Optimal Monetary Policy Under Global and Sectoral Shocks: Is International Monetary Cooperation Beneficial?[*]

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Abstract

A stochastic general-equilibrium model is employed to explore the welfare effects of optimal monetary policy and the potential benefits of policy coordination. Cross-country perfectly symmetric shocks in the traded goods sectors and imperfectly correlated shocks in the non-traded goods sectors are considered. In this set-up, monetary policy may not be able to achieve efficient sectoral resource allocations within countries and avoid inefficient relative price changes across countries. Welfare gains from coordination are sizeable if the shocks to the traded and non-traded goods sectors are negatively correlated and both sectors are of roughly equal size.

1 Introduction

Should monetary policy have an international dimension? Are there welfare gains to be realized through an international coordination of monetary policies? These questions belong to the "classical" issues in international monetary economics. In an interdependent world where policy actions in one country spill over to other countries welfare gains from coordination and an international dimension of optimal monetary policy potentially arise. Classic contributions to these issues are from Hamada (1976), Canzoneri and Henderson (1991) and Oudiz and Sachs (1984). Their main finding was that international policy coordination in response to symmetric (global) and asymmetric shocks is welfare-improving. National monetary policy creates spill-over effects that can be offset in a coordinated policy regime. This conventional wisdom has been challenged in recent years. Obstfeld and Rogoff (2002) argue that the benefits from an international coordination of policies are negligible at best and might even completely disappear. Countries should instead pursue purely inward-looking policies. The international coordination of policies seems to lose its appeal, even theoretically.[1] This conclusion has given rise to a considerable debate concerning the optimal international dimension of monetary policy.[2]

In this paper, a stochastic general-equilibrium model of the New Open Economy Macroeconomics type with monopolistic competition and price stickiness is employed to investigate the welfare effects of optimal monetary policy and the potential benefits of policy coordination. The model considers a combination of global and country-specific sectoral shocks. The tradeable sectors of both economies are hit by global shocks while shocks in the non-tradeable sectors are country-specific and are only imperfectly correlated with one another (and with shocks in the tradeable sectors). A monetary response to one type of shock alters both the resource allocation between sectors within a country and the resource allocation across countries. But this is generally not efficient.[3] Consider, e.g., a productivity shock in the home non-traded goods sector. Such a shock calls for a reallocation of resources between the home traded goods and the home non-traded goods sector but for the relative price between home and foreign tradeables to remain constant. Both goals, however, cannot be achieved simultaneously by a monetary adjust-

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[1]Empirically, the benefits of policy coordination have always been questioned, see, e.g., McKibbin (1997).

[2]In subsequent work, models were presented in which the gains from policy coordination may be non-trivial (see, e.g., Canzoneri et al. (2002b), Pappa (2002) and Sutherland (2002c)).

[3]See also Tille (2002).

ment since a change in the monetary stance in one country will affect the exchange rate and thus international relative prices. The resulting misallocation of resources may give rise to considerable economic costs or, to put it in other words, to potentially high welfare gains of policy coordination. The model departs from the usual approach found in large parts of the literature in some details. Most of the open-economy stochastic general-equilibrium models assume a unitary elasticity of substitution between home and foreign tradeable goods implying constant expenditure shares in tradeable consumption.[4] We, however, consider a more general preference specification over tradeable goods since the assumption of a unitary elasticity seems overly restrictive.[5] Sutherland (2002c) shows that the welfare gains from coordination crucially depend on the degree of cross-country substitutability between goods.[6] In addition, assuming a unitary elasticity between home and foreign tradeable goods (in combination with a suitable representation of the consumption preferences) automatically generates full risk-sharing in consumption (see the contributions cited above). This modeling approach thus replicates the solution with complete financial markets. Obstfeld and Rogoff (2002), however, argue that introducing complete asset markets into a model with price stickiness makes it necessary to give a coherent account of why state-contingent contracts between consumers but not between consumers and producers can be signed. We follow them in assuming that financial markets do not exist. Sutherland (2002c) explicitly explores the role of the financial market structure for the welfare results of policy coordination and concludes that the gains to coordination can be much higher under complete markets that provide full risk-sharing than under financial autarky (i.e. without financial markets). Hence, our results can be understood as giving a lower limit to the welfare gains of coordination.

In contrast to many other contributions to the literature, our model shows that significant welfare gains from coordination can be realized in a relatively simple set-up and without considering financial markets. Key for the welfare benefit of coordination

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[4]A non-exhaustive list comprises Canzoneri et al. (2002b), Clarida et al. (2002), Devereux and Engel (2003), Corsetti and Pesenti (2001a), Corsetti and Pesenti (2002), Corsetti and Dedola (2002), Obstfeld and Rogoff (1998), Obstfeld and Rogoff (2000), Obstfeld and Rogoff (2002) and Sutherland (2002b), Sutherland (2002a).

[5]This is also done by Sutherland (2002c), Benigno and Benigno (2003a), Benigno and Benigno (2003b) and Tille (2002).

[6]The assumption of a non-unitary cross-country substitution elasticity also creates some methodological problems. It requires a solution method based on second-order approximations which has only recently been developed (see the work of Sims (2000) and Sutherland (2002d)). The derivation of explicit welfare solutions in the coordinated and the uncoordinated policy regimes is now possible.

are the sectoral correlation of shocks, the relative size of the economies' tradeable and non-tradeable sector and the cross-country elasticity of substitution. Intuitively, the welfare gains are largest if the shocks to the traded and the non-traded goods sector are negatively correlated while they are comparatively small in magnitude for uncorrelated shocks and negligible if shocks are positively correlated across sectors. Moreover, spill-overs due to the sectoral correlation of shocks are only sizeable if both sectors are of roughly equal size. If, however, one sector predominates the sectoral structure of the economy quite strongly, the welfare gains from coordination become negligible. Certain combinations of the model's key parameters allow for a replication of some important results previously derived in the literature.

The remainder of the paper is structured as follows. The model is developed in the next section. In section 3, the optimal uncoordinated and coordinated monetary policy are derived and the welfare gains from coordination are discussed. The welfare effects and stabilization gains from coordination in absolute and relative terms are numerically analyzed in section 4. Section 5 concludes.

2 The Model

The world economy consists of two equally sized countries inhabited by a continuum of households of the yeoman-farmer type. Households over the [0,1] interval live in the home country, while households in the [1,2] interval are residents of the foreign country. Analogously, goods over the [0,1] interval are produced in the home country while goods in the [1,2] interval are produced in the foreign country. In the following sections, the equations for the representative home household are presented while the equations for the representative foreign household are omitted most of the time. Generally, mirror images hold for the foreign country.

We abstract from dynamic aspects by considering a single period model. This assumption is clearly restrictive since the intertemporal effects of monetary policy have been thoroughly analyzed in the recent literature.[7] But neglecting intertemporal dynamics is a common approach in models of the New Open Economy Macroeconomics type with uncertainty to simplify the analysis of optimal monetary policy. It is common practice in the literature to ignore dynamics either by explicitly focusing on a single period (see,

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[7]See Obstfeld and Rogoff (1995), Obstfeld and Rogoff (1996) and Corsetti and Pesenti (2001b).

e.g., Obstfeld and Rogoff (2000), Obstfeld and Rogoff (2002) and Sutherland (2002c))
or by choosing suitable functional representations of the consumption preferences and
the structure of financial markets (see, e.g., Clarida et al. (2002), Corsetti and Pesenti
(2001a) and Devereux and Engel (2003)).

