Exchange Rate Stabilization and Welfare

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Abstract

This article considers recent literature on optimal monetary policy in simple open-economy models. The presence of pricing to market, incomplete financial markets, and differences in preferences among households (in different countries) introduces some fundamental differences between closed- and open-economy New Keynesian models. In addition to the goals of stabilizing inflation and the output gap, policy makers may target currency misalignments and global imbalances. Optimal policies may involve targeting the exchange rate both directly, because of currency misalignments, and indirectly, because of the effects of exchange rates on imbalances, inflation, and output gaps.

1. INTRODUCTION

Simple, closed-economy, welfare-based New Keynesian policy models focus on the policy trade-offs between stabilizing inflation and reducing the output gap (e.g., see Clarida et al. 1999; Woodford 2003, 2010b). Under welfare-based stabilization, one goal of policy is to minimize the distortions from sticky nominal prices that lead to a misallocation of resources. Inflation is a problem in an economy in which prices are not adjusted continuously, and in which price setting is staggered, because prices do not purely signal relative scarcity, so productive resources are not used efficiently. Firms that adjust their price in a given period will find that demand for their product changes relative to firms that do not, even when there are no changes in tastes or productivity. In addition to the misallocation of productive resources across firms (some producing too much relative to an efficient allocation, and some too little), there may also be overall under- or over-employment of labor and capital, leading to an output gap. In many cases, policies that drive inflation toward zero will also help to eliminate the output gap. However, in the presence of other distortions, such as time-varying monopoly power that leads to cost-push shocks, there may be a trade-off between inflation and output objectives.

This brief review inquires whether there is something different in the analysis of open economies compared to that of closed economies and, in particular, whether eliminating exchange rate misalignments should be an objective of monetary policy separate from the goals of reducing inflation and eliminating output gaps. In other words, if policy could successfully eliminate the output gap and drive inflation to its target, would there be any reason for concern about the exchange rate?

The answer, in short, is yes, according to recent research into optimal monetary policy in open New Keynesian economies. The important difference between the simplest versions of closed- and open-economy macroeconomic models is heterogeneity. Closed-economy models often assume that all consumers have identical tastes (the representative household assumption), that there are complete markets to share risk within the country, and that all consumers face the same prices. Although one could make the same set of assumptions for open economies (and, indeed, many early contributions to the open-economy monetary policy literature did just that), it is at the risk of doing violence to reality. Households in different countries may have different tastes—for example, a home bias that gives greater weight in utility to goods produced domestically. Capital markets may not allow for as much risk sharing among households in different countries as within countries. And there may be pricing to market so that consumers in different countries do not face identical prices for identical goods. All these aspects of open economies may lead to important modifications of policy rules derived in closed-economy settings (for important contributions to the study of the two-country optimal monetary policy problem, see Clarida et al. 2002, Obstfeld & Rogoff 2002, Benigno & Benigno 2003, Devereux & Engel 2003, Devereux 2004, Corsetti & Pesenti 2005).

In a bare-bones, closed-economy model, there is no need for relative price adjustment to allocate resources across goods because all producers are assumed to face identical productivity shocks, all goods enter the utility function symmetrically, and all consumers have identical preferences. However, even the simplest open-economy model must take into account that goods produced in different countries are different—there may be country-specific productivity shocks, and households in different countries may have different preferences over goods produced in each country. Also in contrast to a closed economy, the relative prices of goods in an open economy can potentially adjust, even with no change in nominal goods prices, because the exchange rate may play a role. If goods prices are set in the currency of the producer—producer currency pricing (PCP)—then when a country's currency depreciates, its goods will become cheaper abroad.

It is natural to assume that all households in a closed economy face the same prices for identical goods. There certainly is the possibility of market segmentation and pricing to market in closed economies, but it is reasonable to assume that the macroeconomic consequences are not first order. However, in open economies, there is evidence that there are large differences in consumer prices for very similar goods faced by households in different countries. Moreover, these price differences fluctuate greatly over time and are associated with changes in nominal exchange rates (see Burstein & Gopinath 2014 for a recent survey of the empirical evidence and theoretical models of pricing to market). These facts are broadly consistent with the assumption that consumer prices are set in the currency of the consumer, even for imported goods—local currency pricing (LCP). The presence of LCP introduces a distinct distortion into the analysis of open economies, arising from the failure of the law of one price. As the exchange rate changes, the deviation from equal prices across countries changes.

It is not necessary to be dogmatic about modeling prices as PCP or LCP. Consumer goods surely are priced in local currency, and prices are sticky in the local currency. But many traded goods are intermediate goods. Indeed, even a finished consumer good really is not a final consumer good because it must be transported and distributed to households (see Burstein et al. 2003, 2005; Corsetti & Dedola 2005). Many exported intermediate goods have prices set in the currency of the producer. The distinction between PCP and LCP plays an important role in open-economy monetary policy analysis.

Consider this stylized setting, which may in fact be a reasonable first pass at describing trade and pricing among high-income advanced economies. Two countries (Home and Foreign) may trade goods with each other that are reasonably close but not perfect substitutes. For example, there is a great deal of trade across the Atlantic that involves cross hauling—the United States may export some products within a narrow category of goods but import other products in the same category from Europe. Each good is priced by the producer in its own currency and imported by a distributor. The distributor provides the service of bringing the good to the market, where it will be available for households to buy, and sets a price in the local currency. In this setting, goods are priced by PCP when they reach the dock and LCP when they reach the consumer.

What role does the exchange rate play in achieving efficient allocations? On the one hand, movements in the exchange rate may facilitate relative price movements between Home and Foreign exports at the dock, if it responds appropriately to shocks to productivity or preferences. On the other hand, exchange rate changes could exacerbate the pricing to market distortion because of the LCP of consumer goods (see Devereux & Engel 2007 for an analysis of this setting in a static model; see also Duarte & Obstfeld 2008). An important question for the theory of monetary policy in open economies is whether an optimal policy should attempt to target movements in the exchange rate, or whether the exchange rate is best left to float freely while monetary authorities stick to targeting inflation and the output gap.

