post. A contraction of money supply then leads to an appreciation of the nominal exchange rate and the terms of trade. This equips monetary authorities with an effective policy instrument to stabilize economic fluctuations. On the other hand, the nominal interest rate affects the allocation by changing the expected inflation ex ante. Because inflation works as a tax on labor income, higher expected inflation leads households to claim higher nominal wages. This results in an increase in the prices of goods and thereby causes an appreciation of the terms of trade.[1]

Within this framework which allows the joint analysis of the nominal interest rate and the money supply as combined tools of monetary policy, two important results emerge: First, the equilibrium and hence welfare effects of the nominal interest rate policy are of first order whereas those of the money supply management are of second order. The intuition for this is simple: The money supply is effective only because of sticky wages through ex post deviations of the actual money supply from the expected one. Thus, money supply management only affects the variability of the equilibrium allocation. As a result, the ex ante equilibrium effects of money supply policies are thus of second order. By contrast, the nominal interest rate changes the average labor supply and hence strikes a wedge between the marginal rate of substitution and the marginal rate of transformation. This inefficient wedge is present irrespective of whether wages are flexible or not and irrespective of whether the state of the world is uncertain. Consequently, the equilibrium implications are of first order. Second, regarding the nominal interest rate policy,

[1] Within a closed economy model whose structure is similar to the present open economy model, Ireland (1996) already argues that monetary policy can be conducted in a more general way by using both expected money growth rate and deviations from the expected money growth rate. More recently, Adao et al. (2003) take up his approach and analyze optimal short-run monetary policy in a closed economy real business cycle model with monopolistic firms, a cash-in-advance restriction and preset prices. They, however, directly argue by means of the nominal interest rate (implicitly controlled by the expected money growth rate) and the money supply (ie. state-dependent deviations from the expected money growth rate). For reasons of economic intuition it proves particularly useful to directly follow Adao et al. and refer to the two policy instruments as the nominal interest rate and the money supply.

self-interested national policymakers indeed have an incentive to deviate from the globally optimal nominal interest rate. From a global perspective, the Friedman rule is optimal since it minimizes the wedge between the marginal rate of substitution and the marginal rate of transformation in all instances when wages are flexible and at least on average when wages are sticky. Independent and self-oriented national policymakers, however, strive for an appreciation of the terms of trade in order to improve the domestic labor-leisure trade-off in all instances when wages are flexible and at least on average when wages are sticky. As it is true for the money supply policy, deviations of nominal interest rates from the globally optimal levels are always "beggar-thy-neighbor". The important conclusion to be drawn then is that as long as monetary authorities face the incentive to depart from the optimal monetary policy, gains from international arrangements or institutions that effectively prevent these strategic interactions are of first order. A simple numerical example demonstrates that international coordination of nominal interest rate policy can amount to welfare gains four orders of magnitude larger than gains from coordinating stabilization policies through money supply management. Consequently, potential gains from policy coordination are not negligible.

The reason why it has become widely accepted that potential gains from policy coordinations must be quite limited might be best understood when looking at the literature from an historical perspective: Beginning with the seminal contributions by Hamada (1974, 1976, 1979), the first generation of game-theoretic models - represented most prominently by Oudiz and Sachs (1984), Rogoff (1985), and Canzoneri and Gray (1985)[2] - are based on Old-Keynesian models where policymakers are assumed to minimize an ad hoc motivated quadratic loss function that punishes deviations from given desired levels or blisspoints of the inflation rate, the increase in international reserves, or the output level. These models provide the theoretical rationale for international monetary policy coordination so as to overcome global inefficiencies induced by strategic considerations of independent monetary authorities. While there is no question about the merits of the aforementioned class of models for the purpose of studying international policy coordination, the assumptions of the policy objectives lead immediately to the result of limited gains for two reasons: First, the quadratic loss function itself directly reduces the problem to the minimization of fluctuations around the blisspoints. The consequence is that gains from coordinating monetary policy must be of second order. Second, these studies neglected the possibility that the blisspoints themselves are subject to strategic considerations. As it is demonstrated in this paper, the non-cooperatively set expected inflation rates and hence the non-cooperatively set nominal interest rates differ from the globally optimal one and they hinge crucially on the macroeconomic interdependencies among the different countries. A consistent notion of the desired levels of inflation or output conditioning on the international macroeconomic environment, however, necessarily requires a rigorous welfare foundation.

Such welfare foundations were provided with the advent of the "New Open Economy Macroeconomics" (NOEM) that brought optimizing agents, monopolistic competition and nominal rigidities into dynamic general equilibrium models.[3] This New Keynesian framework forms the basis of the second generation of policy coordination models as in Corsetti

[2]Cooper (1985), Canzoneri and Henderson (1991), and Persson and Tabellini (1995) present excellent overviews of the first generation literature.

[3]Seminal contributions to this literature are Svensson and van Wijnbergen (1989) and Obstfeld and Rogoff (1995, 1996). For an excellent survey see Lane (2001).

and Pesenti (2001), Obstfeld and Rogoff (2002a), and Devereux and Engel (2003).[4] Nevertheless, even though the second generation models provide new important insights to the question of the needs of international policy coordination, the welfare gains are similarly limited as in the first generation models. In contrast to the first generation models, however, the answer to this problem is now inherent to the specification of the conduct of policy itself. In one prominent class of models, as for example in Obstfeld and Rogoff (2002a) and Devereux and Engel (2003), it is assumed that monetary authorities follow policy rules that condition money supply deviations from any given initial stock of money on the realization of shocks. The average inflation rate induced by the mean growth rate of the money supply is implicitly assumed to be zero. In the other prominent class of models, as for example in Clarida et al. (2002) and Galí and Monacelli (2005), it is assumed that policymakers follow interest rate rules that condition on deviations of inflation rates and output from some given reference levels. Equivalent to the problem of exogenous blisspoints discussed above, both the average interest rate as well as the reference value for the inflation and output deviations are not further analyzed but implicitly fixed via the (log)linear approximation of the model about a zero inflation and nonstrategic steady state. Hence, in both classes of models, monetary policy solely focuses on stabilization issues and consequently the welfare gains of policy coordination are of second order.

Surprisingly, there are only very few contributions that consider non-stabilizing monetary policy interaction within a strategic setting. One exception is Cooley and Quadrini (2003) who study optimal monetary policy in a two-country open economy model that is not a variation of the NOEM framework. Instead, they use a limited participation version where purchases of production intermediaries - partly imported - must be financed in advance. Consequently, the nominal interest rate has a distorting effect as it increases the cost of production. In this environment, self-interested monetary authorities face the incentive to increase the nominal interest rate in order to appreciate the terms of trade and thereby to expand domestic production. This leads to strategically induced inflationary biases with inefficiencies that have sizable adverse welfare consequences. Another exception is Arseneau (2007) who studies the importance of the distortion caused by monopolistic competition for the optimal nominal interest rate policy. Similarly to the model here, he motivates money demand within a version of Corsetti and Pesenti (2001) by a cash-in-advance restriction. He also demonstrates that non-cooperative monetary authorities use the nominal interest rate to induce a domestic appreciation of the terms of trade that leads in equilibrium to sizable welfare losses as compared to the cooperative solution. Arseneau, however, concentrates on the interaction between optimal interest rates and the friction of monopolistic competition and thereby seeks to complement Cooley and Quadrini (2003) where production takes place in a perfectly competitive environment.

In contrast, in the present paper, the generalization of monetary policy conduct in an environment with nominal inertia facilitates the joint analysis of both the nominal interest rate (or equivalently the average money growth rate) and the money supply management (or equivalently state-dependent deviations from the expected average money growth rate). Consequently, the model proposed below which is kept close to Obstfeld and Rogoff (2002a) and which is hence in the tradition of the NOEM literature provides a

[4]Other contributions include Benigno and Benigno (2003, 2005, 2006), Clarida et al. (2002), Corsetti and Pesenti (2005), Corsetti et al. (2000), Galí and Monacelli (2005) Kollmann (2003), Liu and Pappa (2005), Pappa (2004), and Tchakarov (2004). Canzoneri et al. (2005), who introduces the above distinction between first and second generation models of international policy coordination, survey the literature and discuss the properties of the second generation models in general.

unifying framework that allows the derivation of more general principles of optimal monetary policy conduct in open economies.

