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Gianluca Benigno and Pierpaolo Benigno

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Gianluca Benigno, London School of Economics (LSE)
Pierpaolo Benigno, New York University and CEPR

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

Implementing Monetary Cooperation Through Inflation Targeting

This Paper presents a two-country dynamic general equilibrium model with imperfect competition and nominal price rigidities in which terms of trade shock coexist with inefficient supply shocks. We analyse the features of the optimal cooperative solution. While movements in the exchange rate should offset terms of trade shocks, inefficient supply shocks are more likely to make a case for a fixed exchange rate regime. Surprisingly, we show that the optimal cooperative solution can be implemented in a strategic context through inflation-targeting regimes. Under these regimes each monetary authority weighs only domestic targets, namely GDP inflation and output gap. Even if there are gains from cooperation, inward-looking monetary policymakers can achieve the first best.

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Gianluca Benigno
Lecturer
Department of Economics
London School of Economics
Houghton Street
London
WC2A 2AE
Tel: (44 20) 7955 7807
Email: g.benigno@lse.ac.uk

Pierpaolo Benigno
Department of Economics
New York University
269 Mercer Street (7th Floor)
New York, NY 10003
USA
Tel: (1 212) 998 8958
Fax: (1 212) 995 4186
Email: pierpaolo.benigno@nyu.edu

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> "*The national economies that make up the world economy have become increasingly interdependent. Monetary policy in each country affects economic welfare both at home and abroad: the policymaker in each country generates externalities for the policymakers in the other countries. Therefore, the policymaker in each country must take account of the actions of policymakers in other countries.*"[1]

The previous quotation outlines the basic idea behind the literature on international monetary policy coordination in the 80's and 90's. The existence of externalities, whether positive or negative, is the source of a need of international cooperation when countries do not internalize the effects of their actions on other countries.

In a recent contribution Obstfeld and Rogoff (2001) challenge this conventional wisdom. They show that there is no need of international monetary policy coordination even in a world where goods and financial markets are perfectly integrated. Their result is supported by a fully state-of-art general equilibrium model where the only source of shocks are perturbations to the efficient level of the terms of trade, i.e. asymmetric productivity shocks. In Benigno and Benigno (2001a), we showed that their conclusion depends crucially on the specification of preferences – namely the assumption of unitary intratemporal elasticity of substitution between Home and Foreign goods. Sutherland (2001) has further quantified that the gains from cooperation are not so small with more general preferences.

Here, we revisit the scope for international monetary policy coordination in a related two-country dynamic general equilibrium model with imperfect competition, price rigidities and producer currency pricing in which efficient terms of trade shocks coexist with inefficient supply shocks. The latter are rationalized through time-varying mark-ups that create a wedge between the efficient allocation and the natural level.[2]

We first show that the nature of the disturbances is important in determining the optimal exchange rate regime. While efficient terms-of-trade shocks should be offset in the cooperative solution by corresponding changes in the exchange rate –as Friedman (1953) argued in his case for flexible exchange rates– we find that asymmetric inefficient shocks point instead toward the need for a fixed exchange rate regime.

We then discuss if it is possible to implement the cooperative outcome in a decentralized strategic setting. Along the lines of Persson and Tabellini (1996), we design monetary policy institutions that replicate the optimal cooperative solution in a strategic framework. Surprisingly, it is sufficient that each policymaker commits to minimize a quadratic loss function which appropriately weighs *only* domestic targets

[1] Canzoneri and Henderson (1991), pg. 1.

[2] In this paper we characterize solutions in which the policymakers and the central planner can commit. In an independent work, Clarida, Gali and Gertler (2001b) have instead analyzed discretionary equilibria. Canzoneri, Cumby and Diba (2001) have explored the gains from coordination when there are important sectorial productivity differences within a single country.

–the output gap and the domestic producer inflation rate. We refer to these institutions as *inward-looking monetary authorities*. Our model supports the adoption of flexible inflation targeting regimes (see Svensson, 2001) even in an international context.

The design of the relative weights in the objective functions of the monetary policymakers depends on how the inefficient supply shocks should transmit in the cooperative solution. When an inefficient inflationary supply shock produces on impact inflation in both countries ("positive-correlated scenario"), then it is optimal to design institutions with a relatively higher weight to the domestic output gap in order to correct for the 'contractionary bias' that would arise in a strategic framework.[3] On the other hand, when the inefficient supply shock has opposite effects on the inflation rates in the two countries ("negative correlated scenario"), the correspondent 'expansionary bias' should be corrected by assigning a higher relative weight to each domestic producer inflation.

The paper is structured as it follows. Section 1 presents the model and Section 2 compares the log-linear approximation of the structural equilibrium conditions with previous work in the literature. Section 3 studies the cooperative solution. Section 4 shows how to implement the cooperative solution in a decentralized context. Section 5 concludes.

1 The Model

In this section we present our two-country dynamic general equilibrium model with money, imperfect competition and price rigidities along the lines of Benigno and Benigno (2001b), Clarida Gali and Gertler (2001a), Gali and Monacelli (2000) and Svensson (2000). A key difference with respect to Benigno and Benigno (2001b) is the assumption that the overall degrees of monopolistic distortions are time-varying. In this way, we rationalize the existence of inefficient supply shocks by creating a time-varying wedge between the natural level of some variables and their efficient level. The other aforementioned works are instead small open-economy models.

Households preferences We consider a two-country economy, Home (H) and Foreign (F). The population on the segment $[0, n)$ belongs to the Home country while the one on the segment $[n, 1]$ belongs to the Foreign country. Each individual maximizes the following utility function:

$$U_t^j = \mathrm{E}_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} \left[U(C_s^j, \xi_{C,s}) + L\left(\frac{M_s^j}{P_s}, \xi_{M,s} \right) - V(y_s(j), \xi_{Y,s}) \right] \right\},$$

where the index j denotes a variable that is specific to household j; E_t denotes the expectation conditional on the information set at date t, while β is the intertemporal

[3] 'Contractionary' and 'expansionary-bias' terminologies are borrowed from the international-monetary-policy-coordination literature, see Canzoneri and Henderson (1991).

discount factor, with $0 < \beta < 1$. Individuals obtain utility, in a separable way, from consumption and the liquidity services of holding money, while they receive disutility from producing a single differentiated good. Here, ξ_C, ξ_M and ξ_Y denote country-specific shocks to the preferences toward consumption, real money balances and production preferences. Country's F variables will be denoted with a star index. All the consumption goods are traded and each household consumes all the domestic and foreign differentiated goods. In fact, U is an increasing concave function of the index C^j defined as

$$C^j \equiv \left[n^{\frac{1}{\theta}} (C_H^j)^{\frac{\theta-1}{\theta}} + (1-n)^{\frac{1}{\theta}} (C_F^j)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}},$$

where C_H^j and C_F^j are consumption sub-indexes of the continuum of differentiated goods produced respectively in country H and F

$$C_H^j \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma}} \int_o^n c^j(h)^{\frac{\sigma-1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}}, \qquad C_F^j \equiv \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_n^1 c^j(f)^{\frac{\sigma-1}{\sigma}} df \right]^{\frac{\sigma}{\sigma-1}},$$

where $\sigma > 1$ is the elasticity of substitution across goods produced within a country and θ is the elasticity of substitution between the bundles C_H and C_F.

The function L is increasing and concave in real money balances, $\frac{M_t^j}{P}$, where P is the consumption-based price index associated with C, defined as

$$P \equiv \left[n(P_H)^{1-\theta} + (1-n)(P_F)^{1-\theta} \right]^{\frac{1}{1-\theta}},$$

with

$$P_H \equiv \left[\left(\frac{1}{n} \right) \int_o^n p(h)^{1-\sigma} dh \right]^{\frac{1}{1-\sigma}}, \qquad P_F \equiv \left[\left(\frac{1}{1-n} \right) \int_n^1 p(f)^{1-\sigma} df \right]^{\frac{1}{1-\sigma}},$$

where $p(h)$ and $p(f)$ are prices in units of domestic currency of the Home-produced and Foreign-produced goods, respectively.

