Pricing-to-market, sectoral shocks and gains from monetary cooperation
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* Views expressed are those of the individual author and do not necessarily reflect official positions of De Nederlandsche Bank.
Abstract

Recent literature states that international monetary cooperation results in substantial welfare gains in an environment with imperfectly correlated sectoral shocks and with prices only set in firms’ (domestic) currency. However, empirical studies provide evidence that firms not only set their prices in their own currency, but in foreign currency as well. The question is whether the result of substantial welfare gains due to imperfectly correlated sector-specific shocks applies to the case where firms in the tradable sector apply pricing-to-market, i.e. prices are set in both domestic and foreign currency. This paper finds that this is not the case. For imperfectly correlated sectoral shocks and local currency pricing, welfare benefits of international monetary cooperation are fairly small.

Keywords: nominal rigidities, international cooperation, local currency pricing

JEL classification: E31, E52, F42

1. Introduction

According to the early Keynesian literature, international monetary cooperation is in general beneficial.\(^1\) Canzoneri and Gray (1985), who built on the insights of Hamada (1974, 1976, 1976), showed that with negative monetary spill-overs, the non-cooperation monetary policy rule does not appear to be optimal, in the sense of being too expansionary compared to cooperation. Therefore, international monetary cooperation can be beneficial. Oudiz and Sachs (1984) provide some empirical evidence that the estimated gains from international monetary cooperation vary between 0.5 and 1.0 percent of gross domestic output. However, this first strand of literature is characterized by complete information. By introducing uncertainty, the gains from international monetary cooperation can be even larger, as Ghosh and Masson (1988, 1991, 1994) suggest.

Recent research has challenged the conventional wisdom that international monetary cooperation is beneficial.\(^2\) Obstfeld and Rogoff (2002) were the first to show that international monetary cooperation may only have small or zero welfare gains.

\(^1\)See Tchakarov (2004) for a brief overview of the early literature on international cooperation.

\(^2\)The models used in this research belong to the class of well specified micro-founded general equilibrium models. See Lane (2001) for a survey. These models have two advantages compared to the early literature. Firstly, the macroeconomic relationships and loss functions are not imposed ad hoc. Secondly, they allow for a rigorous welfare analysis of macroeconomic policy under different economic structures.
However, in their analysis Obstfeld and Rogoff (2002) make two important assumptions: a unitary elasticity of substitution between Home and Foreign tradables, and incomplete financial markets. By dropping the assumption of a unitary elasticity of substitution between Home and Foreign tradables and introducing a financial market, Sutherland (2002) shows that welfare gains from monetary cooperation can be substantial. In addition, by introducing imperfectly correlated sector-specific shocks, substantial welfare gains from international monetary cooperation can be found, as is shown by Berger (2005).

A common feature of the studies by Obstfeld and Rogoff (2002), Sutherland (2002) and Berger (2005) is that firms set prices in their domestic currency, which implies a complete exchange rate pass-through on consumer prices. Campa and Goldberg (2002) provide however, compelling evidence for a partial exchange rate pass-through. This evidence suggests that not all firms set their prices in the producers’ domestic currency. Corsetti and Pesenti (2005a) extend Obstfeld and Rogoff’s analysis to the case where firms set their prices in the households’ currency (familiar as local currency pricing, i.e. LCP, or pricing-to-market) instead of their own currency (familiar as producer currency pricing, PCP), and intermediate cases. As in Obstfeld and Rogoff (2002), Corsetti and Pesenti (2005a) do not find substantial welfare gains from international monetary cooperation.

This paper addresses the question whether substantial welfare gains can be found in the case of LCP by introducing imperfectly sector-specific shocks. This paper adjusts the framework presented in Berger (2005) by adopting the LCP assumption instead of the PCP assumption, and subsequently analyses the welfare implications of imperfectly correlated sector-specific shocks. The framework used in this paper differs from Corsetti and Pesenti (2005a) because we assume as in a Berger (2005) a non-tradable sector and allow for imperfectly correlated sector-specific shocks.

We find no substantial welfare gains from monetary cooperation for the case of LCP and imperfect correlated sector-specific shocks. This result is in line with Corsetti and Pesenti (2005a). One of the reasons is that with LCP the traditional pass-through and expenditure switching effects of movements in the exchange rate are absent. Therefore, the elasticity of substitution between tradables which determines the strenght of the pass-through effect, plays no role and does not effect prices and, finally, welfare. Possible negative welfare effects of monetary policy are only transmitted through the price-setting behaviour of firms. Furthermore, Corsetti and Pesenti (2005a) argued that it would be inefficient for a monetary policymaker to adopt an inward-looking monetary policy. The monetary policymaker not only stabilizes the mark-ups of the domestic firms but also the mark-ups of the foreign firms. In this way the monetary policymaker internalise the monetary spill-overs on foreign

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3See Goldberg and Knetter (1997) for an extensive overview of the literature on exchange rate pass-through on consumer pricing.
4Betts and Devereux (2000a, 2000b) analyses the welfare implications of different degrees of exchange rate pass-through in a non-stochastic framework.
exporting firms. The results below suggest that this still holds for the case of LCP and imperfect correlated sector-specific shocks.

The next section (section 2) briefly describes the well-known workhorse to analyse welfare implications from international monetary cooperation. Subsequently, the welfare metric is introduced (section 3.1) and the model is solved for a second order approximation of the optimal prices (section 3.2). Thereafter, the welfare implications of monetary cooperation are discussed (section 3.3 and 3.4). Finally, the last section concludes.

2. Non-tradable goods and pricing-to-market

Following Obstfeld and Rogoff (2000), Sutherland (2002) and Berger (2005), we focus on a single-period stochastic general equilibrium model. Therefore, the analysis below abstracts from the intertemporal effects of monetary spill-overs. Moreover, in contrast to Sutherland (2002), we only focus on the case of financial autarky. The briefly described model below is a simplified and adjusted version of the framework in Corsetti and Pesenti (2005a) because we assume a single period, and introduce a non-tradable sector and imperfectly correlated sector-specific shocks. Each country’s tradable sector is exposed to the same global shocks. The shocks to the non-tradable sector are country specific.

This section only summarises the important building blocks of the well-known two-country workhorse. We will not go into details of international transmission of productivity shocks and monetary policy. See, for instance, Obtfeld and Rogoff (1995, 2000), and Corsetti and Pesenti (2001) on international spill-overs of monetary policy. Furthermore, Corsetti and Pesenti (2005b) provide an extensive discussion of the now quite popular two-country workhorse used below. Their appendix guides the interested reader through the algebra of the underlying model considered in this section.