The model is presented in the next Section. In Section 3, the equilibrium allocation is derived for both flexible wage and sticky wage environments. In Section 4, I explore the national equilibrium welfare as the policymakers' objectives in detail and demonstrate that the welfare consequences of nominal interest rate policy are indeed of first order whereas the welfare consequences of stabilizing money supply management are of second order. The analysis of optimal monetary policy when set cooperatively and independently follow in Sections 5 and 6, respectively. A numerical example in Section 7 provides an assessment of the quantitative relevance of the findings. Section 8 concludes. Most of the derivations of the equations and the results are delegated to an Appendix which is available upon request.

2 The Model

The model economy consists of two identical countries which are denoted Home (H) and Foreign (F). Each country is populated by a continuum of households and both countries are of equal size one. Firms within a country produce two different consumption goods, one traded good that is demanded across borders, and one non-traded good that is demanded only within borders. In all there are thus four different goods. The goods markets are assumed to be perfectly competitive and goods price are fully flexible. The only productive factor is differentiated labor. Each household is a monopolistic supplier of a specific type of labor and it is identified by superscript i. [5]

Firms and Technologies

Technologies to produce the Home tradable (HT) and the Home non-tradable (HN) goods are identical:

$$Y_{j,s} = A_s \mathcal{L}_{j,s} \quad \text{with} \quad \mathcal{L}_{j,s} = \left(\int_0^1 {L^i_{j,s}}^{\frac{\theta-1}{\theta}} \mathrm{d}i \right)^{\frac{\theta}{\theta-1}}, \tag{1}$$

where $\theta > 1$ and $j \in \{HT, HN\}$. The coefficient A_s denotes the labor productivity and is subject to shocks. The associated wage level to employ a unit of aggregate labor is $W_s = \left(\int_0^1 W_s^{i(1-\theta)} \mathrm{d}i \right)^{\frac{1}{1-\theta}}$, where W_s^i denotes the monopolistic money wage claimed by household i. Accordingly, the demand for specific type of labor provided by Home household i is

$$L_s^i = \left(\frac{W_s^i}{W_s} \right)^{-\theta} L_s, \tag{2}$$

where L_s is Home aggregate demand for labor. The foreigners share an identical aggregation technology and therefore the corresponding equations apply.

[5] The notation I stick to throughout this paper is as follows: Superscripts denote where a variable belongs to, Foreign variables are distinguished by an asterisk *. Subscripts identify the characteristics of that variable, e.g. whether it's a non-tradable or the Home tradable good.

The Households

A Home household i has preferences over consumption and labor effort as described by

$$\mathcal{U}_t^i = E_t \sum_{s=t}^{\infty} \beta^{s-t} U_s^i, \qquad \text{where} \tag{3}$$

$$U_s^i = \left(\frac{{C_s^i}^{1-\rho}-1}{1-\rho} - \frac{1}{\nu} {L_s^i}^{\nu} \right) \qquad \text{with} \qquad C_s^i = \frac{{C_{T,s}^i}^{\gamma} {C_{HN,s}^i}^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}}, \tag{4}$$

$0 < \beta < 1$, $\rho > 0$, $\nu \geq 1$, and $0 \leq \gamma \leq 1$. The consumption index C_s^i aggregates the Home non-tradable good $C_{HN,s}^i$ and tradable goods $C_{T,s}^i$ with unit elasticity of substitution. $C_{T,s}^i$ aggregates the Home tradable good $C_{HT,s}^i$ and the Foreign tradable good $C_{FT,s}^i$ with unit elasticity of substitution and equal shares, i.e. $C_{T,s}^i = 2{C_{HT,s}^i}^{\frac{1}{2}} {C_{FT,s}^i}^{\frac{1}{2}}$. Foreign households have the same preferences over tradable goods but differ with respect to their own non-tradable good. Hence, the corresponding equations apply.

Individual Wealth and Cash Constraints

Households can trade a nominal bond with other households within a country. They cannot, however, trade any assets with households from abroad.[6] The timing protocol when asset and goods markets open within a period follows Lucas (1982). At the beginning of a period s, household i holds nominal wealth $\mathbb{W}_s^i$. In the asset markets, household i receives money transfers X_s^i, decides about the holding of domestic nominal bonds B_s^i that repay in next period $R_s B_s^i$ at a gross nominal return R_s, and about cash holdings M_s^i.[7] The asset market constraint reads

$$M_s^i + B_s^i \quad \leq \quad \mathbb{W}_s^i + X_s^i. \tag{5a}$$

Thereafter, the goods markets open where purchases of consumption goods must not exceed initial cash holdings, ie.

$$P_s C_s^i \quad \leq \quad M_s^i. \tag{5b}$$

At the end of period s, household i receives wage earnings $W_s^i L_s^i$. Thus, the nominal wealth at the beginning of the next period $(s+1)$ is

$$\mathbb{W}_{s+1}^i \quad = \quad M_s^i + R_s B_s^i - P_s C_s^i + W_s^i L_s^i. \tag{5c}$$

[6] This assumption is one of two possible stark assumptions that are sufficient for shutting down the current account which allows the derivation of a closed-form solution. In contrast to the other possible assumption where international financial markets are complete (compare eg. Devereux and Engel (2003)), the lack of international risk sharing preserves an important role for international monetary policy management: As Obstfeld and Rogoff (2002a) point out, optimal international monetary policy conduct requires to also take into account the need for international consumption risk sharing. Since it is a well documented empirical fact that international risk sharing is indeed incomplete (compare Obstfeld and Rogoff (1996)), the extreme assumption of no international financial markets at all seems to be the more revealing one.

[7] Note that following Lucas (1982) directly would also imply households to purchase foreign cash within the asset markets. This, however, is completely equivalent to impose only a single cash constraint since information is complete at the asset markets. I stick to the single cash constraint because it is assumed that households go to domestic retailers only who sell both Home and Foreign goods in domestic currency. This also facilitates the comparison to the standard NOEM approach using money-in-the-utility.

Optimal Decisions

Households optimize their expected lifetime utility (4) by deciding over bond and cash holdings, consumption, and their monopolistic wages subject to the constraints (5a-5c), the demand for their specific type of labor (2), and subject to the constraint that they have to set wages one period in advance. In order to smooth consumption over time, household i demands domestic nominal bonds according to the intertemporal Euler equation

$$\frac{1}{R_s} = \beta \frac{E_s\left({C_{s+1}}^{-\rho}\frac{P_s}{P_{s+1}}\right)}{{C_s}^{-\rho}}. \tag{6}$$

Individual optimization also yields the standard composition of consumption between the tradable goods basket and the non-tradable good and between Home and Foreign tradable goods. The corresponding Home consumption-based price indices are given by $P_s = P_{T,s}^{\gamma} P_{HN,s}^{(1-\gamma)}$ and $P_{T,s} = P_{HT,s}^{\frac{1}{2}} P_{FT,s}^{\frac{1}{2}}$. Overall consumption will be determined by the household's cash holding. In particular, we will assume that the net nominal interest rate will be strictly positive and reaches zero only in the limit. Consequently, the cash constraint is binding and optimality implies that households use all their initial cash for consumption goods purchases.[8]

(Flexible Wages) When the household can set wages instantly, it will equate the real wage to a mark-up over the marginal rate of substituting consumption and labor (MRS) as implied by the condition

$$\frac{W_s^i}{P_s} = \frac{\theta}{\theta - 1} R_s \frac{{L_s^i}^{\nu-1}}{{C_s}^{-\rho}}. \tag{7}$$

The case when wages are flexible will serve as useful benchmark. Equation (7) reveals that households face two different incentives to claim real wages higher than the MRS would dictate: first, wage setters impose a monopolistic mark-up, and second, the cash-in-advance restriction leads the household to take into account that labor income is available for consumption only the period thereafter. This is to be evaluated by the nominal interest rate because the nominal interest rate reflects the opportunity cost of holding money as wealth. Consequently, higher nominal interest rates causes the households to claim higher money wages.