2.1 Preferences

The utility of the representative home household is given by

$$(1) \qquad U = E\left[\log C + \chi \log \frac{M}{P} - \kappa\left(K_T y_H(z) + K_N y_N(z)\right)\right], \ \ \chi, \kappa > 0.$$

C denotes a consumption index defined below; M denotes the domestic money stock, P is
the consumer price index (also defined below) and y_i is the output of consumption good z
in sector $i = H, N$. The subscript "H" ("N") denotes the home tradeable (non-tradeable)
goods sector. (Goods from the foreign country's tradeable goods sector are denoted
by the subscript F, while foreign non-tradeable goods are denoted by the subscript
N^*.) Each household is a monopolistically competitive producer of both a differentiated
tradeable and a differentiated non-tradeable consumption good. Accordingly, households
supply labor services to both consumption goods sectors. The domestic and foreign
production technologies are identical and are linear in hours of work. One unit of labor
input yields one differentiated consumption good. Since work effort is the only input in
the production process in both sectors, the disutility of work can be expressed in terms
of output (third term in brackets on the rhs). E is the rational expectation operator
and K is a log-normally distributed stochastic shock to the labor supply (productivity
shocks) with $E[logK_i] = 0$ and $VAR[logK_i] = \sigma_K^2$, $i = N, T$.[8] For simplicity reasons it is
assumed that the variances of the shocks are identical across countries and sectors. The
subscript "T" denotes a global shock to both (home and foreign) tradeable goods sectors,
while the subscript "N" indicates a shock to the home non-traded goods sector. The
foreign tradeable goods sector is hit by the same shock as the home country, K_T, while the
shock to the foreign N^*-sector, K_N^*, is assumed to be country-specific, $E[logK_{N^*}] = 0$

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[8]The production technology for, e.g., the tradeable sector can be explicitly written as $y_H(z) = K_T^{-1}h$
with h denoting the work effort of the representative household (the production process in the non-
tradeable sector can be formulated equivalently). Rearranging yields the formulation in equation (1).
Shocks $K_i > 0$ with $i = T, N$ hence are negative productivity shocks reducing the quantity of goods
produced with a given labor input.

and $VAR[log K_{N*}] = \sigma_K^2$. I.e. the model considers global as well as country-specific sectoral shocks (see also Tille (2002)).

The consumption index is defined as:

$$(2) \qquad\qquad C = \lambda \, (C_T)^t \, (C_N)^{1-t}$$

where $\lambda = t^{-t}(1-t)^{-(1-t)}$. Home households consume tradeable goods (denoted by the subscript T) and non-tradeables (denoted by the subscript N). The Cobb-Douglas aggregation implies that the substitution elasticity between tradeable and non-tradeable goods is equal to one. The parameter t reflects the relative size of the consumption goods sectors in both economies and can also be interpreted as a measure of the economies' openness.

The basket of tradeable goods, C_T, is a CES aggregate across consumption of tradeable goods produced in Home and Foreign, denoted by C_H and C_F:

$$(3) \qquad\qquad C_T = \left[\left(\frac{1}{2}\right)^{\frac{1}{\theta}} C_H^{\frac{\theta-1}{\theta}} + \left(\frac{1}{2}\right)^{\frac{1}{\theta}} C_F^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

where $\theta > 1$ denotes the elasticity of substitution between home and foreign tradeables. Note that the elasticity of substitution between home and foreign tradeables is higher than that between tradeables and non-tradeables (which is equal to one, see equation (2)). The consumption baskets of home and foreign tradeables, C_H and C_F, are in turn indices of home and foreign differentiated tradeable goods:

$$(4) \qquad C_H = \left(\int_0^1 c_H(z)^{\frac{\varphi-1}{\varphi}} dz \right)^{\frac{\varphi}{\varphi-1}}, \quad C_F = \left(\int_1^2 c_F(z^*)^{\frac{\varphi-1}{\varphi}} dz^* \right)^{\frac{\varphi}{\varphi-1}}.$$

Analogously, the consumption basket of home non-tradeables is defined as

$$(5) \qquad\qquad C_N = \left(\int_0^1 c_N(z)^{\frac{\varphi-1}{\varphi}} dz \right)^{\frac{\varphi}{\varphi-1}}.$$

$c_H(z)$, $c_F(z^*)$ and $c_N(z)$ denote the consumption of a particular brand by a home household. z denotes a home variety, $z \in [0,1]$, and $z^* \in [1,2]$ denotes a foreign variety. Throughout the paper, an asterisk indicates a foreign variable. For simplicity, we assume that the elasticity of substitution between brands, φ, is the same in the tradeable

and the non-tradeable sector. It is further assumed that $\varphi > \theta > 1$. The within-country substitutability is higher than the cross-country substitutability.

2.2 Prices

The consumer price index (CPI), defined as the minimum money expenditure required to purchase one unit of the consumption basket, can be derived as

$$(6) \qquad P \quad = \quad P_T{}^t P_N{}^{1-t}.$$

The price index for tradeables is

$$(7) \qquad P_T = \left[\frac{1}{2} P_H^{1-\theta} + \frac{1}{2} P_F^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

with

$$(8) \qquad P_H = \left(\int_0^1 p_H(z)^{1-\varphi} dz \right)^{\frac{1}{1-\varphi}}, \qquad P_F = \left(\int_1^2 p_F(z^*)^{1-\varphi} dz^* \right)^{\frac{1}{1-\varphi}}.$$

where $p_H(z)$ and $p_F(z^*)$ are the prices of home and foreign tradeables in home currency. The law of one price is assumed to hold, $p_F(z^*) = p_F^*(z^*)S$, where S denotes the exchange rate expressed as the price of foreign currency in home currency. Owing to the existence of non-traded goods purchasing power parity in terms of consumer prices does not hold. But the law of one price for tradeables implies that the price index for tradeables expressed in home currency equals the price index for tradeables in foreign currency adjusted by the exchange rate, $P_T = P_T^*S$.

With $p_N(z)$ denoting the price of a home and a foreign non-tradeable good, the price indexes for non-tradeables are given by:

$$(9) \qquad P_N = \left(\int_0^1 p_N(z)^{1-\varphi} dz \right)^{\frac{1}{1-\varphi}}.$$

2.3 Optimal Choices

Households optimally decide about their (intratemporal) consumption allocation and their money holdings. The representative home household's demands for home trade-

ables ($c_H(z)$), for foreign tradeables ($c_F(z^*)$) and for home non-tradeable goods ($c_N(z)$) are given by

$$(10) \qquad c_H(z) = \left[\frac{p_H(z)}{P_H}\right]^{-\varphi} C_H, \qquad\qquad C_H = \frac{1}{2}t\left[\frac{P_T}{P}\right]^{-1}\left[\frac{P_H}{P_T}\right]^{-\theta} C$$

$$(11) \qquad c_F(z^*) = \left[\frac{p_F(z^*)}{P_F}\right]^{-\varphi} C_F, \qquad\qquad C_F = \frac{1}{2}t\left[\frac{P_T}{P}\right]^{-1}\left[\frac{P_F}{P_T}\right]^{-\theta} C$$

$$(12) \qquad c_N(z) = \left[\frac{p_N(z)}{P_N}\right]^{-\varphi} C_N, \qquad\qquad C_N = (1-t)\left[\frac{P_N}{P}\right]^{-1} C.$$

Foreign demands are

$$(13) \qquad c_F^*(z^*) = \left[\frac{p_F^*(z^*)}{P_F^*}\right]^{-\varphi} C_F^*, \qquad\qquad C_F^* = \frac{1}{2}t\left[\frac{P_T^*}{P^*}\right]^{-1}\left[\frac{P_F^*}{P_T^*}\right]^{-\theta} C^*$$

$$(14) \qquad c_H^*(z) = \left[\frac{p_H^*(z)}{P_H^*}\right]^{-\varphi} C_H^*, \qquad\qquad C_H^* = \frac{1}{2}t\left[\frac{P_T^*}{P^*}\right]^{-1}\left[\frac{P_H^*}{P_T^*}\right]^{-\theta} C^*$$

$$(15) \qquad c_N^*(z^*) = \left[\frac{p_N^*(z^*)}{P_N^*}\right]^{-\varphi} C_N^*, \qquad\qquad C_N^* = (1-t)\left[\frac{P_N^*}{P^*}\right]^{-1} C^*.$$

The aggregate equilibrium conditions for individual goods are $y_H(z) = c_H(z) + c_H^*(z)$, $y_F^*(z^*) = c_F(z^*) + c_F^*(z^*)$, $y_N(z) = c_N(z)$ and $y_N^*(z^*) = c_N^*(z^*)$.