The world consists of two countries: Home and Foreign. Each country is populated by a unit mass of representative households that are immobile across the two countries. Each country produces a variety of tradable and non-tradable goods. The utility maximizing households’ preferences are defined over a consumption index $C(j)$, real money balances $M(j)/P$, and labour supply $l(j)$: $U(j) = \log C(j) + \chi \log \frac{M(j)}{P} - \kappa l(j)$. These preferences are identical in both countries.

Let $C_T(j)$ and $C_N(j)$ be Home individual’s consumption indices for tradable and non-tradable goods respectively. As in Berger (2005), individual $j$’s consumption index is defined as:

$$C(j) = \frac{C_T(j)\gamma C_N(j)^{1-\gamma}}{\gamma\gamma(1-\gamma)^{1-\gamma}}$$

where $0 < \gamma < 1$ is the size of the tradable sector. The weights $\gamma$ and $1 - \gamma$ are, for simplicity, identical across Home and Foreign. In line with Berger (2005) and
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in contrast with Obstfeld and Rogoff (2002) and Corsetti and Pesenti (2005a), the consumption basket for tradables is defined as a CES aggregate:

\[
C_T(j) = \left( \frac{1}{2} \right)^{\frac{1}{\varphi}} C_H(j)^{\frac{\varphi-1}{\varphi}} + \left( \frac{1}{2} \right)^{\frac{1}{\varphi}} C_F(j)^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}}
\]

where \( \varphi > 1 \) is the elasticity of substitution between Home, \( C_H(j) \), and Foreign, \( C_F(j) \), tradables. Furthermore, as in Berger (2005), we assume no Home bias. Households consume an equal share of Home and Foreign tradables. The implied utility based price index for tradables is then given by:

\[
P_T = \left[ \frac{1}{2} P_{H}^{1-\varphi} + \frac{1}{2} P_{F}^{1-\varphi} \right]^{\frac{1}{1-\varphi}}
\]

where \( P_H \) is the price for Home tradables and \( P_F \) is the price for Foreign tradables.

In both countries firms are profit-maximizing monopolistic competitors. The production technology for firm \( z \) is given by \( Y_z = Z_z l(z) \) where the sector-specific productivity shock \( Z \sim N(1, \sigma_Z^2) \) and \( l(z) \) is the amount of labour used in producing variety \( z \). Nominal rigidities are introduced through the price setting behaviour of monopolistic firms. Firms set their prices one period in advance given their expectations of the next period. Here we assume that the international commodity market is segmented. Households face infinitely high costs in purchasing tradables abroad, but there are no trade barriers for firms. Therefore, export firms are able to set different prices for the Home and the Foreign market, i.e. firms are able to apply pricing-to-market.

As in Devereux and Engel (2003), Obstfeld and Duarte (2004) and Corsetti and Pesenti (2005a), and in contrast with Berger (2005), we assume that in advance of the realizations of shocks each firm sets prices in the local currency and supplies every demand at this price.\(^5\) This implies that the law of one price is violated with any unanticipated fluctuation in the exchange rate. The Home firm that produces tradables, maximizes its expected nominal profits, \( \Pi(h) \), with respect to the home, \( p(h) \), and foreign, \( p^*(h) \), price:

\[
\max_{p(h),p^*(h)} E[\Pi(h)] = E \left\{ [p(h) - MC(h)] \int_0^1 c(h,j) dj \right\} \\
+ E \left\{ [S p^*(h) - MC(h)] \int_0^1 c^*(h,j^*) dj^* \right\}
\]

where \( E \) is the expectation operator, \( MC(h) \) is the marginal cost of labour which is derived as the nominal wage rate divided by the sector specific productivity shock,

\(^5\)It is assumed that the productivity shocks to the tradable and non-tradable sector are not too large such that marginal costs always will be lower than the preset prices: \( p(z) \geq MC(z) \) for \( z = h, f, n \). In other words, the participation constraint for firms is not violated (see Corsetti and Pesenti, 2001, p. 428).
i.e. \( W/Z_h, S \) is the Home price of Foreign currency, \( \int_0^1 c(h, j) \, dj \) and \( \int_0^1 c^*(h, j^*) \, dj^* \) are Home and Foreign aggregate demand for variety \( h \) respectively. Each Home variety is an imperfect substitute for all other Home varieties, with constant elasticity of substitution \( \theta \). For the sake of simplicity, this constant elasticity of substitution is the same in Foreign.

The implied optimal prices of Home’s tradable sector are:

\[
\begin{align*}
(5) & \quad p(h) = P_H = \frac{\theta}{\theta - 1} \frac{E[MC(h)C_H]}{E[C_H]} \\
(6) & \quad p^*(h) = P^*_H = \frac{\theta}{\theta - 1} \frac{E[MC(h)C^*_H]}{E[S_C^*H]} \\
\end{align*}
\]

the optimal prices for Foreign’s tradable sector are:

\[
\begin{align*}
(7) & \quad p^*(f) = P^*_F = \frac{\theta}{\theta - 1} \frac{E[MC(f)C^*_F]}{E[C^*_F]} \\
(8) & \quad p(f) = P_F = \frac{\theta}{\theta - 1} \frac{E[MC(f)C_F]}{E[C_F/S]} \\
\end{align*}
\]

and, for completeness, the optimal prices for Home and Foreign non-tradable sector are:

\[
\begin{align*}
(9) & \quad p(n) = P_N = \frac{\theta}{\theta - 1} \frac{E[MC(n)C_N]}{E[C_N]} \\
(10) & \quad p^*(n^*) = P^*_N = \frac{\theta}{\theta - 1} \frac{E[MC(n^*)C^*_N]}{E[C^*_N]} \\
\end{align*}
\]

In the non-stochastic steady state the law of one price is valid, i.e. \( p(h) = S^* p^*(h) \) and \( p^*(f) = p(f)/S \), and the purchasing power parity holds. Compared to Berger (2005) we have two additional pricing equations, namely equations (6) and (8), because firms not only set prices in the currency of the domestic market but also of the foreign market.