(Sticky Wages) When wages have to be posted one period in advance, optimal wage setting requires households to equate the expected marginal loss in utility implied by labor and the expected marginal gain in utility from the additional consumption purchases the period thereafter. Again, by making use of the Euler equation one gets

$$W_s^i = \frac{\theta}{\theta - 1} \frac{E_{s-1}\left({L_s^i}^{\nu}\right)}{E_{s-1}\left(\frac{1}{R_s}\frac{L_s^i}{P_s {C_s}^{\rho}}\right)}. \tag{8}$$

as the optimal wage claim. Similar to the case of flexible wages, households impose a monopolistic mark-up and also take into account the effect of expected nominal interest rates. With preset wages, however, households cannot adjust their money wage claim to the realization of shocks. In contrast to the case of flexible wages where households can effectively control labor effort ex post, ie. after shocks are realized, households are

[8] As it is well known, the cash-in-advance constraint with the Lucas timing convention of markets is binding if the net nominal interest rate is positive. In the sticky wage set up, a zero net nominal interest rate implies real indeterminacy as Carlstrom and Fuerst (1998) show in a comment to Ireland (1996) for a closed economy. Nevertheless, we follow Adao et al. (2003) and assume that the interest rate is positive but arbitrarily close to zero.

assumed to fully supply the amount of labor the firms demand at the posted money wage. By the identical structure of the Foreign households' problem, they obtain equivalent optimality conditions.

Governments' Budget Constraints

National monetary authorities change money supply by making direct money transfers to the households at the asset markets. The associated constraint for the Home authority reads

$$\int_0^1 M_s^i \mathrm{d}i = \int_0^1 M_{s-1}^i \mathrm{d}i + \int_0^1 X_s^i \mathrm{d}i. \tag{9}$$

The money supply will be set according to policy rules that are specified later in the discussion of monetary policy conduct. For the Foreign authority the corresponding equation applies.

3 Equilibrium Allocation

All households within a country are assumed to be identical except for the specific types of labor. This also includes that they start out with identical wealth and that they receive identical money transfers. Thus, by the symmetry of labor demand, all households take identical optimal decisions. We therefore drop superscript i.

Goods Prices and the Terms of Trade

Goods markets are assumed to be perfectly competitive. Since goods prices are flexible, they are set equal to the marginal costs. Consequently, prices of national tradable and non-tradable goods coincide and the identification of whether it is the tradable or non-tradable good can be saved. Goods prices are then

$$P_{H,s} = \frac{W_s}{A_s} \quad \text{and} \quad P_{F,s}^* = \frac{W_s^*}{A_s^*}, \tag{10}$$

respectively. The terms of trade are defined as the price of Home exports over the price of Home imports, ie. $ToT_s = \left(\frac{P_{H,s}}{\mathcal{E}_s P_{F,s}^*}\right)$, where $\mathcal{E}_s$ denotes the nominal exchange rate. In terms of relative wage levels, we can restate the terms of trade as

$$ToT_s = \frac{A_s^*}{A_s}\left(\frac{W_s}{\mathcal{E}_s W_s^*}\right). \tag{11}$$

The real exchange rate RER_s is then by the consumption-based price indices $RER_s = ToT_s^{(1-\gamma)}$.

Ex Post Equilibrium Allocation

As all households within a country take identical decisions and as they start out with identical initial wealth, they will ask and bid identical amounts of nominal bonds. Thus, there is no net trade in bonds and asset market clearing conditions require that households' bond holding is zero in all states. Consequently, households hold only cash as wealth, ie. $\mathbb{W}_s = M_{s-1}$ and $\mathbb{W}_s^* = M_{s-1}^*$. Next, goods markets clearing of tradable goods

necessitates nominal imports to equal nominal exports because nominal trade must be balanced as there are no payments through international financial markets. Moreover, since Home and Foreign households share the same preferences over tradable goods with unit demand elasticity, purchasing power parity holds for the composite of tradable goods. As a consequence, Home and Foreign consumption of tradable goods must be the same, ie. $C_{T,s} = C^*_{T,s}$. Making use of the optimal composition of tradable and non-tradable goods within households' consumption baskets, ie. $C_{T,s} = \gamma \frac{P_s}{P_{T,s}} C_s$ and $C^*_{T,s} = \gamma \frac{P^*_s}{P^*_{T,s}} C^*_s$, respectively, reveals that - in terms of tradable goods - Home and Foreign consumption expenditures must be the same. Following Obstfeld and Rogoff (2002a), overall consumption expenditures are expressed in terms of tradable goods consumption as

$$Z_s = \frac{P_s}{P_{T,s}} C_s \quad \text{and} \quad Z^*_s = \frac{P^*_s}{P^*_{T,s}} C^*_s. \tag{12}$$

The immediate equilibrium consequence then is $Z_s = Z^*_s$. Furthermore, money market clearing and the binding cash-in-advance constraints determine households' nominal expenditures. Taking ratios of the nominal consumption expenditures and using the goods market clearing implication of $Z_s = Z^*_s$, one obtains the equilibrium nominal exchange rate to be solely determined by the ratio of Home and Foreign money supplies. In summary, independent of whether wages are flexible or preset a period before, the equilibrium entails

$$Z_s = Z^*_s \quad \text{and} \quad \mathcal{E}_s = \frac{M_s}{M^*_s}. \tag{13}$$

It turns out to be very insightful to express the national variables in terms of their common and their different components as proposed by Aoki (1981). In particular, let subscript "w" denote the "world" average component which is the geometric mean of Home and Foreign variables and let subscript "d" denote the "difference" component which is the ratio of Home over Foreign variables.[9] The decomposition of Home and Foreign equilibrium consumption levels yields

$$C_{w,s} = Z_s \quad \text{and} \quad C_{d,s} = ToT_s^{-\frac{1}{2}(1-\gamma)}. \tag{14}$$

The world average consumption which is common to both Home and Foreign is clearly Z_s. As a consequence, in equilibrium, the difference between Home and Foreign consumption solely stems from the consumption of non-tradable goods. This is entirely captured by the real exchange rate and hence by the terms of trade. Consequently, the ex post equilibrium allocation is uniquely determined for given common consumption level Z_s and the terms of trade ToT_s. Table 1 summarizes equilibrium consumption, output and labor.

Flexible Wages

When wages are flexible, it is straight forward to obtain

$$Z_s = \left(\frac{(\theta-1)}{\theta} \frac{{A_{w,s}}^{\nu}}{R_{w,s}} \right)^{\frac{1}{\chi}} \qquad \text{and} \qquad ToT_s = \left(R_{d,s} {A_{d,s}}^{-\nu} \right)^{\frac{2}{\gamma}}, \tag{15}$$

[9] As a reminder, for Home and Foreign variables X and X^* the decomposition in levels is $X = X_w X_d$ and $X^* = \frac{X_w}{X_d}$ where $X_w = (XX^*)^{\frac{1}{2}}$ and $X_d = (\frac{X}{X^*})^{\frac{1}{2}}$. The exponents are relative country sizes which in our case is $\{\frac{1}{2}, \frac{1}{2}\}$.

Table 1

Ex Post period equilibrium allocation for given Z and ToT.