Households' optimal money demand is derived by maximizing their utility function subject to their budget constraint. The budget constraint of the representative home household reads:

$$(16) \qquad M - M_0 = p_H(z)y_H(z) + p_N(z)y_N(z) - PC - PT.$$

M_0 and M are money holdings at the beginning and at the end of the period. T denotes real lump-sum taxes in terms of the consumption index. Any seigniorage revenue is rebated through lump-sum transfers. Since, moreover, government spending is assumed to be zero in each country, the government budget constraint can be formulated as $M - M_0 = -PT$. The first order condition for the optimal money demand implies that money market equilibrium is given if

$$(17) \qquad M = \chi PC.$$

The money supply is set by the central bank by following a monetary rule that may depend on the shocks K_T, K_N and K_{N^*}.

$$(18) \qquad M = M_0 \left(K_T\right)^{\delta_{K_T}} \left(K_N\right)^{\delta_{K_N}} \left(K_{N^*}\right)^{\delta_{K_{N^*}}} .$$

The parameters δ_{K_T}, δ_{K_N} and $\delta_{K_{N^*}}$ are chosen before shocks occur and prices are set. The central bank is able to commit to the rule specified in equation (18).[9]

2.4 Financial Markets and the Current Account

Many models examining optimal monetary policy in open economies assume a unitary elasticity of substitution between home and foreign tradeable goods, i.e. $\theta = 1$ (see footnote (4)). This assumption reduces the role of financial markets. It may even render financial markets redundant if utility is logarithmic in consumption. In this case, it is not necessary to model the asset market because the current account is in balance in all states of the world. Full consumption risk sharing is automatically achieved.[10] If financial markets have to be considered explicitly, the great majority of the literature assumes complete markets that provide full risk sharing.[11] Complete financial markets create further spill-over through the current account that magnify the gains from policy coordination compared to the financial autarky case (Sutherland (2002c)).

In this paper, however, we follow Obstfeld and Rogoff (2002) in assuming that financial markets do not exist for reasons discussed in the Introduction. Hence, our results can be understood as giving a lower limit to the welfare gains of coordination. Since we abstract from financial markets, the current account must balance permanently.

$$(19) \qquad C_H^* P_H = C_F P_F.$$

Nominal imports in home currency must equal the export value in home currency.

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[9]It is common practice in the literature to abstract from problems arising from discretionary policy-making. See, e.g., Sutherland (2002c) and Obstfeld and Rogoff (2002).

[10]If only traded goods and full pass-through are considered, utility need not be logarithmic in consumption.

[11]See, e.g., Benigno and Benigno (2003a), Benigno and Benigno (2003b), and Tille (2002) who consider a non-unitary elasticity of substitution and the papers cited in footnote (4).

2.5 Optimal Price Setting

Households are required to set their prices before shocks have been realized and monetary policy has been set. Prices for a differentiated good are set to maximize utility subject to the budget constraint and the total demand for that good.

$$(20) \qquad P_H = \frac{\kappa\varphi}{\varphi - 1} \frac{E(K_T M/\chi Y_H)}{E(Y_H)}, \quad P_N = \frac{\kappa\varphi}{\varphi - 1} \frac{E(K_N M/\chi Y_N)}{E(Y_N)}$$

$$(21) \qquad P_F^* = \frac{\kappa\varphi}{\varphi - 1} \frac{E(K_T M^*/\chi Y_F^*)}{E(Y_F^*)}, \quad P_N^* = \frac{\kappa\varphi}{\varphi - 1} \frac{E(K_N^* M^*/\chi Y_N^*)}{E(Y_N^*)}.$$

where $\varphi/(\varphi - 1)$ is the mark-up factor reflecting the monopolistic competitive market structure. Note that in equilibrium all households choose the same price so that $p_i(z) = P_i$ and $p_i^*(z^*) = P_i^*$ with $i = H, F, N, N^*$. All prices contain a risk premium that is determined by the second moments of variables of the equations' rhs. Generally, from an ex-post point of view producers would wish for higher prices if the marginal costs (which are equal to $\kappa K_i PC = \kappa K_i M/\chi$ with $i = T, N, N^*$) turned out to be high, while they would like to reduce their price ex-post if their marginal costs turned out to be unexpectedly low. Producers further consider the risks emerging from a correlation between marginal costs and goods demand[12] while setting their prices. An increase in the correlation between producers' marginal costs and goods demand leads producers to demand higher prices ex-ante. The reason is that households' production will turn out to be unexpectedly high (due to an unexpected increase in demand) exactly when their marginal costs (due to an unexpected shock) are also (unexpectedly) high. Both impulses reinforce each other in calling for a higher price. In this case, a suboptimally low price is associated with a large-scale loss of potential profit since the profit margin is suboptimally low precisely when (global) demand for that good is high. Hence, households have an incentive to set higher prices ex-ante. The need to hedge this risk of course declines when the correlation falls.

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[12] Output is of course demand-determined if prices are preset at the levels given in equations (20) and (21).

3 Optimal Monetary Policy and Welfare

3.1 Methodology and Welfare Criterion

Exact closed-form solutions for the model cannot be derived since equation (7) and its counterpart in foreign currency are not linear in logs.[13] Instead, we have to resort to second order approximations around a non-stochastic steady state.[14] The non-stochastic steady state of the model is characterized by $\bar{K}_T = \bar{K}_N = \bar{K}_N^* = 1$ and $\bar{\sigma}_{K_T}^2 = \bar{\sigma}_{K_N}^2 = \bar{\sigma}_{K_{N*}}^2 = 0$. All households then produce and consume the same quantity of goods, $\bar{C} = \bar{Y}_H = \bar{Y}_N = \frac{\varphi - 1}{\kappa \varphi}$ where a bar over a variable indicates a non-stochastic steady state value. All prices and price indexes are equal to $\frac{\kappa \varphi}{\varphi - 1} \bar{M}$.

The home and foreign central banks precommit to monetary policy rules that maximize households' ex-ante welfare. The model's welfare measure is based on the representative household's utility function. Following the standard approach in the literature the utility service of real balances is assumed to be small enough to be neglected. (Formally, it is assumed that χ is infinitesimally small, $\chi \to \infty$. See, e.g., Obstfeld and Rogoff (1995)). It can further be shown that the expected disutility of work is constant (see the Appendix) so that the central bank's objective function can be expressed as

$$(22) \qquad E[W] = E\left[\log C - \frac{\varphi - 1}{\kappa \varphi}\right].$$

Maximizing the expected welfare thus is equal to maximizing expected aggregate consumption. Central banks do not care about the production side of economies.[15]

The model is solved in terms of expected log deviations from the deterministic steady state. Expressing equation (22) in terms of deviations from the deterministic steady state yields the welfare criterion used in the remainder of the paper.

$$(23) \qquad \tilde{W} = E[W] - \bar{W} = E[\hat{C}].$$

Equation (23) shows that determining the deviation of welfare from its non-stochastic

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[13]Solving the model exactly would require a unit elasticity of substitution between home and foreign traded goods. The set-up used in this paper is more general and nests the unit elasticity of substitution case.