Prices are set in the currency of the producer and the law of one price holds: $p(h) = S \cdot p^*(h)$ and $p(f) = S \cdot p^*(f)$, where S is the nominal exchange rate (the price of foreign currency in terms of domestic currency). Given these assumptions and the structure of preferences, purchasing power parity holds, i.e. $P = S \cdot P^*$. The terms of trade are defined as the relative price of foreign goods in terms of home goods expressed in the domestic currency, i.e. $T \equiv \frac{P_F}{P_H}$.[4]

Finally V is an increasing convex function of household j's supply of the differentiated good $y(j)$.

[4] With producer currency pricing, and the law of one price holding, this is equivalent if expressed in foreign currency.

Household j's demands of the generic good h, produced in country H, and of the good f, produced in country F, are respectively:

$$c^j(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma}\left(\frac{P_H}{P}\right)^{-\theta} C^j, \qquad c^j(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma}\left(\frac{P_F}{P}\right)^{-\theta} C^j.$$

Total demands of the home and foreign differentiated goods are then given by

$$y^d(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma}\left[\left(\frac{P_H}{P}\right)^{-\theta} C^W + G\right], \qquad y^d(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma}\left[\left(\frac{P_F}{P}\right)^{-\theta} C^W + G^*\right], \tag{1}$$

where C^W is the aggregate consumption in the whole economy and G and G^* are country-specific public expenditure shocks.

We assume that markets are complete both at a domestic and international level. In doing this, we assume that households have access to a complete set of state-contingent one-period nominal bonds denominated in the currency of the Home country (as in Chari, Kehoe and McGrattan, 1998).

Households' optimality conditions

Since households have identical preferences, and markets are complete, the assumption that initial wealth is identical among all the households implies that there is perfect risk-sharing of consumption within each country. On the other hand the assumption of market completeness at an international level implies that marginal utilities of income are equalized across countries

$$U_C(C_t, \xi_{C,t}) = U_C(C_t^*, \xi_{C,t}^*), \tag{2}$$

at all times and across all states of nature.[5] Equation (2) is derived from the set of optimality conditions that characterize the optimal allocation of wealth among the state-contingent securities. At each time t, these conditions are in the same number of the states of nature one-period ahead. Using such conditions, it is possible to price the one-period risk-free nominal interest rate, i, on nominal bonds denominated in Home currency

$$U_C(C_t, \xi_{C,t}) = (1+i_t)\beta \mathrm{E}_t\left\{U_C(C_{t+1}, \xi_{C,t+1})\frac{P_t}{P_{t+1}}\right\}, \tag{3}$$

and the one-period risk-free nominal interest rate, i^*, on nominal bonds denominated in Foreign currency,

$$U_C(C_t^*, \xi_{C,t}^*) = (1+i_t^*)\beta \mathrm{E}_t\left\{U_C(C_{t+1}^*, \xi_{C,t+1}^*)\frac{P_t^*}{P_{t+1}^*}\right\}. \tag{4}$$

[5] Note that consumption is perfectly shared across countries, i.e. $C_t = C_t^*$ only when consumption preference shocks are symmetric, i.e. $\xi_{C,t} = \xi_{C,t}^*$.

Combining equations (2), (3) and (4), we obtain the uncovered interest parity condition

$$(1+i_t)\mathrm{E}_t\left[\frac{U_C(C_{t+1},\xi_{C,t+1})}{U_C(C_t,\xi_{C,t})}\frac{P_t}{P_{t+1}}\right]=(1+i_t^*)\mathrm{E}_t\left[\frac{U_C(C_{t+1},\xi_{C,t+1})}{U_C(C_t,\xi_{C,t})}\frac{P_t^*}{P_{t+1}^*}\right]. \tag{5}$$

The set of optimality conditions is completed by appropriate transversality conditions and by the optimal choices of real-money-balance holdings, in each country.[6] Finally, by applying the appropriate aggregate operators we obtain the domestic and foreign aggregate demand as

$$Y^H=\left(\frac{P_H}{P}\right)^{-\theta}C^W+G, \qquad Y^F=\left(\frac{P_F}{P}\right)^{-\theta}C^W+G^*. \tag{6}$$

From (6), it follows that changes in the terms of trade create dispersion of output across countries.

Price-Setting Behavior

Each producer of a single differentiated good acts in a monopolistic-competitive market. The demand of the differentiated good, (1), is affected by the pricing decision on $p(h)$, for the generic home-produced good, and $p^*(f)$, for the foreign-produced good, respectively.[7] On the other hand, producers take as given P, P_H, P_F and C. The price-setting behavior is modelled following the Calvo-Yun model, under which each producer has the opportunity to change its price with a fixed probability $1-\alpha$ at each point in time.[8] We allow this probability to be different across countries.

A home producer, that sets a new price at period t, maximizes the expected discounted value of her net profits[9]

$$\mathrm{E}_t\sum_{k=0}^{\infty}(\alpha\beta)^k\left[\frac{U_C(C_{t+k},\xi_{C,t+k})}{P_{t+k}}(1-\tau_{t+k})\widetilde{p}_t(h)\widetilde{y}_{t,t+k}(h)-V(\widetilde{y}_{t,t+k}(h),\xi_{Y,t+k})\right],$$

where τ_t is a time-varying tax on firms' revenues. With $\widetilde{p}_t(h)$ we have denoted the price of the good h chosen at date t and with $\widetilde{y}_{t,t+k}(h)$ the total demand of good h

[6] We do not report those conditions here since they will not be used in the analysis that follows. The transversality conditions will be always satisfied in the log-linear approximation to the equilibrium conditions. While the money demand equations are irrelevant for the optimal stabilization policies since we will assume that the utility derived from holding real money balance is small compared to other terms in the utility function.

[7] There is indeed producer currency pricing.

[8] This probability is the same for each producer and is independent of the amount of time elapsed since her last change of price.

[9] It is important to note that all the producers that belong to the same country and that can modify their price at a certain time will face the same discounted value of the streams of current and future marginal costs under the assumption that the new price is maintained. Thus they will set the same price. Note also that revenues are evaluated using the marginal utility of nominal income $\frac{U_C(C_t,\xi_{C,t})}{P_t}$ which is the same for all consumers within a country because of the complete-market assumption.

at time $t+k$ conditional on the fact that the price $\widetilde{p}_t(h)$ has not changed,

$$\widetilde{y}_{t,t+k}(h) = \left(\frac{\widetilde{p}_t(h)}{P_{H,t+k}}\right)^{-\sigma} \left[\left(\frac{P_{H,t+k}}{P_{t+k}}\right)^{-\theta} C_{t+k} + G_{t+k}\right]. \tag{7}$$

The optimal choice of $\widetilde{p}_t(h)$ is

$$\widetilde{p}_t(h) = \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\alpha^i \beta)^k V_y(\widetilde{y}_{t,t+k}(h), \xi_{Y,t+k}) \widetilde{y}_{t,t+k}(h)}{\mathrm{E}_t \sum_{k=0}^{\infty} (\alpha^i \beta)^k \left(1-\mu_{t+k}\right) \frac{U_C(C_{t+k}, \xi_{C,t+k})}{P_{t+k}} \widetilde{y}_{t,t+k}(h)}. \tag{8}$$

where $(1-\mu_t)$ depends on the degree of monopolistic distortions corrected for the distortionary taxation as

$$(1-\mu_t) \equiv \frac{(1-\tau_t)(\sigma-1)}{\sigma}.$$

The Calvo-syle price-setting mechanism implies the following state equation for $P_{H,t}$:

$$(P_{H,t})^{1-\sigma} = \alpha (P_{H,t-1})^{1-\sigma} + (1-\alpha) \widetilde{p}_t(h)^{1-\sigma}, \tag{9}$$

Similar conditions hold for the producers in country F, with the appropriate starred variables.