	Common World Components	Difference Components
Consumption	$C_w = Z$	$C_d = ToT^{-\frac{(1-\gamma)}{2}}$
Output	$Y_w = Z$	$Y_d = ToT^{-\frac{1}{2}}$
Labor	$L_w = A_w^{-1} Z$	$L_d = A_d^{-1} ToT^{-\frac{1}{2}}$

where $\mathcal{X} = \nu - (1-\rho) > 0$ and $\mathcal{Y} = \nu - (1-\rho)(1-\gamma) > 0$. From (15) follows that the higher the world average nominal interest rates, the lower the common consumption $C_{w,s}$. The reason is well understood: Higher nominal interest rates imply an inflation tax on labor income that increases the wedge between the marginal rate of substitution between consumption and labor and the real wage claim. The consequence is an inefficiently low labor supply that results in a reduction of equilibrium output and consumption. The terms of trade, in turn, depend on relative nominal interest rates as these determine relative nominal wage levels and thereby relative goods prices. Higher domestic nominal interest rates cause households to increase their wage claims because they expect higher inflation taxes on labor income. Consequently, goods prices increase and alter the terms of trade. It is important to observe that it is the relative nominal interest rates that affect relative prices and the allocation. National money supplies determine only the national price levels and the nominal exchange rate according to equation (13). When wages are flexible, the nominal exchange rate does not matter for determining the real allocation. The role of the money supply changes, however, when wages are sticky.

Sticky Wages

Preset wages imply that goods prices are fully determined by the realization of productivity levels. The important implication is that the nominal exchange rate uniquely determines the terms of trade as by equation (11). Thus Home and Foreign consumption-based price levels are determined. Home and Foreign consumption levels are therefore determined by the respective money supplies through the cash-in-advance constraint. As a result, and in contrast to flexible wages, the ex post real allocation can only be altered by national money supplies. To be specific, we have that

$$Z_s = \frac{A_{w,s}}{W_{w,s}} M_{w,s} \quad \text{and} \quad ToT_s = \left(\frac{W_{d,s}}{A_{d,s} M_{d,s}} \right)^2 . \tag{16}$$

When goods prices are effectively predetermined, world average consumption Z_s can only be changed ex post by altering the common money supply which reflects in equilibrium a one-to-one change in real balances available for consumption purchases. The terms of trade, in turn, can only be changed ex post by the nominal exchange rate which is determined by the relative money supplies as in (13).

In fact, this monetary propagation mechanism resembles the standard equilibrium transmission of monetary policy in NOEM, (compare eg. Corsetti and Pesenti (2001),

Obstfeld and Rogoff (2002a), or Devereux and Engel (2003)). In sharp contrast, however, and key to the analysis in this paper, the money supply is not the only available monetary instrument to affect the equilibrium allocation. For a more general short-run monetary policy conduct it is important to realize that even though the ex post allocation can only be altered by the actual money supply, the expected period nominal interest rates play a crucial role for the determination of the equilibrium allocation ex ante because they affect the wage setting and hence the terms of trade ex ante. The argument follows the same logic as in case of flexible wages: the announced next period's nominal interest rates convey the expected inflation tax in the following period. Consequently, higher ex ante expected nominal interest rates lead to higher expected inflation taxes the period thereafter and hence to higher wage claims.[10] Recall the optimal wage setting condition (8).

Digression: Degree of Freedom to Choosing Both the Nominal Interest Rate and the Money Supply

In order to see that monetary authorities indeed control two separate policy instruments, note first that within a period each level of the nominal interest rate is consistent with a continuum of that same period's money supplies. The crucial insight is that in equilibrium, given the current allocation and given the other country's monetary policy, the intertemporal Euler equation provides national monetary policy with a degree of freedom to pin down the nominal interest rate because the nominal interest rate relates current money supply and current consumption to the expected future money growth and to expected future consumption. This can be seen directly when wages are flexible. From equation (15) follows that in each instance there are two equations determining the equilibrium allocation in two unknowns, namely Home and Foreign nominal interest rates. There is a continuum of money supplies and associated price levels that are consistent with the equilibrium allocation. Hence, for given current money supply and given future nominal interest rates, the current nominal interest rate can be controlled by appropriately announcing future money supplies and thereby the expected future inflation.

When wages are preset, things are only slightly more involved. Equation (16) implies then that the allocation is determined in each period by Home and Foreign money supplies. As argued above, the nominal interest rates are irrelevant for the current allocation but they do determine the preset wages given the distribution of future allocations (compare again the wage setting condition (8)). The question is, however, whether each nominal interest rate is consistent in the rational expectations equilibrium with a continuum of current money supplies that determine the current allocation and a continuum of future money supplies that determine the distribution of future allocations given future nominal interest rates. The answer is yes and follows in principle the logic of the case when wages are flexible. Suppose that there are no shocks to the economy and hence all variables take their expected values. In this case, the allocation is determined as if wages were flexible and similarly each nominal interest rate is associated with a specific level of expected money supply. Consequently, given the current money supply and hence the current allocation, the nominal interest rate can be effectively chosen by monetary authorities

[10] Note that in stochastic environments ex post monetary policy conduct also influences ex ante wage setting because ex post monetary interventions alter the equilibrium distribution that is relevant for optimal wage setting. This effect has been emphasized by Obstfeld and Rogoff (2000, 2002a,b) and comes in addition to the incentives to alter wages induced by the nominal interest rates. As I argue below, from a welfare perspective, however, the distribution effects are of second order. In contrast, the effects of the nominal interest rates will be of first order.

through an appropriate change of the expected levels of future money supplies. When the future states are stochastic, the distribution of the equilibrium allocation around the expected levels can then be controlled by the distribution of the state-dependent deviations of the actual money supply from the expected money supply. The expected level of money supply only affects the expected levels of consumption and inflation, not their distribution around these expected levels. Hence, the period nominal interest rate can bo effectively controlled by appropriately choosing the expected level of money supply. In principle, instead of arguing via the nominal interest rate and the money supplies as being the two separate policy instruments one could also argue via the expected future money supplies and the state-dependent deviations.[11] As a result, monetary authorities thus dispose of two independent policy instruments - the nominal interest rate and the money supply - no matter whether wages are flexible or preset. Before we turn to the discussion of the general short-run monetary policy conduct, we still have to clarify the equilibrium distribution.

Distribution of the Equilibrium Allocation

Uncertainty stems from productivity shocks that are assumed to be iid log-normal. Letting lower case letters denote logs, productivity shocks have the following properties: $Ea = Ea^* = 0$ and $Var(a) = Var(a^*) = \sigma_a^2$, where $Ea = 0$ is assumed for simplicity. In accordance with the equilibrium variables, these shocks are expressed in terms of a "world" component common to both countries and a "difference" component making up the gap in productivity. Thus we have $a_{w,s} = \frac{1}{2}(a_s + a_s^*)$ and $a_{d,s} = \frac{1}{2}(a_s - a_s^*)$. The distribution of the decomposed shocks implies in turn

$$Var(a_s) = \sigma_a^2 = \sigma_{a_w}^2 + \sigma_{a_d}^2 \qquad \text{since} \qquad Cov(a_{w,s}, a_{d,s}) = \sigma_{a_{w,s},a_{d,s}} = 0.$$

If monetary policies are stationary, iid productivity shocks imply that the households' and firms' optimal decision rules are stationary. As a consequence, the equilibrium of the infinite horizon setup is simply a repetition of the static version of a single period. Furthermore, if the money supply is log-normal, too, the distribution of the equilibrium allocation turns out to be jointly log-normal. Therefore, the solution to the stochastic general equilibrium can be obtained in closed-form. For the rest of the paper, the time-subscripts are skipped for convenience.

4 Short-Run Monetary Policy

The key insight of this paper revolves around the question of how policymakers exploit nominal frictions in different strategic settings in order to improve their respective resident's economic well-being. In particular, on the one hand, the cash-in-advance requirement for goods transactions implies a distorting inflation tax on labor income. Thereby, the monetary authority can influence workers' wage setting through the nominal interest rate policy. On the other hand, wage rigidity places the money supply at monetary authorities' disposal as an instrument by which it can alter the actual allocation ex post.

As demonstrated above, national monetary authorities can set both the period nominal interest rate and the period money supply independently by steering the expected money growth rate and the state-dependent deviations from the announced money growth rate. The important difference between the two policy instruments is the way the affect

[11] Compare also the discussions in Ireland (1996) and Adao et al. (2003).

the equilibrium allocation. The money supply management determines state-dependent spending flows. From an ex ante perspective, this corresponds to changes in the variability of the equilibrium allocation. The nominal interest rate changes the incentives to workers' wage setting and thereby the expected equilibrium levels. Crucially then, from a welfare perspective, the nominal interest rate policy is of first order whereas the money supply management is of second order.