[14]See Sutherland (2002d) and Woodford (2001) for a detailed exposition of the solution method. Other papers that rely on second-order approximations are Benigno and Benigno (2003a), Benigno and Benigno (2003b), Sutherland (2002c) and Tille (2002).

[15]The assumption of log-utility of consumption is crucial for this feature of the model.

steady state value, denoted by $\tilde{W}$, requires the calculation of expected log deviations of variables from their deterministic steady state, denoted by hats $\hat{}$.

If, in addition, the money market equilibrium condition in log deviation form is considered, $\hat{C} = \hat{M} - \hat{P}$, equation (23) can be rewritten as

$$(24) \qquad\qquad\qquad \tilde{W} = -E[\hat{P}]$$

since the log deviation form of the money supply rule (18)

$$(25) \qquad\qquad \hat{M} = \delta_{K_T}\hat{K}_T + \delta_{K_N}\hat{K}_N + \delta_{K_{N^*}}\hat{K}_{N^*}$$

implies that $E[\hat{M}] = 0$.

3.2 Monetary Policy Objective and Approximation of Prices

Before the optimal monetary rules for both policy regimes can be derived, the CPI in log deviation form must be derived.

$$(26) \qquad\qquad \hat{P} = t\hat{P}_T + (1-t)\hat{P}_N, \qquad \hat{P}^* = t\hat{P}_T^* + (1-t)\hat{P}_N^*.$$

Second-order approximations of the price index for tradeables (7) and its foreign counterpart are given by[16]

$$(27) \qquad\qquad \hat{P}_T = \frac{1}{2}\hat{P}_H + \frac{1}{2}\left[\hat{P}_F^* + \hat{S}\right] - \frac{1}{8}(\theta - 1)\hat{S}^2 + o^3,$$

$$(28) \qquad\qquad \hat{P}_T^* = \frac{1}{2}\hat{P}_{F^*} + \frac{1}{2}\left[\hat{P}_H - \hat{S}\right] - \frac{1}{8}(\theta - 1)\hat{S}^2 + o^3$$

where terms of order three and above are collected in o^3. Of course, $\hat{P}_T = \hat{P}_T^* + \hat{S}$ holds.

The optimal preset prices in log deviation form, $\hat{P}_H$, $\hat{P}_N$, $\hat{P}_F^*$ and $\hat{P}_N^*$, must also be approximated with the help of a second-order expansion. The following approximations

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[16]The method is laid out in detail in Sutherland (2002d) and in Tille (2002).

hold:

$$(29)\hat{P}_H = \frac{1}{2}E\left[\hat{K}_T + \hat{M}\right]^2 + E\left[\hat{K}_T + \hat{M}\right]\hat{M} + \frac{1}{2}(\theta - 1)E\hat{S}\left[\hat{K}_T + \hat{M}\right] + o^3,$$

$$(30)\hat{P}_F^* = \frac{1}{2}E\left[\hat{K}_T + \hat{M}^*\right]^2 + E\left[\hat{K}_T + \hat{M}^*\right]\hat{M}^* - \frac{1}{2}(\theta - 1)E\hat{S}\left[\hat{K}_T + \hat{M}^*\right] + o^3,$$

$$(31)\hat{P}_N = \frac{1}{2}E\left[\hat{K}_N + \hat{M}\right]^2 + E\left[\hat{K}_N + \hat{M}\right]\hat{M} + o^3,$$

$$(32)\hat{P}_N^* = \frac{1}{2}E\left[\hat{K}_N^* + \hat{M}^*\right]^2 + E\left[\hat{K}_N^* + \hat{M}^*\right]\hat{M}^* + o^3.$$

As discussed above, prices deviate from their non-stochastic steady state level if marginal costs fluctuate around their deterministic values (first term on the rhs of equations (29) to (32)) and/or variations in the marginal costs and in global demand are correlated (second and third terms on the rhs). An increase in the money supply stimulates domestic demand, giving households an incentive to increase prices above their certainty equivalent level if it can be expected that it coincides with high marginal costs. The correlation between marginal costs and foreign demand is captured by the third terms on the rhs of the tradeable goods prices. A depreciation of the exchange rate increases home producers' price competitiveness giving rise to an expenditure switching towards home goods. Again, a positive correlation results in prices that exceed their certainty equivalent level. Thus, while setting prices households aim at hedging the risks that emerge from the correlation of different states of nature with the global demand for their goods. A negative correlation between their marginal costs and global demand leads households to set lower prices ex-ante. States where shocks increase producers' marginal costs and give them an incentive to produce less are now typically states where the demand for households' goods is quite low.

Finally, the exchange rate can be obtained from the current account balance condition (19) while taking account of the optimal prices given in (20) and (21) and the demand equations (11) and (14). In log deviation form, the exchange rate is given by

$$(33) \qquad\qquad \hat{S} = \frac{1}{\theta}\left(\hat{M} - \hat{M}^*\right) + o^2.$$

The monetary rule for Home in equation (25) and its foreign counterpart imply $E\hat{S} = 0$. We restrict ourselves to a first-order approximation (the term o^2 collects all terms of order two and above) because the exchange rate only appears in equations (29) and

(30), where it is multiplied by $(\hat{K}_T + \hat{M})$ and $(\hat{K}_T + \hat{M}^*)$, respectively, and in equations (27) and (28) in the second order. Since the remainder of the model is limited to a second-order approximation (i.e. contains only variables up to order two), only first order terms in the formulation of the exchange rate are relevant. Equation (33) shows that the exchange rate moves inversely with the elasticity of substitution θ. The lower the degree of substitution between home and foreign tradeables is, the weaker does a given change in international relative prices redirect global demand. The exchange rate changes necessary to eliminate a given current account imbalance through a switching in home and foreign expenditure therefore have to increase if θ falls.

Substituting equations (29), (30), (31) and (32) into equations (27), (28) and (26) yields the home and foreign objective functions in dependence on the shocks and the monetary stances in both countries.

(34)
$$\tilde{W} = -\left\{ \frac{1}{4}tE[\hat{K}_T + \hat{M}][\hat{K}_T + 3\hat{M}] + \frac{1}{4}tE[\hat{K}_T + \hat{M}^*][\hat{K}_T + 3\hat{M}^*] - \frac{1}{8}(\theta - 1)E\hat{S}^2 \right.$$
$$\left. + \frac{1}{4}t[(\theta - 1)/\theta]E\hat{S}[\hat{M} - \hat{M}^*] + \frac{1}{2}(1 - t)E[\hat{K}_N + \hat{M}][\hat{K}_N + 3\hat{M}] \right\}.$$

(35)
$$\tilde{W}^* = -\left\{ \frac{1}{4}tE[\hat{K}_T + \hat{M}][\hat{K}_T + 3\hat{M}] + \frac{1}{4}tE[\hat{K}_T + \hat{M}^*][\hat{K}_T + 3\hat{M}^*] - \frac{1}{8}(\theta - 1)E\hat{S}^2 \right.$$
$$\left. + \frac{1}{4}t[(\theta - 1)/\theta]E\hat{S}[\hat{M} - \hat{M}^*] + \frac{1}{2}(1 - t)E[\hat{K}_N^* + \hat{M}^*][\hat{K}_N^* + 3\hat{M}^*] \right\}.$$