The preset prices contain a risk premium because any unanticipated change in the marginal costs, aggregate demand or exchange rate raises or reduces the ex post mark-up. For example, we can write the optimal domestic price for Home tradables as 
\[
P_H = \frac{\theta}{\theta - 1} \left\{ E[MC(h)] + \frac{\text{Cov}[MC(h), C_H]}{E[C_H]} \right\}.
\]
A higher positive covariance of marginal costs, \( MC(h) \), and aggregate demand for Home tradables, \( C_H \), increases the risk premium, \( \frac{\text{Cov}[MC(h), C_H]}{E[C_H]} \), and therefore increases the local price for Home tradables.

In a similar way, the second-moments at the right-hand side of the other optimal price equations affect the risk premium and the ex ante optimal price. Increased uncertainty about the exchange rate induces Home firms in the tradable sector to set on average a higher Foreign price for Home tradables. In this manner, Home firms can reduce the sensitivity of their profits to exchange rate fluctuations. Monetary policy in both countries can influence these second moments.
3. Welfare analysis of monetary policy

In this section we analyse the welfare implications of various monetary policy strategies such as Nash and cooperation. First, the welfare measure is introduced. Subsequently, the model is solved. Finally, the implications for welfare from the different monetary strategies are analysed. See the appendix for a brief description of the derivations in this section.

3.1. Welfare measure

The framework briefly introduced in section 2 is closed by determining the monetary stance. A change in the monetary stance in one country has spill-over effects in the other country. In the case of LCP, monetary policy results in the following spill-overs: (i) an expenditure level effect and (ii) a terms of trade effect. Given the fixed export and import prices of tradables, there exists no exchange rate pass-through and, hence, no expenditure-switching effect. A Home monetary expansion increases Home aggregate demand and, therefore, the demand for Foreign tradables as well. At the same time, the terms of trade improves, because the exchange rate depreciation improves the profits of Home firms in the tradable sector, but deteriorates the profits of Foreign firms. So to maintain the same level of consumption, Foreign households have to work more. A part of the increase in the aggregate level of Home consumption is, therefore, at the expense of Foreign through a rise in Foreign labour (Corsetti and Pesenti, 2005a).

In the remaining part of this paper, we analyse for the case of LCP whether the inclusion of a non-tradable sector and imperfectly correlated productivity shocks in the economy will result in substantial welfare gains from monetary cooperation. Following the literature, we assume that the monetary policymaker maximizes expected aggregate welfare:

$$E[\Omega] = E \left[ \int_0^1 \left( \log C(j) + \chi \log \frac{M(j)}{P} - \kappa l(j) \right) dj \right]$$

where $M(j)/P$ is the real money balances and $\kappa l(j)$ is the disutility of labour supply, $l(j)$. Following the literature, it is further assumed that utility derived from holding real money balances is infinitely small, i.e. $\chi \rightarrow 0$. Hence, the aggregate welfare metric is reduced to:

$$E[\Omega] = E [\log C - \kappa l]$$

To maximize national welfare monetary authorities commit to a state-contingent monetary policy feedback rule. The feedback rule is $M = M_0 Z_T^{a_1} Z_N^{a_2} Z_N^{a_3}$ in Home and $M^* = M_0^* Z_T^{b_1} Z_N^{b_2} Z_N^{b_3}$ in Foreign.

Policymakers in both countries not only respond to domestic shocks, but also to productivity shocks abroad. If the monetary authorities would pursue an inward
looking policy instead, this could increase the volatility of the nominal exchange rate and, therefore, the mark-ups of exporting firms. An increase in uncertainty about mark-ups can have negative effects on households’ welfare through firms’ price setting behaviour. A higher volatility of the exchange rate induces firms to set higher prices on average because their profits are sensitive to exchange rate fluctuations. As a result of these higher prices consumption and, hence, welfare is reduced. Monetary policy that would neglect spill-over effects on the mark-ups and profits of exporting firms, can only be inefficient then. Therefore, monetary policymakers can improve welfare by taking into account these spill-over effects.

As a result of the CES consumption basket, the model does not have a closed form solution. One way of solving the model is to take a second-order approximation around the non-stochastic steady state. Let $\Delta$ denote the log deviation of variable $X$ from its deterministic steady state, $\Delta = \log X - \log X^\ast$. The monetary policy rules in both countries can then be rewritten as $m = a_1 \Delta T + a_2 \Delta N + a_3 \Delta N^\ast$ and $m^\ast = b_1 \Delta T + b_2 \Delta N^\ast + b_3 \Delta N$. In the non-stochastic steady state it holds that $E[m] = E[m^\ast] = 0$.

Expected welfare in terms of deviations from the non-stochastic steady state for Home (an analogous expression holds for Foreign) is defined as (see the appendix):

$$\Omega = E[p]$$

The optimal monetary policy rule minimizes the expected deviation of the (log) aggregate price index from its (log) steady-state level. Through price stabilization, monetary policy optimizes the aggregate consumption level and, therefore, welfare. The expected disutility of labour drops out of the welfare metric because the expected level of employment is a constant which actually equals the non-stochastic steady-state level of employment (see the appendix).

3.2. Approximations

To solve for the optimal monetary policy rules we approximate the preset prices around their steady state and express these prices in terms of $\Delta T, \Delta N, \Delta N^\ast, \Delta m, \Delta m^\ast,$ and $s$. Subsequently, we substitute these expressions into price indices and, finally, we substitute these price indices into the welfare measure. The second-order ap-

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6Equation (12) corresponds to the policy loss function in terms of consumer prices introduced in Corsetti and Pesenti (2005a, p. 293). As Corsetti and Pesenti (2005a) show, this policy loss function can also be expressed as (i) a function of the expected value of the log average mark-up in the Home market and as (ii) a function of output gaps in Home and Foreign.
proximations of the prices for home and foreign goods are:

\[ p_H = \frac{1}{2} E (m - z_T)^2 + E (m - z_T) m + ||R^3|| \]  
\[ p_H^* = \frac{1}{2} E (m - z_T)^2 + E (m - z_T) m^* - \frac{1}{2} E s^2 - E s m^* + ||R^3|| \]  
\[ p_F = \frac{1}{2} E (m^* - z_T)^2 + E (m^* - z_T) m^* + ||R^3|| \]  
\[ p_F^* = \frac{1}{2} E (m^* - z_T)^2 + E (m^* - z_T) m^* - \frac{1}{2} E s^2 + E s m + ||R^3|| \]

where \( s = m - m^* \). The term \( ||R^3|| \) contains all terms of order three and higher in deviations from the steady state. The second order approximations for the prices of the non-tradables in Home and Foreign are:

\[ p_N = \frac{1}{2} E (m - z_N)^2 + E (m - z_N) m + ||R^3|| \]  
\[ p_N^* = \frac{1}{2} E (m^* - z_N^*)^2 + E (m^* - z_N^*) m^* + ||R^3|| \]