There are yet two other non-monetary frictions in the model economy. The lack of international risk sharing is an important feature as it reveals important strategic interactions between national monetary authorities. The distortion created by monopolistic competition is a constant markup over competitive wages which only overlaps with all other economic effects of interest but which yields no further insights. Therefore I abstract from the distortions created by monopolistic competition and follow Ireland (1996) by considering the limiting case of perfect competition where $\theta \to \infty$ and the wage markup is unity.[12] Moreover, the focus in this paper is not on time-consistency issues. In keeping with the literature, the attention is restricted to monetary policies to which authorities can perfectly commit themselves.

Short-Run Monetary Policy Instruments

To be specific, national monetary authorities' announce the nominal interest rate and the feedback rule that conditions the money supply on productivity shocks. The money supply rules comprise of the feedback coefficients $\mu = \{\mu_{a_w}, \mu_{a_d}\}$ and $\mu^* = \{\mu^*_{a_w}, \mu^*_{a_d}\}$ and they are of the form

$$\hat{m} = \mu_{a_w}\hat{a}_w + \mu_{a_d}\hat{a}_d \quad \text{and} \quad \hat{m^*} = \mu^*_{a_w}\hat{a}_w - \mu^*_{a_d}\hat{a}_d, \tag{17}$$

where variables with a hat denote deviations from their expected value. Accordingly, in (17), $\hat{m}$ and $\hat{m}^*$ denote the log-deviation from the expected money supply, ie. $\hat{m} = m - Em$ and $\hat{m}^* = m^* - Em^*$. Recall that this specification indeed allows the policymakers to set both the nominal interest rate by choosing the expected values for money supply Em and Em^* and the state-dependent deviations $\hat{m}$ and $\hat{m}^*$ in order to react to productivity shocks. Note also that thereby the use of surprise inflation is ruled out. The monetary authorities are committed to these announcements and implement the period monetary policy accordingly.[13]

[12] An alternative assumption is to introduce national fiscal stances that subsidize labor in order to offset the inefficient wage markup. As a matter of fact, in a companion paper I demonstrate that this is indeed part of the optimal monetary and fiscal policy in a two-country sticky wage model like the one at hand. However, it is not necessarily true that non-coordinated fiscal policy indeed sets labor income taxes to offset the monopolistic distortion. Instead, taxes are used to manipulate the terms of trade in exactly the same manner as it turns out to be the case for the nominal interest rate (see Evers (2007)). Arseneau (2007) studies the role of monopolistic markups for nominal interest rate policy conduct in open economies in detail.

[13] Two remarks to the specification of the monetary policy are in order: First, as concerning the period single nominal interest rate, it implies no restriction at all to set it in a non state-contingent way. In case of flexible wages, it can be demonstrated that even the ex post optimal nominal interest rate is independent of the actual realization of the state. To be more precise, the polynomial determining the root to the policymaker's first order condition is linear in the single relevant equilibrium variable consumption. In case of sticky wages, only the expected nominal interest rate matters. Hence, there is no requirement for state-dependent nominal interest rate setting, too. For a more detailed discussion, see the Appendix. Second, as concerning the state-dependent money supply, using the standard feedback rule as eg. in Obstfeld and Rogoff (2002a) and Devereux and Engel (2003) would be to take the following AR(1) form: $m_s = m_{s-1} + \mu_{a_w,s}\hat{a}_{w,s} + \mu_{a_d,s}\hat{a}_{d,s}$. This, however, implies $Em_s = m_{s-1}$, which factually precludes the use of both, the nominal interest rate and the money supply as monetary policy instruments at the same time.

Policymakers' Objective

The objective of national monetary authorities is to maximize their respective residents' welfare. By the simplified iid structure of the model, Home policymaker's problem reduces to choose $\{R, \mu\}$ so as to maximize expected period utility EU. The Foreign policymaker decides over $\{R^*, \mu^*\}$ so as to maximize EU^*. Making use of the equilibrium wage setting, Home and Foreign expected utility can be expressed as

$$EU = E\left(\frac{1}{(1-\rho)} - \frac{1}{\nu}\frac{1}{R}\right)(C)^{(1-\rho)} \qquad \text{and} \tag{18}$$

$$EU^* = E\left(\frac{1}{(1-\rho)} - \frac{1}{\nu}\frac{1}{R^*}\right)(C^*)^{(1-\rho)},$$

respectively. It is important to observe that Home and Foreign policymakers' objectives are symmetric except for the impact of the terms of trade. Recall from the discussion of the equilibrium allocation that the difference between the consumption levels is fully captured by the terms of trade (compare Table 1). Hence, deviations from the jointly optimal monetary policy will be solely on the grounds of strategically motivated manipulations of the terms of trade in the respective country's own favor. Moreover, as the impacts of the terms of trade on Home and Foreign objectives are orthogonal, the incentives to strategically deviate from the socially optimal policy must necessarily be the kind of "beggaring-thy-neighbor".

The expected utility expressed in the closed-form solution of the equilibrium permits further insights into the short-run monetary policy conduct as this allows a particularly convenient separation of the equilibrium implications of monetary policy that directly affect the average consumption level from the equilibrium implications of monetary policy that changes the variability of the allocation and hence consumption. It proves illuminative to write expected utility for the flexible wage environment first because it is embedded in the expression of the expected utility under sticky wages.

Flexible Wages

When wages are flexible, Home expected utility takes the form

$$\begin{aligned} EU|_{flex} &= \left(\frac{1}{(1-\rho)} - \frac{1}{\nu R_w R_d}\right)\left(\frac{1}{R_w}\right)^{\frac{(1-\rho)}{\mathcal{X}}} R_d^{-\frac{(1-\gamma)(1-\rho)}{\mathcal{Y}}} \cdot \exp\{\Omega_{flex}\} \\ &\equiv U_{flex}(R; R^*). \end{aligned} \tag{19}$$

The term Ω_{flex} summarizes the part of expected utility which depends on uncertainty only and it is given by

$$\Omega_{flex} = \frac{(1-\rho)^2\nu^2}{2\mathcal{X}^2\mathcal{Y}^2}\left(\mathcal{Y}^2\sigma^2_{a_w} + (1-\gamma)^2\mathcal{X}^2\sigma^2_{a_d}\right).$$

In case of flexible wages, all variability of the allocation and hence consumption stems from exogenous changes in productivity. Importantly, the nominal interest rate determines the part of expected utility which doesn't depend on uncertainty but it alters the mean level of expected utility. The consequence is that as nominal interest rate policy affects the first moment of expected utility, the policy implications are of first order.