The objective functions (34) and (35) show that monetary policy should optimally aim at minimizing the second moments of variables.[17] Home welfare depends negatively on the variances of marginal costs in both home consumption goods sectors and on the variance of marginal costs in the foreign tradeable sector. An increase in the variance of marginal costs directly translates into higher prices (see equations (29) - (32)), thus reducing consumption and welfare. Since the domestic consumption basket comprises home and foreign goods the variance of marginal costs of all foreign goods consumed in the home country enters home welfare. The variance of the log deviation of the exchange rate from its non-stochastic steady state value is positively correlated with

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[17]If the expectations operator is passed through the right hand side of both equations, second order terms become second moments of variables.

home households' welfare for reasons stressed by Sutherland (2002c). As long as $\theta > 1$ exchange rate volatility is a welfare benefit because large fluctuations in relative prices strengthen households' purchasing power. By switching expenditure towards goods that turn out to be cheapest ex post, households profit from exchange rate volatility. The strength of this effect of course increases in the degree of substitutability between home and foreign tradeables.[18]

Equations (34) and (35) allow some tentative conclusions to be drawn concerning the international dimension of optimal monetary policy and the potential benefit of policy coordination. Monetary policy clearly cannot deliver the flex-price allocation (which is the constrained pareto-efficient allocation, see the Appendix for details) if shocks differ across sectors (see the in depth analysis of this result by Tille (2002)).[19] Reaching the flex-price result would require monetary policy in both countries to change the resource allocation across sectors according to their country-specific shocks and to keep the relative price of home and foreign tradeable goods constant. This is not possible unless the shocks to both countries' non-tradeable sectors are perfectly symmetric. If, however, t approaches one or zero so that all shocks are country-specific, monetary policy clearly is able to deliver the flex-price outcome. In this case, the optimal monetary policy is purely inward looking. Policymakers are only concerned with domestic shocks and do not care about policies abroad. Monetary policy has no international dimension. This scenario is reminiscent of Obstfeld and Rogoff (2002)'s model, where uncoordinated monetary policy is able to implement the constrained pareto-efficient flex-price result (for a unitary elasticity of intertemporal substitution), since only country-specific shocks are considered. The required adjustment of relative prices between home and foreign goods is achieved through exchange rate changes that are fully passed-through to consumption goods prices.[20] This is the basis for Obstfeld and Rogoff (2002)'s claim that monetary policy should be completely inward looking and have no international dimension at all. An international coordination of monetary policy thus cannot improve upon allocations and is therefore not necessary.

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[18] This effect is reflected in the negative correlation between exchange rate variability ($\hat{S}^2$) and the price index for tradeables; see equations (27) and (28).

[19] See the Appendix for a derivation of the allocation that would be chosen by a benevolent planner and the flex-price allocation.

[20] If a non-unitary elasticity of intertemporal substitution is considered, this result only holds for global shocks.

3.3 Uncoordinated versus Coordinated Optimal Monetary Policy

As mentioned above, monetary policy is conducted by following policy rules. Central banks pre-commit to money supply rules that maximize $\tilde{W}$ and $\tilde{W}^*$. In a Nash solution, the home central bank chooses a rule that maximizes $\tilde{W}$ (conditional on the rule for $\hat{M}^*$) and the foreign central bank chooses a rule that maximizes $\tilde{W}^*$ (conditional on the rule for $\hat{M}$). In a cooperative solution, a single world central bank chooses rules for $\hat{M}$ and $\hat{M}^*$ that maximize world welfare given by $\frac{1}{2}[\tilde{W} + \tilde{W}^*]$.[21] The best outcome monetary policy can achieve under predetermined prices is the constrained pareto-efficient flex-price allocation (Reaching the (unconstrained) pareto-optimum requires the elimination of the monopolistic distortions which, of course, cannot be achieved by monetary adjustments.).[22]

3.3.1 No Coordination (Nash-Solution)

Optimal rules in both policy regimes are chosen by optimally setting the feedback parameters δ_{K_T}, δ_{K_N}, $\delta_{K_{N^*}}$ for the home economy and their counterparts $\delta_{K_T}^*$, $\delta_{K_{N^*}}^*$ and $\delta_{K_N}^*$ for the foreign economy. Playing Nash results in the choice of the following parameters for the home and the foreign policymakers' monetary policy rules:

$$(36) \qquad \delta_{K_T} = \delta_{K_T}^* \quad = \quad -\frac{2t}{3(2-t)},$$

$$(37) \qquad \delta_{K_N} = \delta_{K_{N^*}}^* \quad = \quad -\frac{(1-t)\,[3(2-t)+2A]}{\Phi},$$

$$(38) \qquad \delta_{K_{N^*}} = \delta_{K_N}^* \quad = \quad -\frac{2(1-t)A}{\Phi},$$

where $\Phi = 3(2-t)[\frac{3}{4}(2-t) + A]$ and $A = \frac{1}{2}\frac{t(\theta-1)(2\theta-1)}{2\theta^2}$. Owing to the model's symmetry the policymakers in both countries choose policy rules that are mirror images of each other. The feedback parameters of the home and foreign policy rules show that it is

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[21] The weights attached to the national welfare function could as well be made dependent on the countries' bargaining power which might differ from their relative economic size. We abstract from this issue here.

[22] See the appendix for a derivation of the constrained pareto-efficient flex-price allocation. Benigno and Benigno (2003b) have shown that the flex-price allocation is not necessarily constrained pareto-efficient. Under certain circumstances it may not be optimal for the single world central bank to replicate the flex-price allocation but to maintain some sticky-price distortions (see Obstfeld and Rogoff (2002) as well). The conditions under which it is optimal for central banks acting uncoordinated to replicate the flex-price allocation are even more restrictive.

optimal to contract the money supply when the economy is directly hit by a shock. But policymakers also react when the neighboring country's non-tradeable goods sector is hit by a shock. Consider the case of, e.g., shocks to the home economy. Positive shocks $\hat{K}_T > 0$ and $\hat{K}_N > 0$ raise households' (ex-post) marginal costs (their work effort), thus reducing the supply of goods. If prices were flexible, households would increase their prices one to one with the productivity shocks (thereby depressing goods demand) to compensate for the increase in marginal costs (see equation (55) in the Appendix). Hence, the mark-up over prices (households' profit margin) would remain constant. If prices are predetermined, however, a shock that raises marginal costs reduces the price mark-up ex-post. The money supply now has to be adjusted. Here, a monetary contraction is required to stabilize marginal costs and thus the mark-up.

Both policymakers do not only react to shocks hitting their countries but also respond to country-specific shocks in their neighbor countries as long as the economies are open and thus economic interdependencies exist ($t > 0$). The foreign policymaker's monetary policy response to its country-specific shock not only affects the allocation across Foreign's consumption goods sectors but also changes the relative prices between home and foreign tradeables and therefore creates spill-over effects. A shock to the neighboring country's non-tradeable sector will therefore not only provoke a policy reaction in the foreign country but also induce a policy response in the home country. The resulting exchange rate fluctuations lead to inefficient price changes (see also Tille (2002)). Consider, e.g., a shock to the foreign non-tradeable goods sector, $\hat{K}_N^* > 0$. The foreign policymakers responds by contracting the foreign money supply for the same reasons as discussed above. The resulting exchange rate depreciation shifts labor effort from foreign to home households. But as long as the home economy is not hit by a productivity shock home households' socially efficient level of work effort does not change. The optimal policy reaction therefore is a contraction of the home money supply to offset the foreign spill-overs. In the presence of these policy spill-overs, an international coordination of monetary policies may be welfare improving.[23]

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[23]This clearly distinguishes this paper from other work in this field in which the (uncoordinated) Nash solution may be able to replicate the flex-price solution (see, e.g., Obstfeld and Rogoff (2002) and Corsetti and Pesenti (2001a). Hence, in these papers there is no role for international policy coordination. In this paper, however, international policy coordination might be welfare improving for the reasons emphasized by Tille (2002).