The first and second term on the right hand side of the price equations (13)-(18) reflect the effect of the variance and the covariance on the prices. Finally the approximations of the aggregate price index and the price index for tradables are given by:

\[ p = \gamma p_T + \left(1 - \gamma\right) p_N \quad \text{and} \quad p_T = \frac{1}{2} p_H + \frac{1}{2} p_F. \]

Not surprisingly, we observe two differences with the producer currency pricing equations in Berger (2005). Firstly, the pass-through effect is absent in the price index for tradables. In Berger (2005) the approximation of the price index of tradables is

\[ p_T = \frac{1}{2} p_H + \frac{1}{2} \left( p_F^* + s \right) - \frac{1}{8} (\varphi - 1) s^2 + \frac{||R^3||}{2} \]

where the term \( \frac{1}{8} (\varphi - 1) s^2 \) reflects the exchange rate pass-through on Home’s import prices (remember that with PCP \( p_F^* \) is set ex ante by the foreign firms). Note that the strength of the pass-through effect depends on the elasticity of substitution between home and foreign tradables. An interesting feature of LCP is that even with a CES aggregate consumption basket the elasticity of substitution between tradables and non-tradables, \( \varphi \), drops out of the price index for tradables and, hence, does not have any welfare implications.

Secondly, under producer currency pricing the pass-through effect generates an expenditure switching effect. In Berger (2005) this switching effect can be written as \( +\frac{1}{2} (\varphi - 1) E s (m - z_T) \) in \( p_H \) and \( -\frac{1}{2} (\varphi - 1) E s (m - z_T) \) in \( p_F^* \). For example, a depreciation of the Home currency (all other things equal) makes foreign tradables relatively more expensive to home tradables and, therefore, households will switch from foreign tradables towards home tradables. This effect is absent with LCP in equations (13) and (15).

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7With producer currency pricing the log deviation of the exchange rate is given by \( s = \frac{1}{2} (m - m^*) \). The elasticity of substitution between home and foreign tradables, \( \varphi \), determines the sensitivity of the exchange rate to the relative monetary stance (see Sutherland, 2002, and Berger, 2005).
3.3. Welfare and optimal monetary strategies

Substitution of equations (13) to (18) into equation (12) and its Foreign counterpart gives the welfare metric for Home as a function of shocks, the monetary stance in both countries and the exchange rate:

\[
\Omega = -\frac{1}{4}\gamma E(m - zT)^2 - \frac{1}{2}\gamma E(m - zT) m
- \frac{1}{4}\gamma E(m^* - zT)^2 - \frac{1}{2}\gamma E(m^* - zT) m + \frac{1}{4}\gamma E s^2 - \frac{1}{2}\gamma E s m
\]

\[
-(1 - \gamma)\frac{1}{2}E(m - z_N)^2 - (1 - \gamma)E(m - z_N) m
\]

and a similar welfare expression holds for Foreign:

\[
\Omega^* = -\frac{1}{4}\gamma E(m^* - zT)^2 - \frac{1}{2}\gamma E(m^* - zT) m^*
- \frac{1}{4}\gamma E(m - zT)^2 - \frac{1}{2}\gamma E(m - zT) m^* + \frac{1}{4}\gamma E s^2 + \frac{1}{2}\gamma E s m^*
\]

\[
-(1 - \gamma)\frac{1}{2}E(m^* - z_N)^2 - (1 - \gamma)E(m^* - z_N) m^*
\]

The welfare loss depends negatively on the variances of the marginal costs and the covariances of the marginal costs with demand. We again emphasize that under local currency pricing expected welfare does not depend on the substitution elasticity between home and foreign tradables as is the case under producer currency pricing.

The covariance between the nominal exchange rate and domestic demand, \(E s m\), influences Home’s welfare negatively. If the nominal exchange rate tends to be high (low) when domestic demand is high (low), Foreign firms tend to charge higher price and, hence, Home’s welfare is reduced as a result of lower consumption (\(\partial \Omega / \partial E s m < 0\)). Conversely, if the nominal exchange rate tends to be low (high) when domestic demand is high (low) prices set by Foreign firms tend to be lower, and Home welfare is increased (\(\partial \Omega / \partial E s m > 0\)).

The positive effect of the variance of the exchange rate, \(E s^2\), on welfare may be less clear. Sutherland (2002, p. 19) gives an intuitive explanation for the case with producer currency pricing: “The consumer price index is concave in the price of home and foreign goods. Any volatility in the relative price of home and foreign goods (which would result from exchange rate volatility) will reduce the expected level of aggregate consumer prices. This has a positive effect on utility and welfare. (…) when home and foreign goods are substitutable, agents can reduce the average cost of their consumption basket by switching expenditure towards whichever set of goods are cheapest ex post.” However, this mechanism is not at work under local currency pricing. The reason is that import prices are fixed for one period and will not change as a result of nominal exchange rate fluctuations. Therefore, households cannot ex post reduce their average cost of their consumption basket. How to read this positive effect in the case of LCP is not clear yet.
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Figure 1: Nash feedback parameters.

The welfare metrics in equations (19) and (20) clearly demonstrate that monetary policy has international spill-overs. A shift in Home’s monetary stance affects Foreign export firms’ mark-ups and prices, and Foreign level of employment (and vice versa). Therefore, international monetary cooperation may be desirable. To find out to what extent monetary cooperation is beneficial, we now turn to three strategies monetary authorities can pursue.

As a benchmark, the first strategy is a constant money supply. This implies that the feedback parameters are zero and, hence, \( m = 0 \) in Home and \( m^* = 0 \) in Foreign. Besides the constant money supply strategy the monetary authority can also pursue an active stabilization policy such as Nash or cooperation.