In a closed economy, a reasonable simplifying assumption is that agents have access to a complete market of financial assets (i.e., perfect risk sharing). That assumption may not be so reasonable for analyzing open economies. Barriers to capital flows may arise from political, technological, or informational barriers. Indeed, policy makers may be concerned about global imbalances. Current account imbalances can imply wealth redistribution across countries, which provides evidence of market incompleteness (see Ferrero et al. 2010 for a quantitative analysis of monetary policy and the current account). However, in practice, these imbalances very imperfectly measure global wealth reallocations because they omit a role for valuation changes in durable assets (stocks, bonds, and real assets) (see Gourinchas & Rey 2007). The exchange rate can influence international wealth reallocation. To the extent that the exchange rate influences the relative prices of goods, it can change demand for goods and influence trade imbalances. Exchange rate changes also have valuation effects as assets generally have nominal denominations, so the value of a Foreign-denominated asset rises with a Home depreciation.

As this article explains, there is a close parallel between the inefficiencies introduced into global allocations by pricing to market and those introduced by incompleteness of asset markets. Note that the emphasis here is on global allocations. This article surveys recent work that characterizes monetary policy in a cooperative setting, in which the objective is to maximize a measure of global welfare (in a two-country setting) based on Home and Foreign utility. (Closely related important contributions in a small-country context are Gali & Monacelli 2005, Benigno 2009, and de Paoli 2009.) There are two reasons for this focus, rather than considering noncooperative policy games. First, the literature has not recently advanced as far in the analysis of optimal noncooperative monetary policy, so there is less to report. Second, noncooperative policy may involve exchange rate targeting that is beneficial to the country setting the policy but that is harmful to its trading partners (so-called beggar-thy-neighbor policies). In the current international political environment, any monetary policy that appears to deliberately manipulate exchange rates is met with a great deal of opprobrium. In a sense, policy makers have reached a consensus in which they cooperate on exchange rate policy, with an agreement that no country should include the currency as a target of monetary policy. The question raised by the literature is whether that is the appropriate optimal cooperative policy.

This review is highly selective and narrow. It examines simple algebraic characterizations of both the optimal loss function that cooperative policy makers should use under commitment and the optimal targeting rules. (The framework used here draws heavily on Clarida et al. 2002, Benigno & Benigno 2006, Engel 2011, and Corsetti et al. 2010, 2011.) Specifically, it considers models with sparse macroeconomic structures—for example, goods are produced using only labor; financial markets may be exogenously incomplete, but there are no credit constraints or the possibility of default; and there is no unused capacity in production. The models are analyzed in a linear quadratic framework, in which the economy is approximated around an efficient nonstochastic steady state. The early closed-economy optimal monetary policy literature in New Keynesian economies took this approach but quickly advanced to the examination of more complex model economies using more general solution algorithms. Indeed, the open-economy literature has followed close on the heels of the closed-economy literature and incorporated these innovations.

However, there is still room for progress with the very simple analytical models in the open economy because there are conceptual problems that remain unresolved: To what extent, if any, should monetary policy target international variables such as the exchange rate and trade imbalances? Are there other macroeconomic quantities that should be targeted? These simple algebraic models are useful for conveying intuition and simple messages to policy makers about what matters and why. To that end, this article looks at some recent work that derives optimal loss functions for cooperative policy making under commitment, expressing the losses relative to an efficient benchmark in terms of readily measurable and monitored economic variables.

In addition, this work characterizes optimal policy in terms of targeting rules rather than instrument rules (see Svensson 1999, 2002). An instrument rule under commitment, such as a Taylor rule, specifies a reaction function for how the policy instrument (e.g., the interest rate) should respond to a set of macroeconomic variables. A targeting rule under commitment specifies the trade-offs policy makers face in implementing optimal policy. In essence, a targeting rule is a first-order condition for the problem of minimizing the loss function. In practice, policy makers' commitments are probably better described by targeting rules—the trade-off between inflation and the output gap that they aim for, for example. Targeting rules are more robust than instrument rules, in the sense that when the stochastic processes driving the exogenous variables in the economy change, the optimal instrument rule will almost certainly change, but the optimal targeting rule may remain invariant (see Giannoni & Woodford 2010 for a general characterization of optimal target criteria).

A model is laid out in Section 2 that forms the framework for the analysis. This model is based directly on the work of Clarida et al. (2002), Benigno (2004), Engel (2011), Woodford (2010a), and Corsetti et al. (2010, 2011).[1]

2. THE MODEL

There are two countries of equal size, called Home and Foreign. Each country is inhabited by a continuum of households, all identical within each country, normalized to a total of one in each country. Households have utility over the consumption of goods and disutility from the provision of labor services. In each country, there is a continuum of goods produced, each by a monopolist. Households supply labor to firms located within their own country and get utility from all goods produced in both countries. Each household is a monopolistic supplier of a unique type of labor to firms within its country. Monopolistic firms produce output using only labor, subject to technology shocks.

2.1. Households

The representative Home household maximizes

$$U_t(h) = E_t\left\{\sum_{j=0}^{\infty}\beta^j\left[\frac{1}{1-\sigma}C_{t+j}(h)^{1-\sigma} - \frac{1}{1+\phi}N_{t+j}(h)^{1+\phi}\right]\right\}, \sigma > 0, \phi \geq 0, \tag{1}$$

where $C_t(h)$ is the consumption aggregate, β is the discount factor in utility, σ is the inverse of the intertemporal elasticity of substitution, and ϕ is the inverse of the Frisch elasticity of labor supply. Household h has constant elasticity of substitution (CES) preferences defined over an aggregate of Home-produced and Foreign-produced goods, $C_{Ht}(h)$ and $C_{Ft}(h)$. The elasticity of substitution between Home and Foreign aggregates is given by $\varepsilon > 0$. Much of the literature assumes Cobb-Douglas preferences ($\varepsilon = 1$), but Corsetti et al. (2010, 2011) derive the more general case and demonstrate that some conclusions may depend critically on this elasticity. Empirically, there is no clear answer on how to calibrate this elasticity because at business cycle frequencies it is low (less than one, possibly) but is much higher (perhaps around eight) in the long run. A model such as this, with CES preferences and no rigidities that lead to a slow adjustment in trade volumes, will not capture both these empirical regularities, so the model already has a clear limitation.