Sticky Wages

When wages are sticky, Home expected utility can be decomposed such that it contains the expression for expected utility under flexible wages,

$$EU|_{sticky} = U_{flex}(R;R^*)\cdot\exp\{\Omega_{sticky}(\mu;\mu^*)\}. \tag{20}$$

Similarly to the above, $\Omega_{sticky}(\mu,\mu^*)$ summarizes the second moment variance and covariance terms of expected utility, namely

$$\begin{aligned}\Omega_{sticky}(\mu;\mu^*) &= \tfrac{(1-\rho)\nu}{2}\left(\omega-\sigma_z^2-\tfrac{\mathcal{Z}}{4\mathcal{X}}\sigma_e^2+\tfrac{2\nu}{\mathcal{X}}\sigma_{z,a_w}+\tfrac{(1-\rho)(1-\gamma)^2}{\mathcal{X}}\sigma_{e,a_d}\right)\\ &\quad+\tfrac{\nu(1-\rho)(1-\gamma)}{2\mathcal{Y}}\left(-(1-\gamma)\mathcal{X}\sigma_{z,e}+\nu\sigma_{e,a_w}+\tfrac{(1-\rho)(1-\gamma)}{\mathcal{Y}}\sigma_{z,a_d}\right),\end{aligned}$$

where $\mathcal{Z}=\nu-(1-\rho)(1-\gamma)^2$ and ω is a constant independent of endogenous variables.[14]

In contrast to flexible wages where all uncertainty stems from exogenous productivity disturbances, under preset wages an active state-dependent money supply management according to the feedback coefficients $\{\mu,\mu^*\}$ entails endogenous uncertainty over the allocation. Crucially, the money supply policy affects the average level of consumption and hence the expected utility through the changes in the variability of the equilibrium allocation only. Consequently, and in contrast to the welfare implications of the nominal interest rate policy, as the money supply policy affects the equilibrium by altering second moments of the equilibrium distribution of the allocation, the welfare implications are thus of second order. Because the importance of the different implications of the two monetary policy instruments on expected utility cannot be overemphasized, the discussion is summarized in the following proposition:

Proposition 1. *The welfare implications of short-run nominal interest rate policy are of first-order whereas the welfare implications of short-run money supply management are of second-order.*

Proof. See Appendix. □

Proposition 1 shall constitute the backbone of the argument put forth in this analysis. By the discussion in the beginning, the literature on international monetary policy regimes has largely focused on stabilization issues. Gains from policy coordination, however, are quantified to be fairly small. Relating to the discussion in Lucas (2003), gains from stabilization and thereby gains from international coordination of stabilization policies are generically quite limited as they are of second order. On the contrary, the nominal interest rate policy as discussed here means that monetary authorities exploit the inflation tax to govern the workers' wage setting. In terms of Lucas, this denotes a supply side effect which is of first order. Consequently, from a quantitative perspective, welfare gains from international coordination of nominal interest rate policies are to be expected of an order of magnitude larger than welfare gains from coordinating monetary stabilization policy as it has been done in the past. A numerical example shall support this claim. Next, however, the analysis is continued with a discussion of the theoretical results of optimal coordinated and noncooperative international policy conduct.

5 Optimal Cooperative Monetary Policy

When national policymakers coordinate their respective monetary policies, they do so as to maximize the sum of the equally weighted Home and Foreign residents' welfare.

[14] It is defined as $\omega=\frac{(1-\rho)\nu}{2\mathcal{X}^2\mathcal{Y}^2}\left(-\nu^2\mathcal{Y}^2\sigma_{a_w}^2+(1-\rho)(1-\gamma)^2\mathcal{X}\left(\mathcal{Y}^2-\nu\mathcal{X}\right)\sigma_{a_d}^2\right)$.

The Optimal Nominal Interest Rate

The globally optimal interest rate policy is as follows.

Proposition 2. *The optimal nominal interest rate policy is to follow the Friedman rule, ie.*

$$\mathrm{R}^{Opt} = 1,$$

and $\mathrm{R}^{*Opt} = \mathrm{R}^{Opt}$ *by symmetry.*

Proof. See Appendix. □

The optimality of the Friedman rule is well understood.[15] The intuition for this result can be best seen in the context of optimal taxation since it is an immediate implication of the optimal taxation principle (Diamond and Mirrlees (1971)) which postulates not to tax intermediate inputs. Recall that as labor income is available for consumption only the following period, the gross nominal interest rate reflects the intertemporal nominal cost of keeping labor income as cash that cannot be spent within the sam period as when it is earned. This can then be understood as a tax on labor income and thus as a tax on an intermediate input to the production of goods. As a consequence, it is optimal to set the net nominal interest rate to zero and thereby to offset the implicit tax on labor input. Importantly, the optimality of the Friedman rule obtains for both environments, with flexible wages as well as sticky wages. When wages are flexible, a positive net nominal interest rate leads to a distortive wedge between the marginal rate of substituting labor and consumption (MRS) on the one hand and marginal product of labor (MPL) on the other hand in all instances. When wages are sticky, labor is demand determined and the ratio between MRS and MPL is not necessarily at an inefficiently high level. However, expected utility is maximized when the distortion is minimized on average. Hence, the Friedman rule is optimal under sticky wages, too.

The Optimal Money Supply

In contrast to the nominal interest rate, money supply is allocatively effective only when wages are sticky. In the discussion of monetary policy instruments, the bottom line was that the money supply management affects the variability of the equilibrium allocation. As an immediate consequence, the two relevant frictions that impose distortions to the equilibrium allocation which could be on target for the money supply are wage rigidity and the lack of international asset markets. The next proposition states the optimal feedback coefficients on aggregate and asymmetric productivity shocks.

Proposition 3. *The optimal money supply feedback rule follows*

$$\mu_{a_w}^{Opt} = \frac{(1-\rho)}{\mathcal{X}} \quad \textit{and} \quad \mu_{a_d}^{Opt} = \frac{(1-\rho)(1-\gamma)^2}{\mathcal{Z}},$$

where $\mu^{*Opt}_{a_w} = \mu^{Opt}_{a_w}$ *and* $\mu^{*Opt}_{a_d} = \mu^{Opt}_{a_d}$ *by symmetry. Furthermore, with* μ^{Flex} *as the feedback coefficients replicating the flexible wage equilibrium, it follows that*

$$\mu_{a_w}^{Opt} = \mu_{a_w}^{Flex} \quad \textit{and} \quad \mu_{a_d}^{Opt} \begin{cases} > \mu_{a_d}^{Flex} & \textit{if } \rho > 1 \textit{ and } 0 < \gamma < 1, \\ < \mu_{a_d}^{Flex} & \textit{if } \rho < 1 \textit{ and } 0 < \gamma < 1, \\ = \mu_{a_d}^{Flex} & \textit{if } \rho = 1 \textit{ or } \gamma \in \{0, 1\}\ , \end{cases}$$

where $\mu_{a_d}{}^{flex} = \frac{(1-\rho)(1-\gamma)}{\mathcal{Y}}$.

[15] See eg. Chari et al. (1996), Chari and Kehoe (1999), Adao et al. (2003), or Kocherlakota (2005) for closed economy setups and Cooley and Quadrini (2003) and Arseneau (2007) in the context of open economies.

Proof. See Appendix. □

In case of aggregate productivity shocks, the only distortion that matters stems from preset wages. The optimal money supply response is then to replicate the flexible wage allocation. To be more precise, in case of flexible wages it easy to see that the intra-temporal substitution elasticity of consumption and labor is $\frac{1-\rho}{\nu}$. When wages are preset, labor is fully demand determined and hence uncoupled from the consumption decision. As a consequence, in order to mimic the optimal labor-consumption trade-off, the optimal money supply response to aggregate productivity shocks adjusts real balances so that consumption and labor changes in the right proportion. To be specific, consider a positive aggregate productivity shock. If wages were flexible, households' would raise nominal wages up to the point where real wages would equal the marginal rate of substituting labor and consumption (see equation 7). For $\rho > 1$ consumption and labor are substitutes and hence households increase consumption and also reduce labor in response to a rise in real labor income. Under sticky wages, this adjustment is not possible. The positive aggregate productivity shock leads ceteris paribus to a one-to-one drop in goods prices and thereby to a one-to-one increase in consumption whereas employment stays unaffected. As a result, the optimal response of monetary policy must be to dampen the increase of consumption by contracting the money supply. This leads to a reduction of equilibrium employment, too, and thereby the optimal consumption-labor ratio can be restored. In contrast, if $\rho < 1$, consumption and labor are complements and optimality requires a conjoint increase in labor and consumption. As a consequence, money supply must respond pro-cyclically. In case of log-utility, ie. $\rho = 1$, it is optimal that labor doesn't respond to consumption fluctuations at all. The optimality of targeting the flexible wage allocation reproduces the findings of several recent contributions where wage or price rigidity prevents the equilibrium allocation from efficiency.[16]