2 Log-Linear Approximation to the Equilibrium Conditions

Before presenting the log-linear approximation to the structural equilibrium conditions of the model, we characterize the efficient allocation. In such an allocation, real marginal costs behave as in the flexible-price competitive-market economy: in each country, real marginal costs are constant over time and across states of nature and mark-ups are completely eliminated. It follows that

$$U_C(C_t, \xi_{C,t}) \frac{P_{H,t}}{P_t} = V_y\left(\left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t^W + G_t, \xi_{Y,t}\right), \tag{10}$$

$$U_C(C_t^*, \xi_{C,t}^*) \frac{P_{F,t}}{P_t} = V_y\left(\left(\frac{P_{F,t}}{P_t}\right)^{-\theta} C_t^W + G_t^*, \xi_{Y,t}^*\right). \tag{11}$$

Combining (10) and (11) with (2), it is possible to characterize the efficient allocation of $\{C, C^*, T\}$. In a log-linear approximation around the steady-state, we obtain that[10]

$$\widetilde{C}_t^R = v_t^R, \tag{12}$$

[10] A variable with an upper index W denotes a weighted average of the Home and Foreign variables with weights n and $1-n$, respectively. A variable with an upper index R denotes the difference between the Home and Foreign variables. Thus, C^W is world consumption, C^R is the difference between Home and Foreign consumptions.

$$\tilde{C}_t^W = \frac{\rho}{\rho+\eta} v_t^W + \frac{\eta}{\rho+\eta}(\overline{Y}_t^W - g_t^W), \quad (13)$$

$$\tilde{T}_t = \frac{\eta}{1+\theta\eta}(\overline{Y}_t^R - g_t^R), \quad (14)$$

where an upper-tilda variable ($\tilde{}$) denotes the efficient allocation for that variable; v and $\overline{Y}_t$ are re-parametrizations of the shocks to the preferences toward consumption and leisure, respectively, in the Home country; g_t is instead a re-parametrization of the Home public expenditure shock. We can interpret v as a country-specific demand shock, while $\overline{Y}_t$ is a country-specific productivity shock. Finally η and ρ are the inverses of the elasticity of labor supply and the intertemporal elasticity of substitution in consumption, respectively.[11]

In general, the efficient allocation does not necessarily coincide with the flexible-price allocation. Indeed, under price flexibility mark-ups are not completely eliminated and the flexible-price allocation is described by the following conditions

$$(1-\mu_t)U_C(C_t, \xi_{C,t})\frac{P_{H,t}}{P_t} = V_y\left(\left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t^W + G_t, \xi_{Y,t}\right),$$

$$(1-\mu_t^*)U_C(C_t^*, \xi_{C,t}^*)\frac{P_{F,t}}{P_t} = V_y\left(\left(\frac{P_{F,t}}{P_t}\right)^{-\theta} C_t^W + G_t^*, \xi_{Y,t}^*\right),$$

combined with equation (2). In a log-linear approximation in which μ_t and μ_t^* are small and close to zero, the flexible-price allocation is related to the efficient equilibrium in the following way

$$\tilde{\tilde{C}}^R = \tilde{C}_t^R,$$

$$\tilde{\tilde{C}}^W = \tilde{C}_t^W - \frac{\mu_t^W}{\rho+\eta},$$

$$\tilde{\tilde{T}} = \tilde{T}_t - \frac{\mu_t^R}{1+\theta\eta},$$

where a double-tilda variable ($\tilde{\tilde{}}$) indicates the flexible-price allocation.

With this apparatus, we can describe the log-linear approximation to the equilibrium conditions under sticky prices. In presenting the model we will emphasize the differences and similarities with the Keynesian literature on international monetary policy coordination as summarized by Persson and Tabellini (1996) (PT from now on).

Producer inflation rates depend on the current and expected discounted future deviations of the real marginal costs from the steady state. By log-linearizing (8), (9)

[11] We have defined $\rho \equiv -U_{CC}\overline{C}/U_C$ and $\eta \equiv V_{yy}\overline{C}/V_y$, while v_t, $\overline{Y}_t$ are defined as $U_{CC}\overline{C}v_t = -U_{C\xi_C}\xi_{C,t}$ and $V_{yy}\overline{CY}_t = -V_{Y\xi_Y}\xi_{Y,t}$ and $g_t = G_t/\overline{C}$. v_t^*, $\overline{Y}_t^*, g_t^*$ are defined appropriately. The steady-state level of consumption solve the equation $U_C(\overline{C}, 0) = V_y(\overline{C}, 0)$.

and their foreign correspondents, we obtain the two aggregate supply equations for the Home and Foreign country:

$$\pi_{H,t} = k[(\rho+\eta)y_t^W + (1-n)(1+\eta\theta)(\widehat{T}_t - \widetilde{T}_t)] + u_t + \beta E_t \pi_{H,t+1}, \tag{15}$$

$$\pi_{F,t}^* = k^*[(\rho+\eta)y_t^W - n(1+\eta\theta)(\widehat{T}_t - \widetilde{T}_t)] + u_t^* + \beta E_t \pi_{F,t+1}^*, \tag{16}$$

where π_H and π_F^* denote the Home and Foreign producer inflation rates, $\widehat{T}_t$ is the deviation of the terms of trade from the steady state and $\widetilde{T}$ is the efficient allocation of the terms of trade, as defined in (14); y_t^W denotes the world output gap that coincides with the world consumption gap, defined as the difference between the world consumption under sticky prices and its efficient level (13); k and k^* are functions of the structural parameters of the model.[12] More importantly, u_t and u_t^* represent *inefficient supply shocks* that capture the deviations of the flexible-price allocation from the efficient allocation, where $u_t \equiv k\mu_t$ and $u_t^* \equiv k^*\mu_t^*$. In our context, these deviations are produced by variations in the distortionary taxes that apply on the firms' revenues. A similar result can be obtained if the perturbations were originated by exogenous time variations in the degree of monopolistic distortion (due to time variation in the elasticity of substitution within goods in a country, as in Giannoni, 2000) or exogenous variations in the degree of market power of workers in the labor market (see Clarida et al., 1999 and 2001b for this interpretation).

Equations (15) and (16) replace the expectations augmented Phillips's curves in the PT approach. Their supply shocks assume here the forms of *inefficient supply shocks*. In particular, and differently from PT, the terms of trade enter the aggregate supply equations through two microfounded channels. The first is the expenditure-switching effect: an increase in the price of goods produced in country F relative to goods produced in H boasts the demand of goods produced in country H, pushing up producer inflation in this country. The second is the reduction in the marginal utility of nominal income: the optimal response is to increase prices in order to offset the fall in revenues.

Using the definition of the terms of trade, we can decompose the changes in the terms of trade between the nominal exchange rate depreciation and the producers' inflation rate differential

$$\widehat{T}_t = \widehat{T}_{t-1} + \Delta S_t + \pi_{F,t}^* - \pi_{H,t}, \tag{17}$$

where $\Delta S_t = \ln S_t / S_{t-1}$. After log-linearizing equations (6), we obtain that the terms of trade reflect also the differential in the relative output gap

$$\widehat{T}_t = \frac{1}{\theta}(y_{H,t} - y_{F,t}^*) + \widetilde{T}_t, \tag{18}$$

where $y_{H,t}$ and $y_{F,t}^*$ are the Home and Foreign output gaps, respectively.[13]

[12] We have that $k \equiv [(1-\alpha\beta)(1-\alpha)/\alpha] \cdot [1/(1+\sigma\eta)]$ and $k^* \equiv [(1-\alpha^*\beta)(1-\alpha^*)/\alpha^*] \cdot [1/(1+\sigma\eta)]$

[13] Note that equation (18) is also in PT: in our microfounded framework their speculative shock is identified as a terms of trade shock.