Preferences in the two countries may differ in that Home households may put a higher weight, $\nu/2$, $1 \leq \nu \leq 2$, in utility on goods produced in Home, and $(2-\nu)/2$ on Foreign goods. This is a shortcut way of modeling openness—countries that are less open exhibit more bias in favor of their own goods. When $\nu > 1$, Home households exhibit home bias in their preferences. Foreign households' preferences are symmetric, with weight $\nu/2$ on Foreign goods.

In turn, $C_{Ht}(h)$ and $C_{Ft}(h)$ are CES aggregates over a continuum of goods produced in each country, with the elasticity of substitution among both Home and Foreign varieties equal to $\xi > 1$.

[1]There are many other studies that use similar models. Engel's (2011) model is a special case of Benigno's (2004) with symmetry across goods and countries. Engel's model generalizes Clarida et al. (2002) by allowing for home bias in preferences and LCP. Corsetti et al. (2010, 2011) generalize Engel's model by allowing a nonunitary elasticity of substitution among Home and Foreign aggregate goods and, crucially, by allowing for incomplete financial markets.

Foreign households have the same elasticity of substitution among these varieties. It is plausible to assume $\xi > \varepsilon$ so that varieties produced within countries are closer substitutes than the Home and Foreign aggregates are for each other.

$N_t(h)$ is an aggregate of the labor services that the Home household sells to each of a continuum of Home firms. Households receive wage income, $W_t(h)N_t(h)$, and a share of aggregate profits from Home firms. They pay lump-sum taxes each period. We consider various specifications of the menu of assets available to households below.

Foreign households have analogous preferences.

2.2. Firms

Each Home good, $Y_t(f)$, is made according to a production function that is linear in the labor input:

$$Y_t(f) = A_t N_t(f).$$

The productivity shock, A_t, is common to all Home firms. $N_t(f)$ is a CES composite of Home individual household labor. The elasticity of substitution among varieties of Home labor, η_t, is stochastic and common to all Home firms.

Profits are given by

$$\Gamma_t(f) = P_{Ht}(f)C_{Ht}(f) + E_t P^*_{Ht}(f)C^*_{Ht}(f) - (1-\tau_t)W_t N_t(f),$$

where E_t is the nominal exchange rate, $P_{Ht}(f)$ is the Home currency price of the good when it is sold in Home, and $P^*_{Ht}(f)$ is the Foreign currency price of the good when it is sold in Foreign. τ_t is a subsidy to the Home firm from the Home government. $C_{Ht}(f)$ represents aggregate sales of the Home good in Home, and $C^*_{Ht}(f)$ are aggregate sales of the Home good in Foreign. It follows that $Y_t(f) = C_{Ht}(f) + C^*_{Ht}(f)$.

There are analogous equations for $Y^*_t(f)$, with the foreign productivity shock given by A^*_t, the foreign technology parameter shock given by η^*_t, and the foreign subsidy given by τ^*_t.

2.3. Goods Pricing

We assume that firms are owned by households within their own country, and there is no trade in equities. Under PCP, firms set prices in their own country's currency and face a Calvo pricing technology. We assume that the PCP firm sets a single price in its own currency, so the law of one price holds. Under LCP, when firms are allowed to change prices according to the Calvo pricing rule, they set a price in their own currency for sales in their own country and a price in the other country's currency for exports. A given firm may reset its prices with probability $1 - \theta$ each period. When the firm resets its price, it will be able to reset its prices for sales in both markets.

Under PCP, the Home firm that selects its price at time t chooses its reset prices, $P^0_{Ht}(f)$, to maximize

$$E_t \sum_{j=0}^{\infty} \theta^j Q_{t,t+j}\left[P^0_{Ht}(f)\left(C_{Ht+j}(f) + C^*_{Ht+j}(f)\right) - (1-\tau_t)W_{t+j}N_{t+j}(f)\right],$$

subject to the sequence of demand curves from Home and Foreign households. In this equation, we define $Q_{t,t+j} \equiv \beta^j \left(C_{t+j}/C_t\right)^{-\sigma}\left(P_t/P_{t+j}\right)$ as the stochastic discount factor.

Under the Calvo price-setting mechanism, a fraction θ of prices remain unchanged from the previous period. We can write

$$P_{Ht} = \left[\theta(P_{Ht-1})^{1-\xi} + (1-\theta)\left(P^0_{Ht}\right)^{1-\xi}\right]^{1/(1-\xi)}.$$

Under LCP, the firm sets its price for export in the importer's currency rather than its own currency when it is allowed to reset prices. The Home firm, for example, sets $P^*_{Ht}(f)$ in Foreign currency. The firm that can reset its price at time t chooses its reset prices, $P^0_{Ht}(f)$ and $P^{0*}_{Ht}(f)$, to maximize

$$E_t\sum_{j=0}^{\infty}\theta^j Q_{t,t+j}\left[P^0_{Ht}(f)C_{Ht+j}(f) + E_t P^{0*}_{Ht}C^*_{Ht+j}(f) - (1-\tau_t)W_{t+j}N_{t+j}(f)\right].$$

As in the PCP case, a fraction θ of prices remain unchanged from the previous period. The evolution of P_{Ht} and P^*_{Ht} is determined in the standard way in Calvo pricing models. Foreign prices are set analogously to Home prices.