In a Nash equilibrium Home (Foreign) chooses its optimal monetary strategy given the monetary stance in Foreign (Home): \( \min_m \Omega \) and \( \min_m \Omega^* \). The optimal Nash feedback parameters that minimizes the welfare loss are (see the appendix):

\[
\begin{align*}
  a_1^N &= b_1^N = \frac{3\gamma}{6-\gamma} \geq 0 \\
  a_2^N &= b_2^N = \frac{8(\gamma^2 - 4\gamma + 3)}{3(12 - 8\gamma + \gamma^2)} \geq 0 \\
  a_3^N &= b_3^N = \frac{-4\gamma(1-\gamma)}{3(12 - 8\gamma + \gamma^2)} \leq 0
\end{align*}
\]

where \( |a_2^N| = |b_2^N| > |a_3^N| = |b_3^N| \) for \( \gamma \in [0, 1) \). The absolute values of the feedback parameters as a function of \( \gamma \) are plotted in Figure 1. Not surprisingly, as \( \gamma \) increases the monetary policymaker responds stronger to shocks to the tradable sector than to the non-tradable sector.

In Home the policymaker increases the money supply in response to a positive productivity shock to the Home tradable and non-tradable sector, and decreases the money supply in response to a positive productivity shock to the Foreign non-tradable sector. Suppose that Home non-tradable sector is hit by a positive productivity shock. With local currency pricing, Home’s policymaker faces a trade-off between the negative employment gap and consumer prices. The optimal response
to this shock for Home is to increase the money supply. In turn consumption will increase and the employment gap will close. However, the employment gap will not completely close because of the negative spill-overs on Foreign firms’ mark-ups and profits, and, subsequently, on consumer prices of imported goods.

The productivity shock in Home will not only trigger a monetary response in Home but also in Foreign. The exchange rate depreciation as a result of the increase in Home’s money supply, decreases the revenue in Foreign’s currency of each unit sold abroad. This decrease in Foreign firms’ revenues deteriorates Foreign’s terms of trade. To maintain the same consumption level Foreigners have to work more. To offset this positive employment gap, Foreign contracts its money supply. Figure 1 shows, however, that the response on a Foreign country-specific shock is very small compared to the response to a Home country-specific shock. As in Home the Foreign monetary authority will not completely close the employment gap because of the negative spill-overs on the Home firms’ mark-ups and prices. The increase in Home’s consumption comes at the expense of a higher Foreign labour effort and lower Foreign consumption.

The third strategy is monetary cooperation. Under this strategy, a benevolent planner minimizes the global welfare loss, i.e. \( \min_{m, m^*} \left[ \bar{\Omega} + \bar{\Omega}^* \right] \). The optimal policy feedback parameters are now given by:

\[
\begin{align*}
\alpha_1^C &= \beta_1^C = \frac{2\gamma}{3} \geq 0 \\
\alpha_2^C &= \beta_2^C = \frac{2(\gamma^2 - 4\gamma + 3)}{9 - 6\gamma} \geq 0 \\
\alpha_3^C &= \beta_3^C = \frac{-2\gamma(1 - \gamma)}{9 - 6\gamma} \leq 0
\end{align*}
\]

(22) where \(|a_2^C| = |b_2^C| > |a_3^C| = |b_3^C| \) for \( \gamma \in [0, 1) \). The absolute values of the optimal cooperation feedback parameters follow the same pattern as in Figure 1. Figure 2 shows the difference between the absolute values of the optimal feedback parameters under cooperation and Nash. For shocks to the non-tradable sector, the difference in response follow a hump shaped form. For shocks to the tradable sector, a positive difference between the optimal cooperation and Nash feedback parameters remains.

In the Nash as well as in the cooperation equilibrium, monetary policies are strategic substitutes. The sign of the policy response function for both countries is negative, i.e. \( \partial m / \partial m^* < 0 \) and \( \partial m / \partial m^* < 0 \) for \( 0 < \gamma \leq 1 \) (see the appendix). A Foreign monetary expansion results in a domestic monetary contraction. As explained above, the Foreign monetary expansion results in a deterioration of Home’s terms of trade. A part of Foreign’s increase in the aggregate consumption is at the expense of Foreign through a higher level of employment. To offset the negative welfare effects of the increased labour, Home’s optimal response is a money supply contraction such that aggregate demand and the amount of labour is reduced.
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Figure 2: Difference between Nash and cooperation feedback parameters.

Some preliminary welfare conclusions can be drawn from the above derived policy rules when $\gamma = 0$ and $\gamma = 1$. The expected welfare deviations obtained under the constant money supply rule, the optimal Nash rule and the cooperation rule are denoted by $\Omega^M$, $\Omega^N$ and $\Omega^C$ respectively. For $\gamma = 0$, i.e. all goods are non-tradables, there is no monetary interdependence. Policymakers in both countries only respond to country-specific shocks. The optimal feedback parameters are $a^N_2 = b^N_2 = \frac{2}{3}$ and $a^C_2 = b^C_2 = \frac{2}{3}$. The other feedback parameters are zero. The expected welfare deviation from the steady state with Nash and with international cooperation coincide, $\Omega^N = \Omega^C = \frac{1}{6}\sigma^2_{Z_N} > 0$. Monetary cooperation does not yield any welfare gain because there exists no trade linkage between Home and Foreign. Therefore, the monetary stance in one country cannot affect the import prices in the other country. The expected welfare deviation from the steady state given a constant money supply is $\Omega^M = -\frac{1}{2}\sigma^2_{Z_N} < 0$.

For $\gamma = 1$, i.e. all goods are tradables, the optimal feedback parameters for the different monetary strategies are $a^N_1 = b^N_1 = \frac{3}{5}$ and $a^C_1 = b^C_1 = \frac{2}{5}$. The other feedback parameters are zero. Thus, the optimal monetary responses to global shocks in both countries are symmetric. The respective expected welfare deviations are $\Omega^M = -\frac{1}{2}\sigma^2_{Z_T}$, $\Omega^N = \frac{4}{25}\sigma^2_{Z_T}$, and $\Omega^C = \frac{1}{6}\sigma^2_{Z_T}$, which gives a welfare benefit of international cooperation of $\frac{1}{150}\sigma^2_{Z_T}$. This positive welfare deviation is negligible, and is most likely an approximation bias. This result is in line with Corsetti and Pesenti (2005a). They show for the case with only tradables, LCP, and a unitary elasticity of substitution that the welfare gains are zero. The reason is that the optimal monetary policy rules for both countries are symmetric, i.e. both monetary policymakers react the same to the global shocks. As a result the exchange rate does not change and there are no spill-over effects transmitted through the exchange rate. This result can be interpreted as the case for fixed exchange rates as is argued by Devereux and Engel (2003).
3.4. Welfare implications of imperfectly correlated sector-specific shocks

In this section we analyse the impact of different correlations between shocks to the tradable and non-tradable sector on welfare in both countries for $0 < \gamma < 1$. In this case there seems to be scope for monetary cooperation because under Nash the optimal monetary response is asymmetric when shocks to the non-tradable sector are asymmetric. Though the optimal Nash feedback parameters in equation (21) are the same, the shocks to the non-tradable sector in both countries are not the same. As a result, the optimal monetary response in Home and Foreign is not necessarily symmetric and, therefore, can result in spillovers through changes in the exchange rate.