In case of idiosyncratic productivity shocks, the lack of international risk sharing comes in addition to the inefficiency caused by preset wages. Complete asset markets would enable Home and Foreign households to contract state-contingent payments in order to insure against all idiosyncratic risks. The consequence of perfect consumption risk sharing for the initially identical countries would be that for all goods the ratio of Home and Foreign marginal consumption utilities equals the ratio of the respective equilibrium goods prices (compare, for example, Backus and Smith (1993)). In particular, for the basket of tradable goods the implication is that the ratio of Home over Foreign marginal utilities must be unity, ie. $\frac{U_{C_T}}{U_{C_T^*}} = 1$. In terms of the equilibrium without asset markets, the ratio of marginal utilities of tradable goods consumption reads

$$\frac{U_{C_T}}{U_{C_T^*}} = ToT^{-(1-\rho)(1-\gamma)}.$$

Following, the ratio $\frac{U_{C_T}}{U_{C_T^*}}$ decreases in response to, for example, a terms of trade depreciation if $\rho > 1$ and the ratio increases if $\rho < 1$. The intuition is best captured in terms of substitutability and complementarity of consumption goods in the Edgworth-Pareto sense.[17] If $\rho > 1$, the different consumption goods are substitutes. A terms of trade

[16] Examples for closed economies can be found in Rotemberg and Woodford (1997, 1998), Goodfriend and King (1997), Erceg et al. (2000), or Adao et al. (2003). For open economies, compare Obstfeld and Rogoff (2002a), Benigno and Benigno (2003, 2006), or Corsetti and Pesenti (2005).

[17] Two goods are substitutes (complements) in the Edgeworth-Pareto sense if the marginal utility of one good is decreasing (increasing) with the consumption of the other good. For open economy setups, see also Svensson (1987) and Corsetti and Pesenti (2001).

depreciation caused by a positive Home productivity shock leads households to substitute the costlier Foreign goods for the cheaper Home goods. Thereby, Home households consume more Home tradables and non-tradables whereas Foreign households consume less Foreign tradables and non-tradables. In equilibrium, however, it is that Home and Foreign households consume the same amount of tradables, ie. $C_T = C_T^*$. As a consequence, the difference in marginal utilities of tradable goods consumption necessarily stems from the difference in consumption of non-tradables: Home households consume too much tradables relative to non-tradables as risk sharing would imply, Foreign households consume too less tradables relative to non-tradables as risk sharing would imply. The appropriate money supply change to offset this effect is to make Home households pay more for Foreign tradable goods and thereby to make them paying more for overall tradable goods and to make Foreign households pay less for Home tradables and thereby to make them paying less for overall tradable goods. Hence, to attenuate the lack of risk sharing, optimal money supply necessitates an depreciating of Home nominal exchange rate. For $\rho < 1$, when consumption goods are complements, the according logic applies. In this case, however, it is that Home households consume too less tradables relative to non-tradables whereas Foreign households consume too much tradables relative to non-tradables than under perfect risk sharing. The optimal money supply management therefore leads to an appreciation of Home nominal exchange rate in order to make Home households pay less for Foreign goods and to make Foreigners pay more for Home goods.

To see that there is in general a conflict of closing the domestic gaps between the marginal rate of substituting consumption and labor on the one hand and closing the international gap between Home and Foreign marginal consumption utilities on the other hand, suppose that Home and Foreign monetary authorities target the flexible wage allocation and implement ${\mu_{a_d}}^{flex} = {\mu_{a_d}^*}^{flex}$. This policy response, however, never fully offsets the impact of asymmetric productivity shocks on the terms of trade, ie. $\widehat{tot} = -\frac{\nu}{\mathcal{Y}}\hat{a}_d$. Consequently, by the logic developed above, monetary authorities face an incentive also to attenuate the implications of the lack of international consumption risk sharing.[18] Moreover, the trade-off between targeting the two distortions is characterized by a more active response when money supply management targets the flexible wage allocation than it is optimal. To prevent a repetition of arguments, however, a discussion is left to the reader. The importance of this trade-off is also discussed in Obstfeld and Rogoff (2002a).

6 Noncooperative Monetary Policy

In the discussion of national policymakers' objectives, the central message is captured by Proposition 1: The nominal interest rate policy has first-order welfare implications whereas the money supply policy implications are of second order. Consequently, the losses from not coordinating monetary policy are of first-order when national monetary authorities face the incentive to deviate from the jointly beneficial Friedman rule (Proposition 2). In this section it is shown that self-oriented national policymakers follow the Friedman rule if and only if the two countries are closed. As long as there are trade linkages between the two countries, the incentives to manipulate the terms of trade cause the policymakers to unilaterally deviate from the optimal cooperative solution. Thereby, the

[18] There are three special cases where no such trade-off exists: When i) $\rho = 1$, the intertemporal and the intratemporal substitution elasticities coincide and hence risk is fully diversified via goods consumption in market equilibrium; when ii) $\gamma = 1$, only tradable goods are consumed and hence $C_T = C_T^*$ directly implies perfect consumption risk sharing; and when iii) $\gamma = 0$, no tradable goods are demanded at all and therefore the only inefficiency that is prevailing is wage stickiness.

gains from cooperation that are forgone if national monetary authorities act independently are of first order.

The Nominal Interest Rate

The following proposition establishes that the nominal interest rate in a Nash equilibrium of the policy setting game in general differs from the cooperative nominal interest rate.

Proposition 4. *The unique Nash equilibrium of non-cooperatively set nominal interest rates implies*

$$R^{Nash} = 1 + \frac{\gamma \mathcal{X}}{\mathcal{Y} + (1-\gamma)\mathcal{X}},$$

and $R^{*Nash} = R^{Nash}$ *by symmetry. Furthermore,*

$$R^{Nash} > R^{Opt} \quad for \quad \gamma \neq 0 \quad and \quad R^{Nash} = R^{Opt} \quad iff \quad \gamma = 0.$$

Proof. See Appendix. □

The intuition for this finding is straight forward: policymakers face the incentive to improve their respective households' consumption-labor trade-off. If there are any trade linkages between the two countries, ie. if $\gamma > 0$, the non-cooperative solution prescribes the policymakers to induce workers to claim higher wages by raising the nominal interest rate and consequently the implicit tax on labor. For instance, given Foreign wages and goods prices, an increase in Home wages imply an appreciation of the Home's terms of trade. In equilibrium, this causes a fall in labor demand: first, higher wage claims lead to a direct fall in Home labor demand. Second, the increase in the Home's relative prices induces a reduction of the demand for Home goods. As a consequence, both Home labor demand and labor income falls. Foreign households, however, have to give more of their goods in exchange for Home goods. This yields ceteris paribus a higher Home consumption-labor ratio and thereby higher welfare. As a result, domestic policymakers "beggar-thy-neighbor" by inducing the Foreign households to work more and thus to worsen Foreign consumption-labor trade-off. In the symmetric equilibrium, the consequence are higher distortive Home and Foreign nominal interest rates that reduce aggregate output and thereby aggregate consumption as labor is supplied at an inefficiently low level. Again, this holds true for both environments: for flexible wages in all instances and under sticky wages on average.

Importantly, the incentive to unilaterally deviate from the globally optimal Friedman rule is increasing with the degree of openness. That is, the larger the economic interdependence through trade linkages between the two countries, the higher is the incentive to "beggar-thy-neighbor" and to unilaterally manipulate the terms of trade by increasing the domestic interest rate. As the welfare implications are of first-order, the consequences of the failure to cooperate on the nominal interest rates become more severe the more interdependent the countries are.

The Money Supply

The next Proposition shows the equilibrium money supply when national policymakers act independently.