In the Nash regime the optimal monetary policy yields the following welfare:

(39)

$$
\begin{aligned}
\tilde{W} = & -\left(\frac{1}{2} - \frac{2t^2(3-2t)}{3(2-t)^2} - 4(1-t)^2 \frac{3(1-t)(A^2 + \frac{3}{2}(2-t)(A + \frac{3}{4}(2-t)))}{\Phi^2} \right) \sigma_K^2 \\
& + 4(1-t)^2 A \frac{3(1-t)(\frac{3}{2}(2-t) + A)}{\Phi^2} \rho_{K_N,K_{N^*}} \sigma_K^2 \\
& + 4(1-t)t \frac{A(3-2t) + \frac{3}{2}(2-t)(1 - \frac{1}{2}t)}{(2-t)\Phi} \rho_{K_T,K_N} \sigma_K^2 \\
& + 4t(1-t)^2 \frac{\frac{3}{2}(2-t) + A}{(2-t)\Phi} \rho_{K_T,K_{N^*}} \sigma_K^2.
\end{aligned}
$$

The correlation between two kinds of shocks is denoted by ρ_{K_i,K_j} with i and j specifying the shocks, $i = j = T, N, N^*$ and $i \neq j$.

3.3.2 The Gains from Policy Coordination

If monetary policy is internationally coordinated, the single world central bank specifies the home and foreign policy rules by choosing the following set of feedback parameters:

(40)
$$
\delta_{\hat{K}_T}^c = \delta_{\hat{K}_T}^{c^*} = -\frac{2}{3}t
$$

(41)
$$
\delta_{\hat{K}_N}^c = \delta_{\hat{K}_{N^*}}^{c^*} = -\frac{(1-t)\left[\frac{3}{2} + A\right]}{\Psi}
$$

(42)
$$
\delta_{\hat{K}_{N^*}}^c = \delta_{\hat{K}_N}^{c^*} = -\frac{(1-t)A}{\Psi}
$$

where $\Psi = \frac{9}{4} + 3A$. The superscript "c" indicates the cooperative case. The welfare yielded by a coordinated monetary policy for the home economy can then be derived as:

(43)
$$
\begin{aligned}
\tilde{W}^c = & -\left(\frac{1}{2} - \frac{2}{3}t^2 - 3(1-t)^2 \frac{\frac{9}{8} + A(\frac{9}{4} + A)}{\Psi^2} \right) \sigma_K^2 \\
& + 3(1-t)^2 \frac{A + \frac{3}{4}}{\Psi^2} \rho_{K_N,K_{N^*}} \sigma_K^2 \\
& + t(1-t) \frac{(4A + \frac{3}{2}(1+t))}{\Psi} \rho_{K_T,K_N} \sigma_K^2 \\
& + \frac{3}{2} \frac{t(1-t)^2}{\Psi} \rho_{K_T,K_{N^*}} \sigma_K^2.
\end{aligned}
$$

The spill-over effects of monetary policy discussed above clearly imply that there are potential welfare gains to be realized if monetary policy is conducted in a coordinated regime, i.e. by a world central bank. The magnitude of the welfare gains from coordination crucially depend on the correlation of the shocks to the tradeable and the non-tradeable sector. As discussed above, the policy response to a shock in, e.g., the home non-tradeable sector not only alters the resource allocation between the home country's sectors as required but also changes the relative price between home and foreign tradeables, which is inefficient. Analogously, a shock to both countries' tradeable sectors calls for change in both economies' sectoral resource allocation but an unchanged relative price of tradeable goods. This will generally not be achieved, since both countries' non-traded goods sectors are hit by country-specific shocks which, unless perfectly symmetric, call for different policy reactions. Hence, intuitively, the welfare gains from coordination increase if the correlation between shocks to the tradeable and the non-tradeable sectors falls. A necessary precondition for the welfare gains from coordination to arise is that t is neither equal to zero nor to one. If this is the case, the welfare gains of policy coordination vanish completely. The Nash solution and the constrained pareto-efficient flex-price solution then coincide as in Obstfeld and Rogoff (2002) and in Corsetti and Pesenti (2001a) (see also the discussion in Canzoneri et al. (2002b)). The parameter for the monetary policy rule chosen when playing Nash (equations (36) - (38)) and those chosen under coordination (equations (40) - (42)) then coincide.

4 The Correlation of Shocks and the Gains from Coordination

The welfare gains of coordinated policy over the Nash solution will be analyzed in greater detail with the help of some numerical simulations. Since the correlation of the sectoral shocks is at center stage for the welfare gains from coordination in this paper, several scenarios are considered. First, a no-correlation scenario is considered. The correlation of shocks to the consumption goods sectors is assumed to be zero, i.e. $\rho_{K_T,K_N} = \rho_{K_T,K_{N^*}} = 0$. Second, a negative correlation between shocks in the tradeable and the non-tradeable sector is assumed, $\rho_{\hat{K}_T,\hat{K}_N} = \rho_{\hat{K}_T,\hat{K}_{N^*}} = -0.85$. Finally, the case of a positive correlation is examined, $\rho_{\hat{K}_T,\hat{K}_N} = \rho_{\hat{K}_T,\hat{K}_{N^*}} = 0.85$. To sharpen the results, the correlation between both non-tradeable sector shocks is always set equal to zero, i.e. $\rho_{\hat{K}_N,\hat{K}_{N^*}} = 0$.

Other parameter values are taken from the literature (see Chari et al. (2002), Obstfeld and Rogoff (2002) and Sutherland (2002c)). The variance of the shocks is $\sigma_{\hat{K}}^2 = 0.01$

and the parameter t is set equal to 0.6. There is no consensus in the literature on the substitution elasticity between home and foreign goods. Benigno and Benigno (2003a) and Obstfeld and Rogoff (2002) suggest the range between three and six for the cross-country elasticity of substitution, while it is estimated to lie between one and two by Backus et al. (1994) and by Chari et al. (2002), and Pesenti (2002) even views a unit elasticity as empirically warranted. We consider a range between one and eight for θ. Table (1) and Table (2) report the figures for alternative values of the cross-country elasticity of substitution θ.