In the quantitative analysis bellow we follow Chari et al. (2002), Obstfeld and Rogoff (2002), Sutherland (2002) and Berger (2005) and set the variance of all the productivity shocks equal to 1%. In addition, we assume that the correlation between shocks to the tradable and non-tradable sector are the same in both countries, i.e. $\rho_{T,N} = \rho_{T,N^*}$.

Several measures exist to quantify the welfare gains from international monetary cooperation. Sutherland (2002) has introduced the following ratio, $G_R = \frac{\bar{\Omega}_C - \bar{\Omega}_N}{\bar{\Omega}_C - \bar{\Omega}_M} \times 100$. This ratio reflects the additional stabilization gain from cooperation with respect to Nash compared to the total stabilization gain. In Figures 3 and 4 the relative welfare gain from moving from Nash to cooperation is shown for different values for $\rho_{T,N} = \rho_{T,N^*}$, the share of tradables in total consumption $\gamma$, and the correlation coefficient between the shocks to the non-tradable sectors in both countries, $\rho_{N,N^*}$. In Figure 3, where we assume that $\gamma \in [0, 1]$, $\rho_{T,N} \in [-1, 1]$ and $\rho_{N,N^*} = 0$, the gains from cooperation as fraction of the total stabilization gains reach to approximately 30% when tradable and non-tradable sector shocks are imperfectly correlated, and the share of non-tradables, $1 - \gamma$, in total consumption is approximately 0.5. In Figure 4, where we assume that $1 - \gamma = \gamma = 0.5$, $\rho_{T,N} \in [-1, 1]$ and $\rho_{N,N^*} \in [-1, 1]$, the same result appears: relative gains are largest when shocks are asymmetric. As shocks become more symmetric, the easier it becomes for monetary policymakers to stabilize simultaneously mark-ups in both the tradable as the non-tradable sector. Hence, welfare gains from cooperation decrease as the symmetry of shocks increases.

However, Tille (2002) and Canzoneri et al. (2004) have emphasized that the ratio $G_R$ may be the ratio of two small numbers and, therefore, neither gain would be worth mentioning. It turns out for LCP that the absolute welfare gain, $G_A = \bar{\Omega}_C - \bar{\Omega}_N$, from international monetary cooperation is small. This gain varies roughly between 0.002% and 0.015% of steady-state consumption.

Instead of using a ratio such as $G_R$ to measure welfare gains from cooperation, Tille (2002) suggests to measure the gains from Nash and cooperation as a fraction of the welfare loss that these policies avoid: $G_N = \frac{\bar{\Omega}_N - \bar{\Omega}_C}{\bar{\Omega}_M - \bar{\Omega}_C}$ and $G_C = \frac{\bar{\Omega}_C - \bar{\Omega}_N}{\bar{\Omega}_M - \bar{\Omega}_N}$. Given the small absolute welfare gains of cooperation, it can be expected that the Home
Figure 3: Relative welfare gain for $\gamma \in [0, 1]$, $\rho_{T, N} \in [-1, 1]$ and $\rho_{N, N^*} = 0$.

Figure 4: Relative welfare gain for $\gamma = 0.5$, $\rho_{T, N} \in [-1, 1]$ and $\rho_{N, N^*} \in [-1, 1]$. 
monetary authority can avoid most of the welfare loss by setting the own monetary instrument given the Foreign monetary stance. Indeed, the additional loss that can be avoided from moving from Nash to cooperation is small. It varies between 0.04% and 0.3%.

From the results above, it is clear that the absolute welfare gains from monetary cooperation with LCP and imperfectly correlated sector-specific shocks are small. One of the reasons is that with LCP the traditional pass-through and expenditure switching effects of movements in the exchange rate are absent. Given this, there is no role for the elasticity of substitution between tradables which determines the strength of the pass-through effect on prices and, finally, on a country’s welfare.

Moreover, as is argued by Corsetti and Pesenti (2005a), it would be inefficient for a monetary policymaker to adopt an inward-looking monetary policy. Therefore, the Home monetary policymakers stabilizes, besides the mark-ups of the Home firms, also the mark-ups of the Foreign firms that export to the domestic market by reducing the nominal exchange rate volatility. Home monetary policymakers, therefore, internalise the monetary spill-overs on exporting firms. This is, however, exactly the same what a benevolent planner does. In minimizing the aggregate welfare loss, the benevolent planner takes into account the externalities of monetary policy on the mark-ups of exporters and, therefore, set the monetary stance in both countries such that the negative spill-overs are minimized.

4. Conclusion

This paper analyses with a single period stochastic general equilibrium framework the question whether there are substantial welfare gains from international monetary cooperation under local currency pricing and imperfectly correlated sector-specific shocks. This paper adjusts the framework presented in Berger (2005) by adopting the local currency pricing assumption instead of producer currency pricing. The difference with Corsetti and Pesenti (2005a) is that we assume one period, and we introduce a non-tradable sector and imperfectly correlated sector-specific shocks. The relative welfare gains vary between 0.57 percent with symmetric sector-specific shocks up to roughly 30 percent with asymmetric sectoral shocks. However, the results show that the absolute welfare gain from giving up a Nash monetary policy rule in favour of monetary cooperation is fairly small for different cross sectoral correlations. The absolute welfare gain from cooperation can amount to approximately 0.01 percent of steady-state consumption. Hence, within a simple framework with local currency pricing, imperfectly correlated sectoral shocks do not create potential welfare gains from international monetary cooperation. The reason is that in case of LCP the pass-through and expenditure switching effect of movements in the exchange rate are absent. Therefore, the elasticity of substitution between tradables which determines the strength of the pass-through effect, plays no role and does not effect prices and, finally, welfare. Moreover, the monetary authorities already inter-
nalise most of the spill-over effects and there is no need for monetary cooperation. This result is in line with Corsetti and Pesenti (2005a).