2.4. Equilibrium in Goods Markets

Because preferences are homothetic, the demand for goods can be expressed as a function of prices and aggregate consumption in each country. Goods market–clearing conditions in Home and Foreign are given by

$$Y_t = C_{Ht} + C^*_{Ht} = \frac{\nu}{2}\left(\frac{P_{Ht}}{P_t}\right)^{-\varepsilon}C_t + \left(\frac{2-\nu}{2}\right)\left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\varepsilon}C^*_t, \tag{2}$$

$$Y^*_t = C_{Ft} + C^*_{Ft} = \frac{2-\nu}{2}\left(\frac{P_{Ft}}{P_t}\right)^{-\varepsilon}C_t + \left(\frac{\nu}{2}\right)\left(\frac{P^*_{Ft}}{P^*_t}\right)^{-\varepsilon}C^*_t. \tag{3}$$

In these equations, P_t is the exact price index for consumption, given by

$$P_t = \left(\frac{\nu}{2}P^{1-\varepsilon}_{Ht} + \frac{2-\nu}{2}P^{1-\varepsilon}_{Ft}\right)^{1/(1-\varepsilon)}.$$

The Foreign consumer price index, P^*_t, is defined analogously. P_{Ht} is the Home currency price of the Home aggregate good, and P_{Ft} is the Home currency price of the Foreign aggregate good when purchased in Home. P_{Ht} and P_{Ft} are the usual CES aggregates over prices of individual varieties. P^*_{Ht} and P^*_{Ft} are the Foreign currency prices of these aggregates in Foreign.

Wages are set flexibly by monopolistic suppliers of labor and incorporate a markup over their utility cost of work. The government can set a constant output subsidy rate for monopolistic firms, which will achieve an efficient allocation in the nonstochastic steady state. But the markup charged by workers is time-varying because the elasticity of demand for their labor services is assumed to follow a stochastic process. These shocks are sometimes labeled cost-push shocks. From the first-order condition for each household's choice of labor supply, and using the fact that all Home households are identical, we have

$$W_t/P_t = \left(1/(\eta_t - 1)\right) C_t^{\sigma} N_t^{\phi}. \tag{4}$$

Total Home employment is determined by output in each industry:

$$N_t = \int_0^1 N_t(f)df = A_t^{-1} \int_0^1 Y_t(f)df = A_t^{-1}\left(C_{Ht}V_{Ht} + C_{Ht}^* V_{Ht}^*\right), \tag{5}$$

where

$$V_{Ht} \equiv \int_0^1 \left(\frac{P_{Ht}(f)}{P_{Ht}}\right)^{-\xi} df \text{ and } V_{Ht}^* \equiv \int_0^1 \left(\frac{P_{Ht}^*(f)}{P_{Ht}^*}\right)^{-\xi} df.$$

Again, equations analogous to Equations 4 and 5 hold for Foreign firms and households.

2.5. Financial Markets

We consider three different financial market arrangements. In the first, a complete set of state-contingent claims is traded. The familiar equilibrium condition in this case is[2]

$$\left(\frac{C_t}{C_t^*}\right)^{\sigma} = \frac{E_t P_t^*}{P_t}. \tag{6}$$

In the second setup, there is a complete set of contingent claims, but there is a financial market imperfection arising from a tax on (or subsidy to) the proceeds of payoffs from state-contingent claims. Devereux & Yetman (2012) introduce this distortion to financial markets, which creates a wedge between the returns to contingent claims for Home and Foreign households. The revenue from the tax (or cost of the subsidy) is redistributed as (financed by) lump-sum transfers (taxes).[3] Instead of Equation 6, we have

$$\left(\frac{C_t}{C_t^*}\right)^{\sigma} = \frac{E_t P_t^*}{P_t}(1 + t_t). \tag{7}$$

We take this tax as exogenously imposed by some political decision maker from which the monetary policy maker is independent. The tax takes the form

$$1 + t_t = \left(\frac{P_{Ht}C_{Ht} + P_{Ft}C_{Ft}}{P_{Ht}C_{Ht} + E_t P_{Ht}^* C_{Ht}^*}\right)^{\frac{1-\lambda}{\lambda}}. \tag{8}$$

When $\lambda = 1$, the tax is zero, and markets are complete. When $\lambda = 0$, then Equations 7 and 8 imply that trade is balanced: $P_{Ft}C_{Ft} = E_t P_{Ht}^* C_{Ht}^*$. For $0 < \lambda < 1$, if Home has a trade deficit, so $P_{Ft}C_{Ft} > E_t P_{Ht}^* C_{Ht}^*$, then Equations 7 and 8 imply that the tax is positive. In this formulation, the deviation from the complete market's equilibrium is a simple function of the trade imbalance, which (as seen below) will imply that one goal of monetary policy is to eliminate imbalances. The parameter λ may be thought of more generally as an index of market completeness (where 0 is no trade in assets and 1 is completeness.) The smaller is λ, the less are the opportunities for risk

[2]We assume Home and Foreign initially have equal wealth evaluated at state-contingent prices.

[3]Given that we explore optimal cooperative monetary policy, it does not matter which country imposes the tax.

sharing. The Devereux-Yetman framework, however, has no channel through which one country's households can smooth consumption by acquiring claims on households of the other country.

The third possibility that we consider is that only a nominal non-state-contingent bond (denominated in Home currency) is traded. The aggregate budget constraint is given by

$$P_{Ft}C_{Ft} + B_t = E_t P^*_{Ht} C^*_{Ht} + (1 + i_t) B_{t-1}, \quad (9)$$

where B_{t-1} represents interest-bearing bonds acquired in period $t-1$ that pay interest i_t in period t.

Following Corsetti et al. (2010, 2011), we can define the relative demand gap, F_t, as the marginal utility of a unit of currency for Foreign households relative to Home households:

$$F_t = \left(C_t^{*-\sigma}/E_t P_t^*\right)/\left(C_t^{-\sigma}/P_t\right). \quad (10)$$

If markets are complete, then from Equation 6, we obtain $F_t = 0$. If $F_t \neq 0$, then markets are incomplete. If state-contingent payoffs are taxed as in Equation 7, then we have $F_t = 1 + t_t$.