An open-economy version of the IS curve can be obtained by a weighted average with weights n and $1-n$ of the log-linear approximation of equations (3) and (4):

$$E_t y_{t+1}^W = y_t^W + \rho^{-1} n(\widehat{i}_t - E_t \pi_{H,t+1} - \widetilde{R}_t^W) + \rho^{-1}(1-n)(\widehat{i}_t^* - E_t \pi_{F,t+1}^* - \widetilde{R}_t^W), \quad (19)$$

where $\widehat{i}_t$ and $\widehat{i}_t^*$ are the log deviations from the steady state of the Home and Foreign nominal interest rates, respectively, and $\widetilde{R}^W$ represents the efficient perturbations to the world real interest rate. Note that since markets are complete, we need only one Euler equation, once we use the property that the marginal utilities of consumption are equalized across countries. The Euler equation (19) relates the expected growth in the world output gap to a weighted average of the domestic and foreign real interest rate gaps, expressed as deviations of the real interest rate, in units of domestic-produced and foreign-produced goods respectively, from the efficient world rate. By log-linearizing (5) we obtain the uncovered interest parity which links the expected nominal exchange rate depreciation to the nominal interest rate differential:

$$\mathrm{E}_t \Delta S_{t+1} = \widehat{i}_t - \widehat{i}_t^*. \quad (20)$$

3 Optimal Cooperative Solution

In this section we characterize the efficient response of macroeconomic variables to the various shocks that affect the economy, whether in the form of terms of trade or inefficient supply shocks. This problem has been extensively studied in the Keynesian literature on international monetary cooperation, (see Canzoneri and Henderson, 1991, and PT, 1996). Importantly, we propose both a microfounded model and a welfare criterion, based directly on consumers' utility. This approach is then consistent with other contributions in the open-economy literature, Obstfeld and Rogoff (1998, 2001), Devereux and Engel (2000) and Corsetti and Pesenti (2001b). However, the latter works have focused on static models, in which prices are pre-set one-period in advance and the only source of shocks comes from movements in the terms of trade. Here, we examine the efficient stabilization plan in a dynamic framework where the terms of trade shocks coexist with inefficient supply shocks. As in Benigno and Benigno (2001a) we allow for a non-unitary intratemporal elasticity of substitution between Home and Foreign goods which turns out to affect critically the normative conclusions of the aforementioned works.

In evaluating different regimes, we rely on a quadratic approximation of the welfare criterion, which makes our framework closer to the linear-quadratic models that have been extensively used in the Keynesian literature.[14]

In a closed-economy model, Woodford (1999b) has shown that a quadratic approximation of consumers' utilities can be written as a weighted average of the squares

[14] Obstfeld and Rogoff (2001), Devereux and Engel (2000) and Corsetti and Pesenti (2001b) are instead able to derive exact expressions for the utility-based welfare functions.

of producer inflation rates and output gap. Similarly, from a central planner perspective, our welfare criterion consider the sum of consumers' utilities in the world economy.[15] By taking a quadratic approximation we obtain the following centralized welfare[16]

$$W^C = -\mathrm{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t L_t^C \right\}, \tag{21}$$

where

$$L_t^C = (\rho + \eta) \cdot [y_t^W]^2 + n(1-n)(1+\eta\theta)\theta \cdot [\widehat{T}_t - \widetilde{T}_t]^2 + n\frac{\sigma}{k}(\pi_{H,t})^2 + (1-n)\frac{\sigma}{k^*}(\pi_{F,t}^*)^2.$$

The loss function (21) evaluates the distortions existing in the economy. As in the closed economy framework (Woodford, 1999b), price stickiness, combined with staggered prices, creates an inefficient dispersion of demand across goods that are produced using the same technology. The squares of the producer inflation rates in each country capture these costs. Our criterion penalizes for the deviations of the actual terms of trade from the efficient level. For example, when country H experiences a favorable productivity shocks, the price of the goods produced in this country should fall relative to those produced in country F, in order to distribute demand efficiently from goods produced in country F to those in H. Finally the world output gap should be completely stabilized in a specular way to what happens to the domestic output gap in a closed-economy model.

Three key parameters determine the relative importance of each component. The intertemporal elasticity of substitution is crucial for weighing the world output gap; the intratemporal elasticity between Home and Foreign goods is important for the relative weight of the terms of trade component while the elasticity of substitution across differentiated goods within a country matters in weighing the squares of the producer inflation rates.

The Optimal Stabilization Plan Under Commitment The efficient plan is obtained by maximizing the welfare of society (21) under the structural equilibrium conditions (15) and (16). Equation (17) determines residually the exchange rate, while (19) and (20) determine the optimal path of the nominal interest rates.

Following Currie and Levine (1993) and Woodford (1999a), the optimal plan can be described using the Lagrangian method, with multiplier λ and λ^* associated with

[15] We are disregarding the liquidity services obtained by holding money. In doing this, we are implicitly assuming either that these liquidity services are small with respect to the other terms that contribute to the utility of the consumer or that the model can be intepreted as a cash-less limiting case, as in Woodford (1998).

[16] The quadratic approximation of the welfare function is taken around the steady state in which the taxation subsidy completely offsets the monopolistic distortions in both countries, see Benigno (2001c).

the aggregate supply equations (15) and (16).[17]

The first-order necessary conditions with respect to y_t^W, $\widehat{T}_t$, $\pi_{H,t}$ and $\pi_{F,t}$ are

$$\begin{aligned} y_t^W &= -[n\widetilde{\lambda}_t + (1-n)\widetilde{\lambda}_t^*], && (22)\\ \theta(\widehat{T}_t - \widetilde{T}_t) &= -(\widetilde{\lambda}_t - \widetilde{\lambda}_t^*), && (23)\\ \sigma\pi_{H,t} &= \widetilde{\lambda}_t - \widetilde{\lambda}_{t-1}, && (24)\\ \sigma\pi_{F,t}^* &= \widetilde{\lambda}_t^* - \widetilde{\lambda}_{t-1}^*, && (25) \end{aligned}$$

at each date $t \geq 0$ and for each possible state, where we have defined $\widetilde{\lambda}_t \equiv k\lambda_t$ and $\widetilde{\lambda}_t^* \equiv k^*\lambda_t^*$. In addition, we have the initial conditions

$$\lambda_{-1} = \lambda_{-1}^* = 0, \qquad (26)$$

since there is no previous commitment at time 0. The optimal plan is then described by equations (15), (16), (22), (23), (24), (25) and the initial conditions (26). We can characterize some implications of the optimal cooperative solution without the need of solving this set of equations. Indeed we can use equations (22) and (23) to obtain

$$\begin{aligned} y_{H,t} &= -\widetilde{\lambda}_t, && (27)\\ y_{F,t}^* &= -\widetilde{\lambda}_t^*, && (28) \end{aligned}$$

which imply the following relations between producer inflation rates and output gaps

$$\begin{aligned} \sigma\pi_{H,t} &= y_{H,t} - y_{H,t-1}, && (29)\\ \sigma\pi_{F,t}^* &= y_{F,t} - y_{F,t-1}. && (30) \end{aligned}$$

Under the optimal cooperative solution each country should adjust its domestic producer inflation in response to changes in its domestic output gap. Equations (29) and (30) are similar to the conditions that would hold in the closed-economy case under commitment. As Clarida, Gali and Gertler (1999) and Woodford (1999a) have emphasized, the commitment solution exhibits inertia. The history-dependence of the optimal plan is required to affect in a credible way the expectations of the private sector on the future path of inflation. This happens to be a peculiar characteristic of commitment solution in forward-looking models (see Woodford, 1999a). Not surprisingly, those principles extend to the open-economy cooperative solution.

The first important implication of the optimal stabilization plan can be obtained by observing that from the set of equations (15), (16), (22), (23), (24), (25) and the initial conditions (26), the solution for the normalized Lagrangian multiplier is independent of the shocks $\widetilde{T}_t$.