References


Appendix

Derivation of the welfare metric

The aggregated expected welfare deviation from steady state is given by \( \tilde{\Omega} = E [\Omega] - \Omega = -E [p] \). The first step is to show that the expected disutility of labour, which equals the steady-state value of the disutility of labour, is constant. For this we need to determine the equilibrium labour supply. The labour market equilibrium condition is \( \int_0^1 l(j) \, dj = \int_0^1 l(n) \, dn + \int_0^1 l(h) \, dh \).

Labour demand in the non-tradable sector is given by \( l(n) = Z_N^{-1} Y_n \). Using the resource constraint \( Y_n = \int_0^1 c(n, j) \, dj = (1 - \gamma) \frac{PC}{P^N} \) we can rewrite the demand for labour in the non-tradable sector as \( l(n) = Z_N^{-1} (1 - \gamma) \frac{PC}{P^N} \). Now substitute for \( PC = \frac{M}{\chi} \) from the money demand condition and substitute for \( P_N = \frac{\theta_k}{\theta - 1} \frac{E[CN]}{E[C_N]} \) from the firm’s profit maximization problem and labour demand in the non-tradable sector \( n \) is given by:

\[
(A.1) \quad l(n) = (1 - \gamma) \frac{\theta - 1}{\theta \kappa} \frac{M}{Z_N} E [C_N] \frac{E[Z_N C_N]}{E[C_N]}
\]

Taking expections yields \( E[l(n)] = (1 - \gamma) \frac{\theta - 1}{\theta \kappa}. \)

Labour demand in the tradable sector \( h \) is given by \( l(h) = Z_T^{-1} Y_h \) and from the resource constraint we have \( Y_h = \frac{1}{\gamma} \left[ P_T^{-(1-\varphi)} P_H^{-\varphi} PC + (P_H^*)^{-(1-\varphi)} (P_H^*)^{-\varphi} P^* C^* \right] \).

Now substitute for \( PC = \frac{M}{\chi}, P^* C^* = \frac{M^*}{C^*}, P_H = \frac{\theta_k}{\vartheta - 1} \frac{E[Z_T C_H]}{E[C_H]}, P_H^* = \frac{\theta_k}{\vartheta - 1} \frac{E[Z_T C_H^*]}{E[C_H^*]}, P_F = \frac{\theta_k}{\vartheta - 1} \frac{E[Z_T C_F]}{E[C_F]}, \) and labour demand in sector \( h \) is written as:

\[
(A.2) \quad l(h) = \frac{1}{2} \gamma \frac{\theta - 1}{\theta \kappa} \frac{2 M_T}{Z_T} \left( \frac{E[Z_T C_H]}{E[C_H]} \right)^{1-\varphi} \left( \frac{E[Z_T C_F]}{E[C_F]} \right)^{1-\varphi}
\]

\[
+ \frac{1}{2} \gamma \frac{\theta - 1}{\theta \kappa} \frac{2 M_T}{Z_T} \left( \frac{E[Z_T C_H^*]}{E[C_H^*]} \right)^{1-\varphi} \left( \frac{E[Z_T C_F^*]}{E[C_F^*]} \right)^{1-\varphi}
\]

In \( l(h) \) the nominal exchange rate is not determined yet. The nominal exchange rate \( S \) is derived from the current account condition for Home \( C_H^* SP_H^* = C_F^* P_F. \)
Substitute for the export demand $C^*_H$ and the import demand $C_F$ yields the equality $P^*C^*S = PC$. Using the money demand functions the exchange rate is written as $S = M/M^*$. Substituting for $S = M/M^*$ and taking expectations reduces equation (A.2) to $E[\ell(h)] = \gamma n \frac{\theta-1}{\theta \kappa}$.

Taking expectations of the labour market equilibrium yields:

\begin{equation}
E \left[ \int_0^1 l(j) \, dj \right] = E \left[ \int_0^1 E[\ell(n)] \, dn \right] + E \left[ \int_0^1 E[\ell(h)] \, dh \right]
\end{equation}

which equals to $E[\ell] = \frac{\theta-1}{\theta \kappa}$. On average, expected employment is equal to the natural rate or equally the steady-state level of employment. The intuition behind this result is that, in equilibrium, …rms set their prices such that they will operate on their flexible-price supply curve (see Corsetti and Pesenti, 2005b, p. 5).

The expected welfare deviation from steady state is defined as $\Omega \equiv E[\Omega] - \bar{\Omega}$. Using the result that $E[\ell] = \frac{\theta-1}{\theta \kappa} = \bar{l}$ we can write $\Omega \equiv E[\log \frac{C}{C}]$. Using $m - p = c$ and $E[m] = 0$ we finally arrive at $\bar{\Omega} = -E[p]$.

**Approximations of the prices**

To analyse the welfare implications of uncertainty we take a second-order approximation of the optimal prices set by the …rms. Let $x$ denote the log deviation of variable $X$ from its deterministic steady state, $x = \log X - \log \bar{X}$. Because we restrict ourselves to a second-order approximation the aggregate price index can be approximated with a first-order approximation, $p = \gamma p_T + (1 - \gamma) p_N$, because $p_T$ and $p_N$ are of order two.

To derive $p_T = \frac{1}{2} p_H + \frac{1}{2} p_F$ we first rewrite equation (3) as $P^{1-\varphi}_T = \frac{1}{2} P^{1-\varphi}_H + \frac{1}{2} P^{1-\varphi}_F$. The second order approximation of the left hand side is:

\begin{equation}
P^{1-\varphi}_T = \bar{P}^{1-\varphi}_T \left[ 1 + (1 - \varphi) p_T + \frac{1}{2} (1 - \varphi)^2 p_T^2 \right] + \|R^3\|
\end{equation}

where we used $X = \bar{X}(1 + x + \frac{1}{2}x^2)$. The term $\|R^3\|$ contains all terms of order three and higher in deviations from the steady state. For the right hand side of $P_T$ we have the following second order approximations:

\begin{equation}
P^{1-\varphi}_H = \bar{P}^{1-\varphi}_H \left[ 1 + (1 - \varphi) p_H + \frac{1}{2} (1 - \varphi)^2 p_H^2 \right] + \|R^3\|
\end{equation}

\begin{equation}
P^{1-\varphi}_F = \bar{P}^{1-\varphi}_F \left[ 1 + (1 - \varphi) p_F + \frac{1}{2} (1 - \varphi)^2 p_F^2 \right] + \|R^3\|
\end{equation}

Using the result that in the non-stochastic steady state $\bar{P}_H = \bar{P}_F = \bar{P}_T$ holds, substitution of equations (A.5) and (A.6) into (A.4) and a rearrangement of terms
gives:
\[ p_T = \frac{1}{2} p_H + \frac{1}{4} (1 - \varphi) p_H^2 + \frac{1}{2} p_T + \frac{1}{4} (1 - \varphi) p_T^2 + \| R^3 \| \]

Since we restrict ourselves to a second-order approximations and \( p_H \) and \( p_T \) are of order two the terms \( \frac{1}{4} (1 - \varphi) p_H^2 \) and \( \frac{1}{4} (1 - \varphi) p_T^2 \) are collected in \( \| R^3 \| \). This gives \( p_T = \frac{1}{2} p_H + \frac{1}{2} p_T + \| R^3 \| \).