2.6. Log-Linearized Model

In this section, we take a log-linear approximation of the model above around the efficient nonstochastic steady state. That is, we assume that shocks are small so that the approximations are reasonable and, furthermore, that policies are in place (such as constant taxes, noted below) that make the nonstochastic steady state efficient. The assumption that policies render the nonstochastic steady state efficient is one of convenience that in many cases greatly simplifies some algebraic expressions in the article.[4] Lowercase letters refer to the deviation of the log of the corresponding uppercase letters from the log of the steady state.

If there is pricing to market, Engel (2011) shows that under the pricing rules defined above, the currency misalignment is equal for both Home and Foreign aggregate goods:

$$m_t \equiv e_t + p^*_{Ht} - p_{Ht} = e_t + p^*_{Ft} - p_{Ft}. \quad (11)$$

We can define the terms of trade as

$$s_t \equiv p_{Ft} - p_{Ht} = p^*_{Ft} - p^*_{Ht}, \quad (12)$$

where the second equality follows from Equation 11.

The market-clearing conditions (Equations 2 and 3) are approximated as

$$y_t = \frac{\nu}{2} c_t + \frac{2-\nu}{2} c^*_t + \frac{\varepsilon\nu(2-\nu)}{2} s_t, \quad (13)$$

$$y^*_t = \frac{\nu}{2} c^*_t + \frac{2-\nu}{2} c_t - \frac{\varepsilon\nu(2-\nu)}{2} s_t. \quad (14)$$

We can approximate the financial market equilibrium condition in Equation 10 as

[4]Benigno & Woodford (2012) present a more general linear quadratic approach without the assumption that policies are in place to make the nonstochastic steady state efficient.

$$\sigma c_t - \sigma c_t^* = m_t + f_t + (\nu - 1)s_t. \tag{15}$$

We define relative and world values for any variables x_t and x_t^* as $x_t^R \equiv (1/2)(x_t - x_t^*)$ and $x_t^W \equiv (1/2)(x_t + x_t^*)$. We can use Equations 13–15 to express c_t, c_t^*, s_t, and s_t^* in terms of y_t and y_t^* and the price deviations, m_t:

$$c_t^R = \frac{\nu - 1}{D} y_t^R + \frac{\varepsilon\nu(2-\nu)}{2D}(m_t + f_t), \tag{16}$$

$$c_t^W = y_t^W, \tag{17}$$

$$s_t = \frac{2\sigma}{D} y_t^R - \frac{(\nu - 1)}{D}(m_t + f_t), \tag{18}$$

where $D \equiv \varepsilon\sigma\nu(2-\nu) + (\nu - 1)^2$.

When there is a complete set of contingent claims but a distortionary tax, as in Equations 7 and 8, f_t is given by

$$f_t = \frac{2(1-\lambda)(2-\nu)\big(\sigma(\varepsilon\nu - 1) + 1 - \nu\big)}{(1-\lambda)(2-\nu)\big(1+\nu(\varepsilon - 1)\big) - 2\lambda D} y_t^R - \frac{(1-\lambda)(2-\nu)\big(1+\nu(\varepsilon-1) - D\big)}{(1-\lambda)(2-\nu)\big(1+\nu(\varepsilon-1)\big) - 2\lambda D} m_t. \tag{19}$$

When $\lambda \neq 0$, the capital market distortion f_t is, from Equation 8, equal to $(1-\lambda)/\lambda$ times the log of the ratio of Home expenditures relative to Home income from sales of its output. Thus, f_t is positive when Home runs a trade surplus and negative when it runs a trade deficit. In the case in which all capital flows are shut off and trade is forced to be balanced in every period ($\lambda = 0$), Equation 19 reduces to

$$f_t = \frac{2\big(\sigma(\varepsilon\nu - 1) + 1 - \nu\big)}{1 + \nu(\varepsilon - 1)} y_t^R + \frac{D - 1 - \nu(\varepsilon - 1)}{1 + \nu(\varepsilon - 1)} m_t. \tag{20}$$

When only a non-state-contingent bond is traded, so that the economy faces the constraint in Equation 9, then f_t is given by

$$f_t = \frac{-2D}{(2-\nu)\big(1+\nu(\varepsilon-1)\big)}\left(b_t - \beta^{-1} b_{t-1}\right) + \frac{2\big(\sigma(\varepsilon\nu - 1) + 1 - \nu\big)}{1+\nu(\varepsilon - 1)} y_t^R + \frac{D - 1 - \nu(\varepsilon-1)}{1+\nu(\varepsilon-1)} m_t, \tag{21}$$

where b_t denotes the level (not the log) of the Home economy's holdings of bonds divided by steady-state nominal output. If the economy were constrained to zero bond holdings, and so had balanced trade, then Equation 21 reduces to Equation 20.

The first-order condition in Equation 4 is approximated as

$$w_t - p_{Ht} = \sigma c_t + \phi n_t + \frac{2-\nu}{2} s_t. \tag{22}$$

The labor market–clearing conditions given by Equation 5 can be approximated as $n_t = y_t - a_t$, and $n_t^* = y_t^* - a_t^*$.

Under PCP and LCP, following the usual derivations, we obtain a log-linearized New Keynesian Phillips curve for an open economy:

$$\pi_{Ht} = \delta(w_t - p_{Ht} - a_t) + \beta E_t \pi_{Ht+1},$$

or

$$\pi_{Ht} = \delta\left[\left(\frac{\sigma}{D} + \phi\right)\tilde{y}_t^R + (\sigma + \phi)\tilde{y}_t^W + \frac{D - (\nu - 1)}{2D}(m_t + f_t)\right] + \beta E_t \pi_{Ht+1} + u_t, \tag{23}$$

where $\delta \equiv (1 - \theta)(1 - \beta\theta)/\theta$, and $u_t \equiv \delta/(\eta_t - 1)$.