[17] In order to obtain some simplification, we have multiplied the first lagrangian multiplier by $2n$ while the second multiplier by $2(1-n)$.

Proposition 1 *Following efficient terms of trade shocks, the optimal cooperative policy requires to completely offset these shocks with movements of the exchange rate and of the terms of trade. All the other variables should not respond. The first best is achieved and the optimal cooperative equilibrium replicates the efficient allocation as defined in (12) to (14).*

The optimal response to terms of trade shocks resembles the argument of Friedman (1953) for flexible exchange rates. Whenever there are shocks that requires an efficient adjustment to international relative prices, the easier way to obtain that adjustment, in a world in which producer prices are sticky is through exchange rate changes. According to our welfare criterion, the efficient allocation can be replicated. Indeed this policy avoids the cost of inflation, i.e. of creating dispersion of demand across goods produced with the same technology. A similar result can be found in Benigno (2001a), Devereux and Engel (2000), Obstfeld and Rogoff (2001). However, for it to be true, market completeness and producer currency pricing are crucial assumptions. With incomplete markets, by a second-best arguments, producer inflation rates should be state-contingent (see Obstfeld and Rogoff, 2001 and Benigno, 2001b). With imperfect pass through, instead, the role of the exchange rate as a switching-expenditure device is dampened (see Devereux and Engel, 2000 and Corsetti and Pesenti, 2001b). In a multi-sectorial setting, Canzoneri et al. (2001) show that sector-specific productivity shocks, within country, can create other cases of departure.

The argument for flexible exchange rates does not extend to the case when the economies are affected by inefficient supply shocks. The first best cannot be achieved.

Corollary 2 *In the optimal cooperative solution, following inefficient supply shocks producer inflation rates are state contingent.*

The presence of inefficient supply shocks creates a further distortion in the economy. Stabilizing producer inflation rates to zero is suboptimal and a sticky price allocation can improve upon the flexible price one.

Properties of the Nominal Exchange Rate under Cooperation Despite the fact that the optimal stabilization problem is more complicated, we can obtain some interesting results by inspection. We start by characterizing the behavior of the producer price levels and the nominal exchange rate. Using equations (17), (23), (24) and (25), we obtain that

$$p_{H,t} = \frac{\widetilde{\lambda}_t}{\sigma}, \qquad (31)$$

$$p^*_{F,t} = \frac{\widetilde{\lambda}^*_t}{\sigma}, \qquad (32)$$

$$s_t = \left(\frac{1}{\sigma} - \frac{1}{\theta}\right) \widetilde{\lambda}^R_t + \widetilde{T}_t, \qquad (33)$$

where p_H, p_F^* and s are logs of the producer price levels and the exchange rate, respectively. Conditions (31) – (33) show that the logs of the producer price levels and of the exchange rate are stationary variables since both the Lagrangian multipliers and the shocks are stationary. This results is familiar to the closed-economy literature. As shown in Clarida et al. (1999) and Woodford (2000) prices should go back to the initial level under inefficient supply shocks. In our open-economy context, this property extends directly to the nominal exchange rate. Even if there are no direct costs in the welfare criterion (21) related to the exchange rate volatility, a necessary condition for an allocation to be optimal is that the exchange rate should be stationary following stationary disturbances of any nature (i.e. terms of trade or inefficient supply shocks).

Moreover when $k = k^*$, we can solve for the optimal path of the exchange rate obtaining

$$s_t = \delta_1 s_{t-1} + \left(\frac{1}{\sigma} - \frac{1}{\theta}\right) \frac{\sigma\delta_1}{(1 - \delta_1\beta\omega^R)} u_t^R + \widetilde{T}_t - \delta_1 \widetilde{T}_{t-1},$$

where δ_1 is the stable root associated with the second-order difference equation in $\widetilde{\lambda}_t^R$ and ω^R denotes the autoregressive component of the inefficient relative supply shock, u_t^R. Even when $\omega^R = 0$, the nominal exchange rate displays an inertial behavior following an inefficient relative supply shock. This is strictly related to the inertial nature of the optimal stabilization plan.

Proposition 3 *In the optimal cooperative solution, whether there are efficient terms of trade or inefficient supply shocks, drawn from stationary distributions, producer prices and the exchange rate are stationary variables. In particular, following inefficient supply shocks, the optimal cooperative solution implies a fixed exchange rate regime as long as* $\theta = \sigma$.

The nature of the shocks affects the choice of the exchange rate regime: in fact when $\theta = \sigma$ and the only source of shocks is given by inefficient supply shocks, the optimal cooperative equilibrium implies a fixed exchange rate regime. We can interpret this result by referring to arguments familiar to the optimal-taxation literature. The welfare criterion (21) accounts for the distortions existing in the model. Just as distorting taxes create deadweight losses, distortions that allow monetary policy to have real effects generate costs. And just as the elasticity of the tax base is important in evaluating distortionary taxes, in this case elasticities are important in evaluating the optimal stabilization plan. In particular inefficient terms of trade adjustments are more costly the higher is the elasticity between Home and Foreign goods (θ), since the international inefficient dispersion of output would be greater. Producer inflation rates are more costly the higher is σ, since the inefficient dispersion of prices within a country would be greater. When $\theta = \sigma$, the elasticities that measure the costs of inefficient terms of trade movements and inflation changes are the same: terms of trade and inflation differential should be moved in the same directions and proportions. When $\theta \neq \sigma$, the terms of trade and inflation rate differential should move with different magnitude. The gap is brought about by movements in the exchange rate.

The type of disturbance is then crucial in determining the choice between fixed versus flexible exchange rates: inefficient supply shocks point in favor of fixed exchange rates while terms of trade shocks suggest a flexible exchange rate regime. The case for a fixed exchange rate regime as the optimal cooperative solution seems of particular interest when we look at plausible values for the elasticities. The parameter σ can be directly related to the degree of monopoly power. In the US, a reasonable estimation of the mark-up is 15 percent, which means a value for σ equal to 7.88. Looking at the other parameter, according to some recent studies, such as Harrigan (1993) and Trefler and Lai (1999), a sensible assumption for θ is 6.

The Transmission Mechanism of Inefficient Supply Shocks We now examine how inefficient supply shocks propagate across different countries. We start by considering the special case when $\theta = \rho^{-1}$. Under this restriction, the centralized welfare criterion can be written as a weighted average of Home and Foreign domestic targets

$$L_t^C = nL_{H,t} + (1-n)L_{F,t}, \tag{34}$$

with

$$L_{H,t} = (\rho+\eta)\cdot(y_{H,t})^2 + \frac{\sigma}{k}(\pi_{H,t})^2 \qquad\qquad L_{F,t} = (\rho+\eta)\cdot(y_{F,t}^*)^2 + \frac{\sigma}{k^*}(\pi_{F,t}^*)^2$$

where $L_{H,t}$ and $L_{F,t}$ corresponds to the loss functions that can be obtained from quadratic approximations of the welfare of the single countries, but in a closed-economy model, as shown in Woodford (1999b). Moreover, the two aggregate supply equations collapse to

$$\begin{aligned} \pi_{H,t} &= k(\rho+\eta)y_{H,t} + u_t + \beta E_t \pi_{H,t+1}, \\ \pi_{F,t}^* &= k^*(\rho+\eta)y_{F,t}^* + u_t^* + \beta E_t \pi_{F,t+1}^*. \end{aligned}$$

In the optimal cooperative solution the couple of sequences $\{\pi_{H,t}, y_{H,t}\}$ and $\{\pi_{F,t}^*, y_{F,t}^*\}$ should only react to their respective inefficient supply shocks.

Proposition 4 *When there are asymmetric inefficient supply shocks, if* $\theta\rho = 1$, *the optimal paths for the producer inflation rates and output gaps in each country mirror the one that would arise in a closed-economy model.*

Despite the orthogonality of domestic producer inflation and output gap to foreign inefficient supply shocks, there exist spillover effects that affect the consumption gap, which is risk-shared across countries. However, terms of trade vary in order to insulate any effects of aggregate demand on domestic and foreign output gap. These movements are accompanied by changes in the nominal exchange rate as long as $\theta \neq \sigma$.