θ	1	2	4	6	8
$\tilde{W}^c - \tilde{W}$	0.039	0.040	0.041	0.041	0.041
$\frac{(\tilde{W}^c - \tilde{W})*100}{\tilde{W}^c - \tilde{W}^M}$	11.3%	11.85%	12.15%	12.24%	12.29%
$\frac{(\tilde{W}^M - \tilde{W})*100}{\tilde{W}^M}$	61.50%	59.89%	58.96%	58.67%	58.50%
$\frac{(\tilde{W}^M - \tilde{W}^c)*100}{\tilde{W}^M}$	69.33%	67.94%	67.12%	66.84%	66.70%

Table 1: Welfare Gain from Coordination in the No-Correlation Scenario

θ	1	2	4	6	8
$\tilde{W}^c - \tilde{W}$	0.072	0.074	0.074	0.074	0.074
$\frac{(\tilde{W}^c - \tilde{W})*100}{\tilde{W}^c - \tilde{W}^M}$	97.08%	108.63%	116.50%	119.34%	120.79%
$\frac{(\tilde{W}^M - \tilde{W})*100}{\tilde{W}^M}$	0.44%	-1.17%	-2.10%	-2.41%	-2.56%
$\frac{(\tilde{W}^M - \tilde{W}^c)*100}{\tilde{W}^M}$	14.93%	13.54%	12.72%	12.44%	12.30%

Table 2: Welfare Gain from Coordination in the Negative-Correlation Scenario

θ	1	2	4	6	8
$\tilde{W}^c - \tilde{W}$	0.0059	0.0069	0.0075	0.0076	0.0077
$\frac{(\tilde{W}^c - \tilde{W})*100}{\tilde{W}^c - \tilde{W}^M}$	0.95%	1.13%	1.23%	1.25%	1.27%
$\frac{(\tilde{W}^M - \tilde{W})*100}{\tilde{W}^M}$	122.56%	120.95%	120.02%	119.72%	119.57%
$\frac{(\tilde{W}^M - \tilde{W}^c)*100}{\tilde{W}^M}$	123.73%	122.34%	121.52%	121.24%	121.10%

Table 3: Welfare Gain from Coordination in the Positive-Correlation Scenario

The first row in both tables gives the welfare gain of the optimal coordinated policy (denoted by $\tilde{W}^c$) relative to the optimal uncoordinated (Nash) monetary policy (denoted by $\tilde{W}$). $\tilde{W}^M$ denotes a policy of holding the money supplies constant, i.e. not reacting at all to shocks which is equivalent to a monetary targeting regime. The ratio in row 2, introduced by Sutherland (2002c), gives the welfare gain from coordination relative to the welfare that can be achieved by moving from the no-response policy to the optimal coordinated policy. This ratio can be interpreted as reflecting the welfare gain from coordination relative to the maximal overall stabilization gain.[24] The ratios in rows 3 and 4 document the welfare loss that can be avoided by giving up an inactive policy in favor of the optimal uncoordinated (row 3) and in favor of the optimal coordinated (row 4) active policy.[25]

For reasons stressed above, the welfare gains from coordination are highest if the sectoral shocks are negatively correlated while the welfare gains from coordination are quite small if shocks are not correlated across sectors, or are even negligible if the correlation is close to one. In the no-correlation and the positive correlation scenario, moving from an optimal uncoordinated policy to an optimal coordinated policy accounts for only comparatively small fractions of the maximal overall stabilization gain that can be achieved by pursuing active monetary policies (see row 2 in Table 1 and 3). In the no-correlation case, this figure always is about 12%. If a positive correlation of shocks across sectors is assumed, the stabilization gain from coordination is barely noticeable (being around 1%). In terms of stabilization gains, coordinating policies hardly has any benefit at all.

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[24] A related ratio was introduced by Obstfeld and Rogoff (2002).

[25] Canzoneri et al. (2002a) suggest these ratios.

The figures reported in rows 3 and 4 of Tables 1 and 3 show that an active stabilization policy is able to eliminate a large share of the welfare loss that arises when monetary policy is inactive.[26] But the figures also show that the additional gain of coordinating policies is quite small. In the no-correlation scenario, coordinating policies leads to further welfare gains that only amount to roughly 13% and 15% of the gain that is achieved by giving up the inactive policy and switching to the Nash policy (difference between rows 3 and 4 for a given value of θ in relation to row 3). Table 3 shows that the additional welfare gain yielded by policy coordination is quantitatively negligible when the sectoral correlation of shocks is positive. The welfare results yielded by the optimal uncoordinated and by the optimal coordinated policy are nearly the same. Hence, the benefit of moving from the optimal Nash policy to the optimal coordinated policy in both the no-correlation and the positive correlation scenario are clearly dwarfed by the potential gains associated with giving up a passive policy in favor of a policy that allows for an active stabilization of shocks.

The picture changes if sectoral shocks are negatively correlated (see Table 2). The optimal active policies are now only able to offset a by far smaller fraction of the welfare loss under passive policy (rows 3 and 4). Pursuing Nash policies may even cause larger welfare losses than not reacting at all to shocks. For a relatively high substitutability of home and foreign tradeables in particular, refraining from an active policy response to shocks is superior in welfare terms.

But now the additional welfare gain from coordination is sizeable. The optimal coordinated policy is able to close the utility gap between the no-response solution and the active policy by roughly 12.5% to 15%, while the Nash policy is welfare inferior to the passive policy except for the case $\theta = 1$ (see row 4). The welfare difference between the optimal coordinated and the optimal uncoordinated policy becomes visible in particular if it is expressed in relative terms. In relation to the welfare results of the optimal uncoordinated regime, there is a huge benefit of moving from playing Nash to adopting a coordinated policy approach (difference between rows 3 and 4 in relation to the results in row 3). This is confirmed by the figures reported in the second row. By coordinating policies, policymakers are able to reap almost completely the maximal stabilization gain that can be achieved by an active policy.[27] Giving up an inactive policy in favor of an

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[26]In the case of a positive sectoral correlation of shocks an active policy is even able to eliminate the welfare loss of an inactive stabilization policy completely.

[27]Figures above 100% are possible of course since monetary targeting may be superior to the optimal

optimal stabilization of shocks now accounts only for a negligible share of the overall stabilization gain associated with pursuing active policies. As opposed to the scenarios discussed above, there is now a huge benefit to coordination, while the welfare benefit of adopting an active policy is not unambiguous. Switching from an inactive policy to the optimal uncoordinated policy may be detrimental.

No gain from coordination at all emerges for a special parameter combination. If all shocks are perfectly correlated with one another, i.e. $\rho_{K_T, K_N} = \rho_{K_T, K_{N^*}} = \rho_{\hat{K}_N, \hat{K}_{N^*}} = 1$ the Nash and the coordinated solution coincide. All shocks are now effectively global shocks that have no sectoral component.

In all tables, the welfare gain from coordination increase in θ (see the first rows in all tables) since θ determines the strength of the expenditure switching effect of exchange rate changes.[28] Thus, the degree of substitutability between home and foreign tradeables is an important determinant of the spill-over effects of monetary policy and affects the reallocation of resources in the aftermath of shocks. The welfare gains from policy coordination also vary in dependence on the parameter t. The largest gains to coordination arise for intermediate values of t (see figure 1 in the Appendix). In the case of a shock to the home non-traded goods sector discussed above, the spill-over effects to the traded goods sector are only sizeable if the non-traded goods sector is non-negligible in size, and they only lead to a serious misallocation of resources if the traded goods sector is non-negligible in size. If, however, one sector predominates strongly, the spill-over effects arising from less than perfect sectoral correlation of shocks are of the second-order. The misallocation of resources that monetary policy may bring about gives rise to minor economic costs only or, to put it in other words, the potential welfare gains of policy coordination are negligible. If t is equal to zero or one so that one sector vanishes completely, the Nash solution replicates the flex-price solution. In this case, the policymakers have a sufficient number of policy instruments to produce the constrained pareto-efficient solution without coordination.

The gains from coordination can become quite large, at least in relative terms in our model even though no financial markets exist in the model. This may be surprising in the light of the results from Sutherland (2002c) who shows that the coordination gains are quantitatively small if no financial markets exist. In his model, these gains only become considerably large if complete financial markets that provide full risk-sharing are

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uncoordinated policy.

[28]See also Sutherland (2002c) and Benigno and Benigno (2003a).

assumed. But, in contrast to our model, Sutherland (2002c) only considers economies made up of a single sector. Hence, spill-over effects of monetary policy that are based on the imperfect correlation of sectoral shocks and that are at center stage in our model, are absent in his.