Here we introduce the notation $\tilde{x}_t \equiv x_t - \overline{x}_t$ for any variable x_t. $\overline{x}_t$ denotes the value that x_t would take on, given the sequence of shocks, if prices were flexible and the optimal subsidy to monopolies were in place so that the flexible price equilibrium was efficient. Hence, $\tilde{x}_t$ represents the gap between x_t and its efficient level, $\overline{x}_t$.

Similarly, for foreign producer price inflation, we have

$$\pi_{Ft}^* = \delta\left[-\left(\frac{\sigma}{D} + \phi\right)\tilde{y}_t^R + (\sigma + \phi)\tilde{y}_t^W - \left(\frac{D - (\nu - 1)}{2D}\right)(m_t + f_t)\right] + \beta E_t \pi_{Ft+1}^* + u_t^*. \tag{24}$$

Under PCP, Equations 23 and 24 hold with $m_t = 0$.

Additionally, under LCP, there are the price adjustment equations for the local prices of imported goods:

$$\pi_{Ht}^* = \delta\left[\left(\frac{\sigma}{D} + \phi\right)\tilde{y}_t^R + (\sigma + \phi)\tilde{y}_t^W - \left(\frac{D + \nu - 1}{2D}\right)(m_t + f_t)\right] + \beta E_t \pi_{Ht+1}^* + u_t, \tag{25}$$

$$\pi_{Ft} = \delta\left[-\left(\frac{\sigma}{D} + \phi\right)\tilde{y}_t^R + (\sigma + \phi)\tilde{y}_t^W + \frac{D + \nu - 1}{2D}(m_t + f_t)\right] + \beta E_t \pi_{Ft+1} + u_t^*. \tag{26}$$

Equations 1–26 lay out the simplest version of a two-country model that incorporates the important features that differentiate open-economy from closed-economy models: differences in preferences, pricing to market, and incomplete markets. Section 3 presents a version of the loss function for cooperative monetary policy and derives targeting rules under commitment.

3. OPTIMAL MONETARY POLICY

As is well known, with appropriate rewriting of the objective function, the problem of the policy maker—here, to maximize the sum of Home and Foreign utility—can be cast as a linear quadratic problem in which the policy maker minimizes a loss function that expresses variables in terms of deviations from their values under an efficient equilibrium (see, e.g., Woodford 2003). This approach also has the appeal of delivering an objective function that can be easily understood and interpreted in the light of practical experience with monetary policy.

For the PCP model presented above, Corsetti et al. (2010, 2011) and Engel (2011) show that the loss function can be expressed as the expected present discounted value of the period-by-period loss given by

$$\Psi_t \propto \left(\frac{\sigma}{D} + \phi\right)\left(\tilde{y}_t^R\right)^2 + (\sigma + \phi)\left(\tilde{y}_t^W\right)^2 + \frac{\varepsilon\nu(2 - \nu)}{4D}(f_t)^2 + \frac{\xi}{2\delta}\left((\pi_{Ht})^2 + \left(\pi_{Ft}^*\right)^2\right). \tag{27}$$

For the LCP model, the loss function is given by the expected present discounted value of

$$\Psi_t \propto \left(\frac{\sigma}{D}+\phi\right)\left(\tilde{y}_t^R\right)^2+(\sigma+\phi)\left(\tilde{y}_t^W\right)^2+\frac{\varepsilon\nu(2-\nu)}{4D}(f_t+m_t)^2+ \\ \frac{\xi}{2\delta}\left(\frac{\nu}{2}(\pi_{Ht})^2+\frac{2-\nu}{2}(\pi_{Ft})^2+\frac{\nu}{2}\left(\pi_{Ft}^*\right)^2+\frac{2-\nu}{2}\left(\pi_{Ht}^*\right)^2\right). \tag{28}$$

Under both PCP and LCP, the loss depends on output gaps in both countries as functions of the square of the overall world output gap, $\tilde{y}_t^W$, and the square of the relative Home versus Foreign output gap, $\tilde{y}_t^R$. Inflation matters in the New Keynesian model under staggered price setting because it leads to relative price misalignments and hence inefficient allocation of production within each country. In the PCP model in which firms set only one price, this misallocation arises from inflation in the producer prices in each country. Under LCP, the misallocation arises from the inflation of each country's good in each currency, so there are four inflation terms in the loss function.

As Engel (2011) emphasizes, even when there are no financial market imperfections ($f_t = 0$), there can still be a loss arising from pricing to market, $m_t \neq 0$. Perform the thought experiment of setting the output gaps in both Home and Foreign to zero, $\tilde{y}_t^R = 0$ and $\tilde{y}_t^W = 0$, which means that the aggregate output levels in each country are at the efficient level. Suppose also that the inflation of all prices is zero. In this case, there is no distortionary misallocation of production across goods within each country. If output gaps and inflation are zero, every firm in both countries is producing at its efficient level. If there are no financial market imperfections, $f_t = 0$, then why is there still a loss relative to the efficient outcome, represented in Equation 28 by the term $[\varepsilon\nu(2-\nu)/4D](m_t)^2$?

The answer is that goods are misallocated between Home and Foreign consumers. Under an efficient allocation, the marginal utility of each good should be equal for Home and Foreign consumers.[5] For example, the log of the marginal utility of the Home aggregate good is (approximately) equal to $-\varepsilon^{-1}c_H + (\varepsilon^{-1}-\sigma)c$ for the Home household, and $-\varepsilon^{-1}c_H^* + (\varepsilon^{-1}-\sigma)c^*$ for the Foreign household. The demand functions are $c_H = -\varepsilon(p_H - p) + c$ and $c_H^* = -\varepsilon(p_H^* - p^*) + c^*$. Using these and the complete market relationship given in Equation 15 (with f_t set to zero), we have that the marginal utility of Home goods is $p_H - p - \sigma c$ for Home households, and $m + p_H - p - \sigma c$ for Foreign households. Those are not equal unless there is no pricing to market so $m = 0$. In states of the world in which prices are higher in Foreign, so $m > 0$, the Foreign households will have higher marginal utility and therefore lower consumption levels than Home households.