Again a look at the data is here necessary to see whether this case is plausible. Rotemberg and Woodford (1997) in their estimated optimizing model find a value for ρ equal to 0.16. Only in this case, ρ^{-1} will be close to θ. On the other hand, Eichenbaum et al. (1988) suggest that a sensible range for ρ is from 0.5 to 3 making this case less plausible.

Using the above limiting case, we now discuss the more general case in which the condition $\theta\rho = 1$ is not met. To this end, we can rewrite the two aggregate supply equations as

$$\pi_{H,t} = k[(\rho+\eta)y_{H,t} + (1-n)(1-\rho\theta)(\widehat{T}_t - \widetilde{T}_t)] + u_t + \beta E_t \pi_{H,t+1}, \quad (35)$$
$$\pi^*_{F,t} = k^*[(\rho+\eta)y^*_{F,t} - n(1-\rho\theta)(\widehat{T}_t - \widetilde{T}_t)] + u^*_t + \beta E_t \pi^*_{F,t+1}, \quad (36)$$

where we have decomposed the real marginal costs in the domestic output gap and terms of trade gap. In the optimal cooperative solution, the transmission mechanism of inefficient supply shocks depends crucially on $\theta\rho$ being greater or less than 1. From (27), (28), (31) and (32), we can observe that the output gap in each country is negatively related to its respective producer price level. Consider a positive (adverse) supply shock in the Home country. As in the closed-economy counterpart, this shock produces on impact inflation in the Home country and a reduction in the output gap. The increase in the producer price level in country H tends to worsen the terms of trade of that country and improve those of country F (i.e. T decreases). The impact on foreign inflation and output gap depends on $\theta\rho$. First, assume $\theta\rho < 1$ (what can be labelled as the 'positive correlated scenario'). From (36), an improvement of the foreign terms of trade increases on impact foreign producer inflation and the foreign producer price level (not enough to offset the initial decrease in T). Then the foreign output gap should also decrease. Under this scenario, an adverse shock in the Home economy will produce the same pattern of producer inflation and output gap in both countries, still with different magnitude. The intuition is related to whether the improvement in the Foreign terms of trade increases or decreases the marginal revenues of the Foreign firms. In fact, marginal revenue in the foreign economy depends on the factor

$$\frac{U_C(C^W_t)P_{F,t}}{P_t} = \frac{U_C\left(Y_{F,t}\left(\frac{P_{F,t}}{P_t}\right)^{\theta}\right)P_{F,t}}{P_t}.$$

This factor represents firms' marginal revenues as if market were perfectly competitive. When the elasticity of the marginal revenue with respect to the terms of trade is positive, an improvement in the Foreign terms of trade decreases the marginal revenues since the increase in the general level of prices P offsets the increase in the marginal utility of consumption. This is so when $\theta\rho < 1$. Given that marginal revenues fall, foreign firms should rise their prices in order to protect their profits. The expenditure switching effect captured by the parameter θ is not so strong to sustain a positive output gap in the foreign economy. So, output gap in the foreign economy falls.

On the other hand, when $\theta\rho > 1$ (what can be labelled as the 'negative correlated scenario'), the marginal revenues of the firms increases in country F, so that they can cut their prices on impact. The foreign output gap increases since the expenditure-switching effect is stronger. In this case, the adverse supply shock produces on impact inflation in the home economy and a deflation in the foreign economy, while home output gap falls and foreign output gap rises. In later quarters, the home economy will experience periods of deflation, while the foreign economy periods of inflation.

An Example We now compare the optimal cooperative solution with an inflation targeting regime, in which each country is committed to stabilize its producer inflation rate in each period, i.e. $\pi_{H,t} = \pi^*_{F,t} = 0$ at each time t and state of nature. We perform the comparison in a calibrated example, where we assume that the slope of the new Keynesian Phillips curve is identical across countries, i.e. $k = k^*$. We calibrate the set of parameters β, η, θ, ρ, σ, ϕ, k following Rotemberg and Woodford (1997) and Benigno (2001b) to 0.99, 0.47, 6, 2, 7.88, 1.5 as if the timing of the model was quarterly. We also assume that the inefficient supply shocks and the terms of trade shocks are distributed according to the following processes

$$\begin{aligned} u_t &= \omega_1 u_{t-1} + \varepsilon_t, \\ u^*_t &= \omega_2 u^*_{t-1} + \varepsilon^*_t, \\ \widetilde{T}_t &= \omega_3 \widetilde{T}_{t-1} + \xi_t \end{aligned}$$

where ε_t, ε^*_t, ξ_t are i.i.d. shocks and $\omega_1 = \omega_2 = \omega_3 = 0.3$.

Figure 1 shows the impulse responses of the relevant variables of the model to a one-time increase in u.[18] Figure 2 shows instead the impulse responses following a one-time increase in $\widetilde{T}$.

As in the closed-economy model, an inflationary inefficient supply shock in country H increases on impact the inflation rate and decreases the output gap . The rise in the home inflation rate appreciates on impact the terms of trade, T decreases. Given the calibration assumed, we are in the 'negative spillover' scenario, where an inflationary shocks in the home country produces a deflation in the other country. The foreign output gap is pushed up in a persistent way. In later quarters the persistent recession in the home economy curbs the inflationary pressure into a deflation, while the opposite happens in the foreign country. Not surprisingly, the exchange rate does not react a lot, since θ and σ are very close. Instead, the inflation-targeting policies stabilize the producer inflation rates at a cost of excess fluctuations in the output gaps and the exchange rate.

[18] We consider a one-time increase in u of one unit that leads to a one unit increase in the home producer inflation rate at an annualized rate, keeping constant the terms of trade gap, the world output gap and the expectations of future producer inflation rates.

Figure 2 shows that the terms of trade shock is absorbed by movements in the exchange rate and terms of trade, in the optimal cooperative solution. In this case, the inflation-targeting policies reproduce the efficient allocation.

4 Implementing the Cooperative Solution

In this section, we investigate whether it is possible that policies taken in a non-cooperative environment can implement the optimal cooperative solution. Recently, Obstfeld and Rogoff (2001) have shown that self-oriented monetary policymakers can replicate the cooperative outcome in a decentralized framework so that there is no need of international monetary policy coordination. In their case, "self-oriented" refers to policymakers that maximize the welfare of the consumers within their countries.

In a previous work (Benigno and Benigno, 2001a) we have shown that, in the presence of efficient terms of trade shocks, there are no gains from coordination when each policymaker is committed to maximize her utility-based welfare function and either $\theta = 1$ or $\rho\theta = 1$. On the other hand the presence of inefficient supply shocks creates always a scope for international monetary policy coordination.[19] Even in the case of no interdependence, i.e. $\rho\theta = 1$, the optimal stabilization plan depends on the nature of the game, being cooperative or non cooperative. The underlying reason is that the optimal cooperative outcome is a second best solution and the perceived trade-off is different whether we consider the country or the central-planner level.

In general, when there are gains from coordination, the evaluation of the welfare of the single countries requires a second-order approximation of the structural equilibrium conditions as in Sutherland (2001) (see also Kim and Kim, 2000 on this point). Here we look at the problem from a different perspective. We try to design institutions that can implement the cooperative solution. In particular we seek to design objective functions for committed monetary policymakers in both countries.[20] These objective functions do not necessarily coincide with the welfares of the country.

Following the recent widespread adoption of inflation-targeting regimes across several countries, we assume that each policymaker is committed to an inflation-targeting regime. As in Svensson (2001), we model these regimes with targeting rules in which policymakers are committed to minimize a given loss functions. In particular we assume that home and foreign policymaker are committed to minimize

[19] Clarida et al. (2001a), focusing on inefficient supply shocks, made a case against the need of international monetary policy coordination since their small-open-economy stabilization problem is similar to a closed-economy one. They obtain this result since they assume an exogenous path for the relevant variables in the world economy. Our model is instead a general-equilibrium one.