To derive equation (13), we define \( F \equiv E [C_H] \) and \( G \equiv E \left[ \frac{M}{\pi z_T} C_H \right] \). From this \( P_H = \frac{\theta \kappa}{\theta - \tau} F \) and \( p_H = g - f \) follow. \( f \) can be rewritten as:
\[ (A.8) \quad f = E c_H + \frac{1}{2} E c_H^2 - \frac{1}{2} f^2 + \| R^3 \| \]

Similarly \( g \) is:
\[ (A.9) \quad g = E [z_T + m + c_H] + \frac{1}{2} E [z_T + m + c_H]^2 - \frac{1}{2} g^2 + \| R^3 \| \]

Using the following expectations \( E [z_T] = 0 \) and \( E [m] = 0 \), \( g \) can be rearranged as:
\[ (A.10) \quad g = E c_H + \frac{1}{2} E \left[ (m - z_T)^2 + c_H^2 + 2 (m - z_T) c_H \right] - \frac{1}{2} g^2 + \| R^3 \| \]

Using \( p_H = g - f \) and the expressions for \( f \) and \( g \) gives the second-order approximation of the price charged by Home firms to domestic households:
\[ (A.11) \quad p_H = \frac{1}{2} E (m - z_T)^2 + E (m - z_T) c_H + \| R^3 \| \]

Notice that the second-order terms in \( \frac{1}{2} f^2 \) and \( \frac{1}{2} g^2 \) cancel and the terms of order three and higher are collected in \( \| R^3 \| \).

To derive equation (14) define \( F \equiv E [SC_H] \) and \( G \equiv E \left[ \frac{M}{\pi z_T} C_H^* \right] \). It follows that \( P_H^* = \frac{\theta \kappa}{\theta - \tau} F \) and \( p_H^* = g - f \). In a similar way as above \( f \) is derived as:
\[ (A.12) \quad f = E s + E c_H^* + \frac{1}{2} E (s + c_H^*)^2 - \frac{1}{2} f^2 + \| R^3 \| \]

and \( g \) is:
\[ (A.13) \quad g = E c_H^* + \frac{1}{2} E \left[ (m - z_T)^2 + c_H^* + 2 (m - z_T) c_H^* \right] - \frac{1}{2} g^2 + \| R^3 \| \]

\( S \) can be approximated with a first-order approximation, because \( s \) appears in terms of order two and we restrict ourselves to a second-order approximation. From the current account condition (see above) the approximation of \( S \) is \( s = m - m^* \). Using \( p_H^* = g - f \), \( E [z_T] = 0 \), \( E [m] = E [m^*] = 0 \) and, therefore, \( E [s] = 0 \) yields:
\[ (A.14) \quad p_H^* = \frac{1}{2} E (m - z_T)^2 + E (m - z_T) c_H^* - \frac{1}{2} E s^2 - E sc_H^* + \| R^3 \| \]
The second-order approximations of the prices for the non-tradable and Foreign goods are obtained in a similar way. In the second-order approximations the terms \( c_H, c_H^*, c_F \) and \( c_F^* \) are still unknown and have to be derived from \( C_i = \frac{1}{2} \gamma \frac{PC}{P} \) and from \( C_i^* = \frac{1}{2} \gamma \frac{P'C^*}{P} \) for \( i = H, F \). We can restrict ourselves again to a first-order approximation because \( c_H, c_H^*, c_F \) and \( c_F^* \) appear in terms of order two. Substitution of \( PC \) and taking a first order approximation gives \( c_i = p_i + m + \| R^2 \| \). Since \( p_i \) contains elements of order two and higher the approximation for \( C_i \) reduces to \( c_i = m + \| R^2 \| \) and for Foreign \( c_i^* = m^* + \| R^2 \| \). Substituting these expressions into the approximations of the preset prices above and for the analogously defined approximations for Foreign results in the equations (13) to (18).

**Optimal monetary policy rules**

Substitution of the approximations in the respective price indices and, in turn, into equation (12) yields the expected welfare deviation from steady state in Home and Foreign. Under Nash the Home monetary policymaker minimizes the expected welfare loss by setting the Home money supply given the Foreign money supply. The Foreign monetary authority does the same. From the first order conditions for the minimization problems \( \min_m \Omega \) given \( m^* \) and \( \min_{m^*} \Omega^* \) given \( m \) we have the following two policy response functions in the two unknowns \( m \) and \( m^* \):

\[
(A.15) \quad m = \frac{3\gamma}{2(3-\gamma)} z_T + \frac{2(1-\gamma)}{3-\gamma} z_N - \frac{\gamma}{2(3-\gamma)} m^*
\]

\[
(A.16) \quad m^* = \frac{3\gamma}{2(3-\gamma)} z_T + \frac{2(1-\gamma)}{3-\gamma} z_N^* - \frac{\gamma}{2(3-\gamma)} m
\]

Solving for \( m \) and \( m^* \) gives the feedback parameters in (21).

Under cooperation a benevolent planner minimizes the aggregate welfare loss of both countries \( \min_{m, m^*} \left[ \Omega + \Omega^* \right] \). From the first order condition, the following two policy response functions in the two unknowns \( m \) and \( m^* \) are obtained:

\[
(A.17) \quad m = \frac{2\gamma}{3-\gamma} z_T + \frac{2(1-\gamma)}{3-\gamma} z_N - \frac{\gamma}{3-\gamma} m^*
\]

\[
(A.18) \quad m^* = \frac{2\gamma}{3-\gamma} z_T + \frac{2(1-\gamma)}{3-\gamma} z_N^* - \frac{\gamma}{3-\gamma} m
\]

Solving for \( m \) and \( m^* \) yields the feedback parameters in (22).
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