5 Conclusion

Based on the model developed in this paper, the answers to the questions posed in the Introduction are: For a wide range of parameter values national monetary policies should not be purely inward-looking but optimally respond to economic developments abroad. Moreover, considerable welfare gains could be realized from an international coordination of monetary policies. The key element of the model that gives rise to these results is the consideration of global sectoral and imperfectly correlated country-specific sectoral shocks. Both country-specific shocks to the non-traded goods sector and global shocks to the traded goods sector leave monetary policy with the task of bringing about an optimal reallocation of resources across consumption goods sectors within a country, but leaving international prices unchanged. But monetary policy cannot deliver both. Hence, spill-over effects are created that give rise to potentially high welfare gains of policy coordination.

Numerical simulations of the model show that the welfare effects from coordination can be sizeable for certain parameter settings. The correlation of shocks, the elasticity of substitution between home and foreign goods, as well as the relative size of the consumption goods sectors play an important role in determining the benefits of policy coordination.

The model abstracted from financial markets due to the reasons stressed by Obstfeld and Rogoff (2002). In the light of the results by Sutherland (2002c), the welfare gain from coordination under financial autarky can be regarded as a lower limit. Hence, in future research it would be interesting to explore how an intermediate financial market structure (i.e. financial markets that offer less than full risk sharing) influences the model's results.

Appendix

Derivation of the Welfare Function (22)

The proof can be found in Sutherland (2002b) (see also, e.g., Corsetti and Pesenti (2001a), Canzoneri et al. (2002b), Sutherland (2002a), and Tille (2002)). Hence, we will restrict ourselves to sketching the main idea only. We start with a reformulation of the optimal price setting conditions:

$$(44) \qquad E\left\{\frac{P_H(z)Y_H(z)}{PC}\right\} = \frac{\kappa\varphi}{\varphi-1}E\left\{K_T y_H(z)\right\}$$

$$E\left\{\frac{P_N(z)Y_N(z)}{PC}\right\} = \frac{\kappa\varphi}{\varphi-1}E\left\{K_N y_N(z)\right\}$$

The individual and the governmental budget constraint are now combined to get $PC = P_H(z)y_H(z) + P_N(z)y_N(z)$. Substituting this result into equation (44) above yields the desired result.

Planner's Allocation and Flex-Price Allocation

In this section, the allocation under flexible prices and the allocation chosen by a benevolent planner are derived. We start by turning to the planner's allocation (see Tille (2002)). A central planner aims at maximizing a weighted average of home and foreign welfare with the weights reflecting the relative country size. The planner allocates the same level of consumption to home and foreign households, $C = C^*$. The planner maximizes

$$logC - \kappa\frac{1}{2}\left(K_T y_H(z) + K_T y_F^*(z^*) + K_N y_N(z) + K_N^* y_N^*(z^*)\right)$$

subject to the market clearing conditions

$$y_H(z) = c_H(z) + c_H^*(z) \qquad\qquad y_N(z) = c_N(z)$$

$$y_F^*(z^*) = c_F^*(z^*) + c_F(z^*) \qquad\qquad y_N^*(z^*) = c_N^*(z^*)$$

with respect to $c_H(z)$, $c_F(z^*)$, $c_N(z)$, $c_F^*(z^*)$, $c_H^*(z)$, and $c_N^*(z^*)$. The first order conditions are

$$(45) \quad \frac{1}{C}\frac{\partial C}{\partial C_T}\frac{\partial C_T}{\partial C_H}\frac{\partial C_H}{\partial c_H(z)} = \frac{1}{C}\frac{\partial C}{\partial C_T}\frac{\partial C_T}{\partial C_F}\frac{\partial C_F}{\partial c_F(z^*)} = \frac{1}{2}\kappa K_T$$

$$(46) \quad \frac{1}{C}\frac{\partial C}{\partial C_N}\frac{\partial C_N}{\partial c_N(z)} = \frac{1}{2}\kappa K_N$$

$$(47) \quad \frac{1}{C}\frac{\partial C}{\partial C_T^*}\frac{\partial C_T^*}{\partial C_F^*}\frac{\partial C_F^*}{\partial c_F^*(z)} = \frac{1}{C}\frac{\partial C}{\partial C_T^*}\frac{\partial C_T^*}{\partial C_H^*}\frac{\partial C_H^*}{\partial c_H^*(z)} = \frac{1}{2}\kappa K_T$$

$$(48) \quad \frac{1}{C}\frac{\partial C}{\partial C_N^*}\frac{\partial C_N^*}{\partial c_N^*(z^*)} = \frac{1}{2}\kappa K_N^*.$$

These conditions can be used to derive the consumption allocation a benevolent planner would choose expressed as relative consumption levels:

$$(49) \quad \frac{C_H}{C_F} = \frac{C_F^*}{C_H^*} = 1$$

$$(50) \quad \frac{C_H}{C_T} = \frac{C_F}{C_T} = \frac{C_F^*}{C_T^*} = \frac{C_H^*}{C_T^*} = \frac{1}{2}$$

$$(51) \quad \frac{C_N}{C_H} = \frac{C_N}{C_F} = 2\frac{K_T}{K_N}$$

$$(52) \quad \frac{C_N^*}{C_F^*} = \frac{C_N^*}{C_H^*} = 2\frac{K_T}{K_N^*}$$

$$(53) \quad \frac{C_N}{C_T} = \frac{K_T}{K_N}$$

$$(54) \quad \frac{C_N^*}{C_T^*} = \frac{K_T}{K_N^*}.$$

The first order conditions imply that the allocation is symmetrical across households, i.e. $c_H(z) = C_H$, $c_H^*(z) = C_H^*$, $c_N(z) = C_N$, $c_F^*(z^*) = C_F^*$, $c_F(z^*) = C_F$ and $c_N^*(z^*) = C_N^*$.

The solution under flexible prices is now derived and compared to the planner's allocation. If households can adjust their prices after shocks have occurred and monetary policy has been set, the solutions for the optimal prices, given in equations (20) and (21), hold ex-post. Thus, we have

$$(55) \quad P_H^{flex} = \frac{\kappa\varphi}{\varphi-1}K_T M^{flex}, \qquad P_N^{flex} = \frac{\kappa\varphi}{\varphi-1}K_N M^{flex}$$

$$(56) \quad P_{F^*}^{flex} = \frac{\kappa\varphi}{\varphi-1}K_T M^{*flex}, \qquad P_{N^*}^{flex} = \frac{\kappa\varphi}{\varphi-1}K_N^* M^{*flex}.$$

where the superscript "flex" indicates flex-price values of variables. Relative prices in the flex-price scenario simply reflect differences in productivity. Plugging these prices into the equations for consumption demand (10) - (15) yields the flex-price allocation. The relative consumption levels are exactly the same as those that would be chosen by a benevolent planner as given in equation (49) - (54). In this model, the flex-price allocation is thus constrained pareto-efficient insofar as it constitutes the first best solution contingent upon the monopolistic distortions (see Obstfeld and Rogoff 2000, 2002).[29] The allocation under flexible prices may therefore serve as a benchmark for the assessment of the welfare effects of monetary policy under preset prices.

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[29]Benigno and Benigno (2003b) have shown that the flex-price allocation is not necessarily constrained pareto-efficient (see footnote (21)). The allocation effects of the monopoly distortion may be offset by a production subsidy. This is considered, e.g., in Woodford (2001), Clarida, Gali and Gertler (2002), Pappa (2002) and Sutherland (2002c).

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