In essence, under complete financial markets, the marginal utility of a dollar is equalized between Home and Foreign households. If prices are higher in Foreign (when expressed in the same currency as prices in Home), then Foreign must have a higher marginal utility of goods. Trade in the complete set of contingent claims does not lead to an efficient allocation because goods markets are segmented and there is pricing to market.

The monetary policy maker therefore targets not only output gaps and inflation, but also the deviations from the law of one price, $m_t \equiv e_t + p_{Ht}^* - p_{Ht} = e_t + p_{Ft}^* - p_{Ft}$. In practice, nominal prices in each currency tend to be much more stable than nominal exchange rates, so a policy of targeting m_t entails a great deal of nominal exchange rate stabilization.

The notion that markets are complete internationally is far-fetched, but in the context of the model, it is easy to see that trade in a limited number of assets could replicate the complete markets outcome. Consider this observation of Engel & Matsumoto (2009).[6] Suppose each period trade is

[5]In general, these marginal utilities should be equal up to a multiplicative constant given by the relative wealth of Home and Foreign households, but we have assumed equal wealth.

[6]Heathcote & Perri (2013) make a very similar point.

balanced, except that Home receives a nominal payoff of K_t from a bet placed prior to the realization of the state at time t (or pays $-K_t$ if it loses the bet):

$$P_{Ft}C_{Ft} = E_t P^*_{Ht} C^*_{Ht} + K_t.$$

This can be approximated as

$$\frac{2-\nu}{2}\left(s_t - m_t + c_{Ft} - c^*_{Ht}\right) = k_t,$$

where k_t is the payoff divided by Home's steady-state nominal income. Now replace c_{ft} and c^*_{Ht} with their demand functions to get

$$\frac{2-\nu}{2}\left((1-\varepsilon\nu)s_t - m_t + c_t - c^*_t\right) = k_t.$$

A complete markets equilibrium, from Equation 15, achieves $\sigma c_t - \sigma c^*_t = m_t + (\nu - 1)s_t$. That same allocation can be achieved if

$$k_t = \frac{2-\nu}{2\sigma}\left((1-\sigma)m_t + \left(\sigma - 1 + \nu(1-\sigma\varepsilon)\right)s_t\right).$$

First, as is well known, markets are effectively complete with no asset trade when utility is logarithmic in aggregate consumption ($\sigma = 1$) and preferences over Home and Foreign aggregates are Cobb-Douglas ($\varepsilon = 1$). In that case, the required payoff to achieve the complete markets allocation is $k_t = 0$. More generally, if two (zero net position) assets are traded—one whose payoff is linearly related to m_t and the other to s_t—markets are completed (up to a linear approximation). Or, using Equation 18, the complete market allocation can be replicated when

$$k_t = \frac{2-\nu}{2\sigma}\left((1-\sigma)m_t + \left(\sigma - 1 + \nu(1-\sigma\varepsilon)\right)\left(\frac{2\sigma}{D}y^R_t - \frac{(\nu-1)}{D}m_t\right)\right),$$

which suggests that markets can be completed with trade in an asset whose payoff is linearly related to m_t and another whose payoff is related to y^R_t. For example, a forward foreign exchange position (or, equivalently, a bond swap) might replicate movements in m_t relatively well, while options on the aggregate stock market may replicate movements in y^R_t. In short, there may well be a sufficient menu of assets available to hedge the type of aggregate risks that concern policy makers, even if markets are not complete.

It is nonetheless more realistic to assume market incompleteness. Even if a sufficient menu of assets exists, there may be policy or other barriers that prevent the efficient working of these markets, which motivates the Devereux & Yetman (2012) model. Alternatively, given the well-known home bias in equity holdings, the approach of Corsetti et al. (2011) of assuming trade only in bonds that are not state contingent may be a reasonable approximation to reality. When markets are incomplete, the deviation from market completeness, f_t, generates a loss in welfare (unless by some great coincidence $f_t + m_t = 0$, even when $f_t \neq 0$ and $m_t \neq 0$). In turn, the exchange rate may play an important role in diminishing the deviation, through its effect on the trade balance. There are two potential channels. First, when price setting is PCP and there is no pricing to market ($m_t = 0$), the nominal exchange rate can influence f_t through its effect on the terms of trade, $s_t = e_t + p^*_{Ft} - p_{Ht}$. Because under PCP the producer currency prices p_{Ht} and p^*_{Ft} adjust slowly, the major channel of short-run influence on the terms of trade is the nominal exchange rate, which in turn influences the trade balance through an expenditure-switching effect. A Home depreciation raises the relative price of Foreign goods, causing households in both countries to switch demand toward Home goods. The role of the exchange rate can be seen more directly by rewriting the expression for f_t from the Devereux-Yetman model (Equation 19) and the Corsetti et al. model (Equation 21) as, respectively,

$$f_t = \frac{(1-\lambda)(2-\nu)\big(\sigma(\varepsilon\nu-1)+1-\nu\big)}{(1-\lambda)(2-\nu)-2\lambda\sigma}s_t + \frac{(1-\lambda)(2-\nu)(\sigma-1)}{(1-\lambda)(2-\nu)-2\lambda\sigma}m_t, \tag{29}$$

$$f_t = \frac{-2D}{(2-\nu)\big(1+\nu(\varepsilon-1)\big)}\left(b_t-\beta^{-1}b_{t-1}\right) + \big(\sigma(\varepsilon\nu-1)+1-\nu\big)s_t + (\sigma-1)m_t. \tag{30}$$

Under LCP, consumer prices are set in local currency, so the exchange rate has a much smaller influence on the terms of trade, $p_{Ft}-p_{Ht}=p^*_{Ft}-p^*_{Ht}$. It has a short-run influence only through its effect on the demand for goods whose prices are reset. In fact, in the important special case in which there are no wealth effects on labor supply, as we examine below, monetary policy has no effect on the terms of trade under LCP. However, the second channel of influence of the exchange rate on the trade balance is through its effects on the deviation from the law of one price, $m_t \equiv e_t + p^*_{Ht} - p_{Ht} = e_t + p^*_{Ft} - p_{Ft}$. A Home depreciation will increase the Home currency revenue from exports $(e_t + p^*_{Ht})$ and reduce the Foreign currency revenue from exports $(p_{Ft} - e_t)$, which works to increase Home's trade balance.