[20] In a closed economy, Jensen (2001), Vestin (2000) and Woodford (2000) have studied the design of the objective function of a monetary policymaker that is unable to fulfill credible commitments. In an open-economy model, the implementation of the cooperative solution is still an issue even if policymakers can commit.

their respective loss functions L and L* of the form

$$\mathrm{L} = E_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\varpi(\rho+\eta)y_{H,t}^2+\frac{\sigma}{k}\pi_{H,t}^2\right]\right\} \qquad \mathrm{L}^* = E_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\varpi^*(\rho+\eta)y_{F,t}^{*2}+\frac{\sigma}{k^*}\pi_{F,t}^{*2}\cdot\right]\right\}, \tag{37}$$

where ϖ and ϖ^* are non-negative parameters.

The above loss functions corresponds to 'flexible' inflation-targeting rule, using the terminology of Svensson (2001), where each policymaker is penalized for the deviations of the inflation rate from the target (zero in this case), and for changes in the output gap. In practice, this seems a good representation of the objective function of monetary policymaker in inflation-targeting regimes, as discussed in Svensson (2001), and even in other regimes, see Blinder (1997) for the US case.

The open-economy extension of 'inflation-targeting' regimes requires an additional qualification in terms of choosing the proper measure of inflation rate to target, i.e. whether GDP or CPI inflation. Here we design our regimes in terms of GDP inflation rate for three reasons. Firstly, as shown in works by Aoki (2001) and Benigno (2001a), the inflation originated from sectors affected by price rigidity is the appropriate inflation to target when trying to minimize the distortions existing in the economy. Secondly, the loss functions L and L^*, when ϖ and ϖ^* are equal to one, coincide exactly with the loss functions that one would get as an approximation of the welfare in the closed-economy counterpart of the model presented here, as shown in Woodford (1999b). This property will be useful later in discussing the results. Thirdly, choosing CPI inflation rather than producer inflation would have implied a direct target to the exchange rate. We instead restrict our analysis to policymakers that are *inward-looking* in the sense that their targeting rules include *only* domestic targets.[21] There is another dimension along which the policymakers are self-oriented: we assume that they interact strategically as in a Nash equilibrium when each policymaker sets the strategy in terms of her producer inflation and takes the strategy of the other policymaker as given.

As in Rogoff (1985), our delegation problem boils down to choosing appropriately the relative weights to the output gap and the producer inflation rate in the loss function. In our case the parameters ϖ and ϖ^* are chosen so that the allocation that results from the strategic interaction between the policymakers replicates the cooperative solution.

We show that there is always a positive answer to this problem. We start from the case in which the only disturbances are given by terms of trade shocks.

Proposition 5 *When there are only efficient terms of trade shocks, the decentralized commitment to loss function L and L^* reproduces the cooperative solution for any ϖ and ϖ^*.*

[21] This is different from Obstfeld and Rogoff (2001) where each policymaker maximizes the country specific utility based welfare function. In general this function depends on open economy elements such as the terms of trade.

The case of only terms of trade shocks follows directly from the discussion of the previous sections (see Proposition 1). Stabilizing producer inflation rates to zero, in each country, achieves the first-best. There are enough instruments to cope with all the distortions in the economy. Since in this case there is no trade-off between domestic output-gap and producer inflation rate, then any targeting rule in the class of flexible inflation-targeting rule L and L^* can achieve the first-best in a decentralized framework.

When instead there are inefficient supply shocks, the first-best is not achievable. The following proposition holds.

Proposition 6 *In a Nash equilibrium in which each policymaker is committed to a flexible inflation targeting policy of the form (37), following inefficient supply shocks, the cooperative allocation can be achieved if and only if*

$$\varpi = \frac{\theta(\rho+\eta) + (1-\rho\theta)}{\theta(\rho+\eta) + n(1-\rho\theta)}, \qquad \varpi = \frac{\theta(\rho+\eta) + (1-\rho\theta)}{\theta(\rho+\eta) + (1-n)(1-\rho\theta)},$$

In particular $\varpi > 1$ and $\varpi^* > 1$ if $\rho\theta < 1$ and $\varpi < 1$ and $\varpi^* < 1$ if $\rho\theta > 1$. Note that when $\rho\theta = 1$, then the cooperative allocation can be replicated if and only if $\varpi = \varpi^* = 1$.

As we discussed before when $\rho\theta = 1$ there is complete separation in the optimal stabilization plan between Home and Foreign inefficient supply shocks. Indeed, domestic output gap and inflation rate should react only to domestic inefficient shocks and not to foreign ones. An inspection of the centralized welfare criterion (34) can help to identify the appropriate design of the decentralized solution. It is sufficient that each policymaker commits to maximize its appropriate targets, producer inflation and output gap, in the exact combination as they are in (34). It is again worth noting that when $\varpi = \varpi^* = 1$ the loss functions L and L^* correspond to the losses that one would get as an approximation of the welfare in the closed-economy version of this model. Since there is no strategic interdependence in the stabilization problem, policymakers should act as if they were maximizing the welfare of a closed economy in order to obtain the cooperative solution.[22]

We now discuss the general case, $\rho\theta \neq 1$. We can write equations (35) and (36) using condition (18) as

$$\pi_{H,t} = k[(\rho+\eta)y_{H,t} + (1-n)\frac{(1-\rho\theta)}{\theta}(y_{H,t} - y^*_{F,t})] + u_t + \beta E_t \pi_{H,t+1}, \quad (38)$$

$$\pi^*_{F,t} = k^*[(\rho+\eta)y^*_{F,t} - n\frac{(1-\rho\theta)}{\theta}(y_{H,t} - y^*_{F,t})] + u^*_t + \beta E_t \pi^*_{F,t+1}, \quad (39)$$

[22] However, in the open-economy model, these loss functions do not maximize the welfares of the single countries, since the welfare of each country has an higher weight on the disutility of output relative to the utility consumption than the centralized welfare criterion. Indeed, the disutility of output in the centralized criterion is weighed by the size of the country.

from which we can define

$$p_1 \equiv k[(\rho+\eta)+(1-n)\tfrac{(1-\rho\theta)}{\theta}], \quad p_2 \equiv -k(1-n)\tfrac{(1-\rho\theta)}{\theta},$$
$$p_3 \equiv k^*[(\rho+\eta)+n\tfrac{(1-\rho\theta)}{\theta}], \qquad p_4 \equiv -k^* n\tfrac{(1-\rho\theta)}{\theta}.$$

Combining the above equations we get

$$\pi_{H,t} = p_5 k(\rho+\eta) y_{H,t} + u_t + p_6(\beta E_t \pi^*_{F,t+1} - \pi^*_{F,t}) + p_6 u^*_t + \beta E_t \pi_{H,t+1}, \quad (40)$$
$$\pi^*_{F,t} = p_7 k^*(\rho+\eta) y^*_{F,t} + u^*_t + p_8(\beta E_t \pi_{H,t+1} - \pi_{H,t}) + p_8 u_t + \beta E_t \pi^*_{F,t+1}, \quad (41)$$

where

$$p_5 = \tfrac{p_3 p_1 - p_2 p_4}{p_3 k(\rho+\eta)}, \quad p_6 = \tfrac{p_2}{p_3},$$
$$p_7 = \tfrac{p_3 p_1 - p_2 p_4}{p_1 k^*(\rho+\eta)}, \quad p_8 = \tfrac{p_4}{p_1}.$$

In the Nash allocation, the monetary policymaker in country H maximizes L, under the constraint (40) taken as given the sequence $\{\pi^*_{F,t}\}_{t=0}^{\infty}$ chosen by the policymaker in country F.