Proposition 5. *The unique Nash equilibrium of non-cooperatively set money supply rules is*

$$\mu_{a_w}^{Nash} = \frac{(1-\rho)}{\mathcal{X}} \quad and \quad \mu_{a_d}^{Nash} = (1-\rho)(1-\gamma)\left(\frac{\mathcal{X}+(1-\gamma)\mathcal{Y}}{\mathcal{Z}\mathcal{Y}+(1-\gamma)\mathcal{X}^2}\right),$$

and $\mu^{*Nash}_{a_w} = \mu^{Nash}_{a_w}$ *and* $\mu^{*Nash}_{a_d} = \mu^{Nash}_{a_d}$ *by symmetry. Furthermore,*

$$\mu_{a_w}^{Nash} = \mu_{a_w}^{Opt} \quad and \quad \mu_{a_d}^{Nash} \begin{cases} < \mu_{a_d}^{Opt} & \text{if } \rho > 1 \text{ and } 0 < \gamma < 1. \\ > \mu_{a_d}^{Opt} & \text{if } \rho < 1 \text{ and } 0 < \gamma < 1. \\ = \mu_{a_d}^{Opt} & \text{if } \rho = 1 \text{ or } \gamma \in \{0, 1\}\ . \end{cases}$$

Proof. See Appendix. □

Not surprisingly, in case of aggregate productivity shocks, the Nash solution does not differ from the optimal solution. Aggregate shocks shift consumption expenditures in a way that is common to both countries. Therefore, the policy targets coincide. Why, however, is it that national policymakers do not use aggregate productivity shocks as a stochastic anchor to manipulate the terms of trade? Indeed, they face the incentive to do so. Nevertheless, the only friction that prevents from individual optimality is wage rigidity. Therefore, the only incentive to manipulate the terms of trade is to achieve the optimal consumption-labor trade-off. Hence, the optimal policy response to aggregate productivity shocks also solves the Nash problem.

This is no longer the case for asymmetric productivity shocks. As laid out above, optimal cooperative money supply management faces a trade-off between targeting the domestic gap between the marginal rate of substituting consumption and labor and the international gap between Home and Foreign marginal consumption utilities. Proposition 5 shows that as long as imperfect international risk sharing is a matter of concern, ie. as long as $\rho \neq 1$ or $0 < \gamma < 1$, both single national monetary authorities unilaterally deviate from the jointly optimal response and thereby from the optimal trade-off. The reason is again that self-oriented policymakers try to rather close the domestic gap to improve the domestic consumption-labor trade-off. In fact, in the non-cooperative Nash equilibrium, authorities set money supply to react more actively to idiosyncratic shocks than it is globally efficient. Hence, from the discussion of the optimal trade-off follows that non-cooperative policymakers attach more value to targeting the domestic gap at the expense of a widening of the international gap. The immediate consequence is that the unilateral deviation "beggars-thy-neighbor".

7 A Numerical Example

A numerical example shall illustrate the quantitative importance of international monetary policy cooperation and evaluate the different welfare implication of the nominal interest rate policy and the money supply management. To keep the comparison to the literature simple, I take parameters values from Obstfeld and Rogoff (2002a): $\sigma_{a_w} = \sigma_{a_d} = 0.01$ and $\nu = 1$. Moreover, two possible trade scenarios are considered: a low-trade scenario ($\gamma = 0.2$) which corresponds to an import over GDP ratio of 10% and high-trade scenario ($\gamma = 0.6$) which corresponds to an import over GDP ratio of 30%.

Table 2
Gains from International Monetary Policy Coordination.

	Low-trade scenario ($\gamma = 0.2$)					High-trade scenario ($\gamma = 0.6$)				
	Different values for ρ					Different values for ρ				
	$\rho = .5$	$\rho = 1$	$\rho = 2$	$\rho = 4$	$\rho = 8$	$\rho = .5$	$\rho = 1$	$\rho = 2$	$\rho = 4$	$\rho = 8$
Welfare Measure (compensating % change in consumption)[a]										
ξ^{R}	1.674	0.537	0.155	0.042	0.011	11.566	5.831	2.378	0.811	0.243
ξ^{M}	0.151	0	0.062	0.158	0.229	0.007	0	0.006	0.019	0.037
ξ	1.827	0.537	0.217	0.200	0.240	11.574	5.831	2.384	0.830	0.280

[a] Following Lucas (1987, 2003), ξ denotes the percentage compensation of consumption so that $U((1+\xi)C^A, L^A) = U(C^B, L^B)$, where A and B are two different policies. Moreover, the decomposition of the equilibrium welfare yields the measure ξ^{R} for the welfare implication of different nominal interest rates and ξ^{M} for different money supply managements.

The gains from international monetary policy coordination are reported in Table 2. For varying values of ρ, three numbers are stated: ξ denotes the necessary percentage increase in consumption so that households are indifferent between international monetary policy coordination and independent policy conduct. By the structure of the model, the overall measure can be further decomposed into ξ^R for nominal interest rate policy and ξ^M for money supply management.

Independent of the degree of openness γ, welfare gains from coordinating the nominal interest rate are decreasing in ρ. For larger values of ρ, the inter-temporal substitution elasticity is decreasing. Consequently, as households attach greater importance to actual consumption, the higher non-cooperative nominal interest rate and hence the intertemporal costs of holding labor income as cash doesn't preponderate too much. Importantly, the gains are, however, increasing in the extend to which the two countries are linked through trade. Clearly, the more important the terms of trade are for domestic households, the more prone are domestic policymakers to manipulate relative nominal goods prices in order to make national residents better off. In contrast, welfare gains from coordinating the money supply management are increasing in absolute deviation of ρ from unity because thereby the consequences of the lack of international risk sharing are more pronounced. Gains are, however, smaller in the high-trade scenario because international consumption risk sharing is achieved to a larger extend through international trade on goods markets and consequently the relative importance of attenuating the lack of international asset markets is decreasing.

Notably, as already indicated by Proposition 1, since the nominal interest rate effects are of first order, welfare gains are of first order. In the high-trade scenario, gains from coordinating the nominal interest rate are up to 4 orders of magnitude larger than gains from coordinating macroeconomic stabilization through money supplies. These results are consistent on the one hand with the broad literature on policy coordination that concentrated on stabilization issues as in Obstfeld and Rogoff (2002a), Pappa (2004), and

Canzoneri et al. (2005), and on the other hand with the very recent considerations of the optimal nominal interest rate policy in open economies in Cooley and Quadrini (2003) and Arseneau (2007).

8 Conclusion

Within the large body of the literature on international monetary policy coordination, the broad consensus is that gains from policy coordination are small if not negligible. This view is corroborated by theoretical considerations that focus on the coordination of international monetary stabilization policies. While all these contributions deserve their very merits for revealing important insights, the finding that the quantitative importance is fairly small is not surprising: stabilization policies target the variability of the allocation and monetary policy focuses on short-run demand side management. They are hence generically of second order. However, to plagiarize Lucas (2003), the "*potential for welfare gains from better long-run, supply side policies exceeds by far the potential from further improvements in short-run demand management*".

The contribution of the present paper is to take up this proposition and introduce it into the context of international monetary policy coordination. The arguments made are formalized within a simple dynamic stochastic two-country model with preset wages and cash-in-advance restrictions. In this environment, monetary authorities can manipulate the terms of trade by conducting a general short-run monetary policy using both the nominal interest rate and the money supply. On the one hand, money supply affects the allocation and the terms of trade ex post by altering relative nominal spending and thereby the nominal exchange rate. In this respect, monetary policy is used in the traditional way so as to stabilize macroeconomic fluctuations by fine tuning spending flows. On the other hand, the nominal interest rate affects the allocation and the terms of trade ex ante by altering the households' wage setting conditions and thereby goods prices. In this respect, monetary policy changes the incentives to work and might cause inefficiencies on the supply side. It is demonstrated that the resulting welfare implications of nominal interest rate policy are of first order whereas the welfare implications of money supply management are of second order.

The important consequence - and the central message of this analysis - is that gains from coordinating money supply management are generically of second order if they focus on stabilization issues. In contrast, gains from preventing excessively high nominal interest rates resulting from self-interested strategic manipulations of the terms of trade are of first order and hence expected to be of higher orders of magnitude. A numerical example of the simple model already indicates that welfare gains from globally optimal monetary policy conduct might be substantial. The present analysis of a more general monetary policy conduct in interdependent economies hence leads to the conclusion that gains from policy coordination might have been to a large extend underestimated.

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