The first-order necessary conditions with respect to $y_{H,t}$ and $\pi_{H,t}$ are

$$\varpi y_{H,t} = -p_5 \widetilde{\psi}_t, \quad (42)$$
$$\sigma \pi_{H,t} = \widetilde{\psi}_t - \widetilde{\psi}_{t-1}, \quad (43)$$

at each date $t \geq 0$ and for each possible state, where ψ_t is the Lagrangian multiplier associated with the constraint (40); we have defined $\widetilde{\psi}_t \equiv k\psi_t$. In addition, we have the initial conditions

$$\psi_{-1} = 0. \quad (44)$$

Looking at the problem of policymaker F and maximizing L^* with respect to $y_{F,t}$ and $\pi^*_{F,t}$, we obtain that

$$\varpi^* y^*_{F,t} = -p_7 \widetilde{\psi}^*_t, \quad (45)$$
$$\sigma \pi^*_{F,t} = \widetilde{\psi}^*_t - \widetilde{\psi}^*_{t-1}, \quad (46)$$

at each date $t \geq 0$ and for each possible state, where ψ^*_t is the Lagrangian multiplier associated with the constraint (40) and $\widetilde{\psi}^*_t \equiv k^* \psi^*_t$. In addition, we have the initial conditions

$$\psi^*_{-1} = 0. \quad (47)$$

The set of equilibrium conditions (15), (16), (42), (43), (45), (46) with the initial conditions (44), (47) are equivalent to the set of equilibrium conditions that characterize the optimal cooperative solution if and only if $\varpi = p_5$ and $\varpi^* = p_7$.

Even if there is a need of monetary coordination at an international level, this need can be satisfied by delegating monetary policy to *inward-looking* institutions that care only about domestic objectives. In particular in the 'positive-correlated scenario', a relative higher weight should be given to the stabilization of the domestic output gap in comparison to the scenario in which there is no strategic interdependence across countries ($\rho\theta = 1$). The intuition for this result can be understood by inspecting equations (38) and (39). In fact, an adverse inefficient supply shock can be absorbed by an increase in home producer inflation, a decrease in home output gap and in the one-period ahead expectations on the producer inflation rate. When $\rho\theta < 1$ and while acting strategically, each policymaker has an incentive to lower her output gap below the foreign one in order to export the shock to the other country, through an appreciation of her own terms of trade. This incentive creates a 'contractionary' bias that can be corrected by assigning a relatively higher weight to the output gap in the flexible inflation-targeting regime. On the contrary, when $\rho\theta > 1$, each country would tend to be more expansionary reducing less the output gap and increasing more the response of the producer inflation rate. This 'expansionary bias' can be corrected by giving higher weight to the inflation rate than to the output gap in the loss function.

A final result is related to the degree of openness. The more open is a country, i.e. the more the country is affected by terms of trade movements, the higher is the conflict in the stabilization problem. In this case the correction should be greater. Indeed, if for example $n < 1/2$, the home country will be more open (and the foreign country more closed), then $\varpi > \varpi^* > 1$ if $\rho\theta < 1$ and $\varpi < \varpi^* < 1$ if $\rho\theta > 1$.

5 Conclusions

In this work we proposed a standard two country dynamic general equilibrium model with imperfect competition and nominal price rigidities. Despite goods and financial market integration, the scope for international monetary policy coordination arises from two sources: the interaction between non-unitary intratemporal elasticity of substitution and terms of trade shocks (see Benigno and Benigno, 2001a and Sutherland, 2001) and the presence of inefficient supply shocks.

While the nature of the shock is important in determining the optimal choice of exchange rate regime, we show that by committing to a properly designed flexible inflation targeting regimes our monetary authorities can replicate the optimal outcome independently of the type of shock. Importantly these institutions are *"inward-looking"* in the sense that each policymaker cares *only* about domestic targets –the output gap and the domestic producer inflation rate.

Further research should investigate the robustness of these findings when asset markets are incomplete and when there are deviations from the assumption of producer currency pricing.

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Figure 1: Impulse Response Functions, Inefficient Supply Shocks.

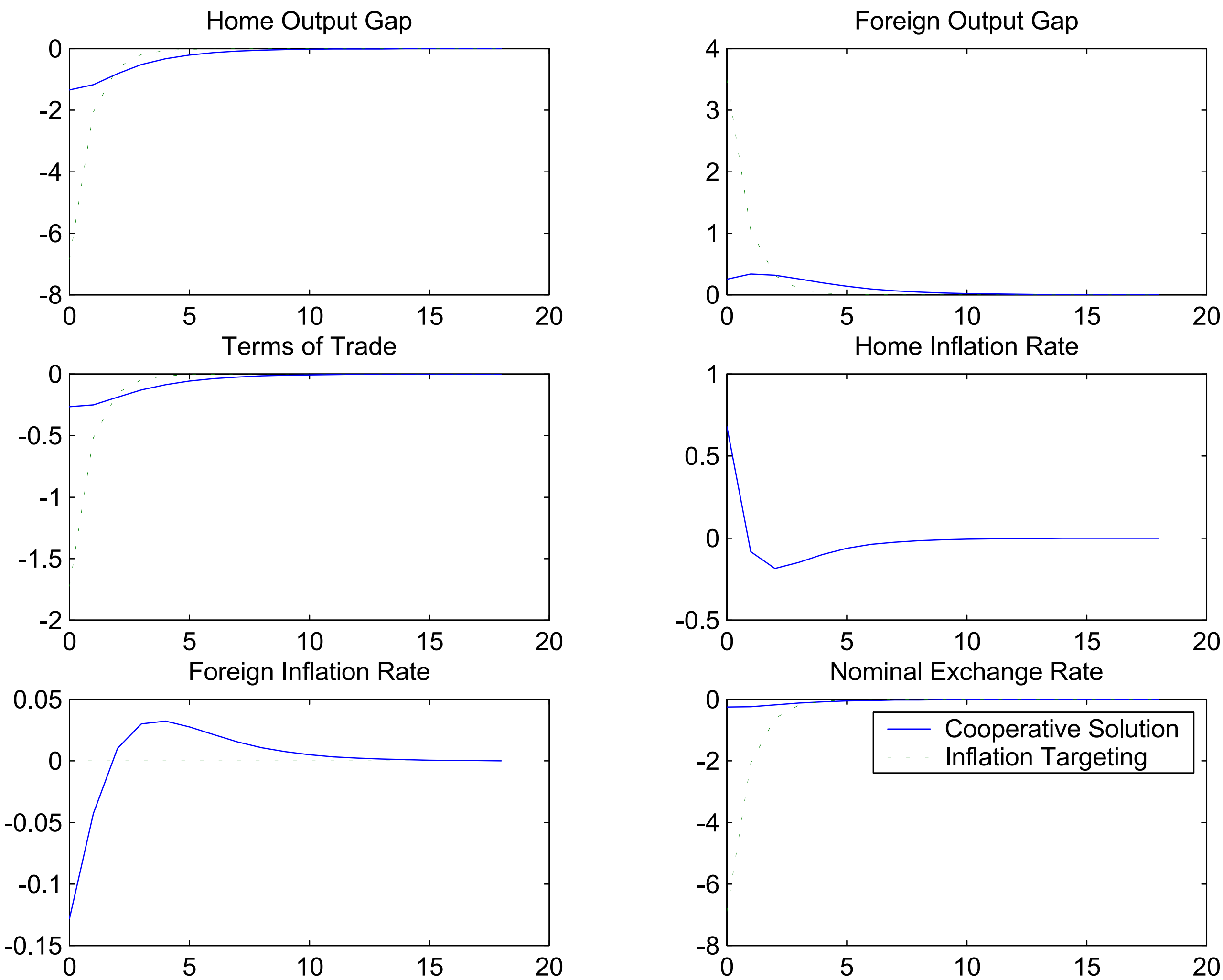

Figure 2: Impulse Response Functions, Terms of Trade Shocks.