The weight given to $(f_t+m_t)^2$ in the loss function, $\left[\varepsilon\nu(2-\nu)\right]/4D$, is greater the more open is the economy (the closer is ν to one), and the greater is the elasticity of substitution between Home and Foreign aggregates, ε. However, the weight in the loss function given to $(f_t+m_t)^2$ is small compared to the weights on the squared output gap and squared inflation rate terms. Take the parameterization (set to quarterly frequency) as given in Corsetti et al. (2011): $\sigma=2$, $\phi=2$, $\xi=6$, $\theta=0.75$, and $\beta=0.99$. Then take a set of parameters that enhances the importance of the pricing to market and incomplete market distortions: assume no home bias in preferences, $\nu=1$, and take the high-elasticity parameterization from the Corsetti et al. model for the substitution between Home and Foreign aggregates, $\varepsilon=6$, which implies that imported goods are equally good substitutes as locally produced substitutes for any product (i.e., $\xi=\varepsilon$). Under this parameterization, the weight in the loss function on $(f_t+m_t)^2$ is 0.125, compared to weights of 2.17 on $\left(\tilde{y}^R_t\right)^2$, 4.0 on $\left(\tilde{y}^W_t\right)^2$, and 34.95 on the squared inflation terms. Note that these weights are calibrated for a quarterly frequency. Measured at an annual frequency, the weight on inflation falls to 1.99. So the weight on the loss from $(f_t+m_t)^2$ is approximately one-sixteenth the weight of the loss from the relative output gap, or inflation measured at annual rates, which means that the loss to welfare of a 1% relative output gap or an annual inflation rate 1% above target is approximately the same as the loss from a 4% currency misalignment.

Above we see that the policy maker's loss function depends on open-economy variables, m_t and f_t, which in turn are directly influenced by exchange rates. But the exchange rate also influences output gaps and inflation. We can use Equations 16–18 to write

$$\tilde{y}^R_t = \frac{D}{2\sigma}\tilde{s}_t + \frac{\nu-1}{2\sigma}(m_t+f_t). \tag{31}$$

In turn, in the incomplete markets models from Equations 29 and 30, f_t can be written as a function of m_t and s_t. So the relative Home to Foreign output gap is driven by exchange rates: in the PCP model through the influence on the terms of trade and in the LCP model through pricing to market, m_t.

Similarly, the exchange rate plays a role in inflation determination. There is a direct role for m_t in the open-economy Phillips curves (Equations 23–26), where we see that an increase in m_t raises

Home inflation and lowers Foreign inflation. But m_t and s_t also influence inflation through their effects on f_t (Equations 29 and 30) and $\tilde{y}_t^R$, as in Equation 31. The monetary policy maker may be concerned about currency misalignments because of their effects on the traditional objectives of monetary policy: inflation and the output gap.

3.1. Targeting Rules

Here we present optimal targeting rules for the cooperative monetary policy problem of minimizing the loss under commitment. Policy makers have two policy instruments (e.g., the Home and Foreign interest rates) that they may use to achieve the two target criteria. We consider these rules in six cases: complete markets, incomplete markets as in Devereux-Yetman, and incomplete markets with non-state-contingent bonds only traded as in Corsetti et al. (2011), each under PCP and LCP.

Under LCP, the expressions for the optimal targeting rules can be quite cumbersome because, taking first differences of Equation 18, we get a backward-looking constraint on relative inflation rates internally in each country:

$$\pi_{Ft} - \pi_{Ht} = \pi^*_{Ft} - \pi^*_{Ht} = \frac{2\sigma}{D}\left(y_t^R - y_{t-1}^R\right) - \frac{(\nu-1)}{D}\left[(m_t + f_t) - (m_{t-1} + f_{t-1})\right].$$

However, quite simple expressions arise in the special case of utility that is quasi-linear in labor, $\phi = 0$, which implies that there are no wealth effects on labor supply. In this case, as Engel (2011) shows, the terms of trade evolve independently of monetary policy choices [i.e., s_t is a "term independent of policy, (t.i.p.)," in the language of Woodford (2003)]:

$$s_t - s_{t-1} = -\delta\tilde{s}_t + \beta E_t(s_{t+1} - s_t) + 2u_t^R. \tag{32}$$

That monetary policy does not influence s_t under LCP reflects that there is no role for the nominal exchange rate to directly influence relative prices, in contrast to the PCP case. Firms set a different price for their goods in each currency, and those prices adjust slowly.

We can then rewrite the objective function as

$$\Psi_t \propto \frac{\sigma}{D}\left(\tilde{y}_t^R\right)^2 + \sigma\left(\tilde{y}_t^W\right)^2 + \frac{\varepsilon\nu(2-\nu)}{4D}(f_t + m_t)^2 + \frac{\xi}{2\delta}\left(\left(\pi_t^R\right)^2 + \left(\pi_t^W\right)^2 + \frac{\nu(2-\nu)}{4}(s_t - s_{t-1})^2\right),$$

where, under LCP, π_t^R (π_t^W) refers to relative (world) consumer price inflation. That is,

$$\pi_t^R = \frac{1}{2}\left(\frac{\nu}{2}\pi_{Ht} + \frac{2-\nu}{2}\pi_{Ft} - \frac{\nu}{2}\pi^*_{Ft} - \left(\frac{2-\nu}{2}\right)\pi^*_{Ht}\right),$$

and π_t^W is defined analogously. We can summarize the inflation process with equations for relative and world consumer price inflation:

$$\pi_t^R = \delta\left[\frac{\sigma(\nu-1)}{D}\tilde{y}_t^R + \frac{\sigma\varepsilon\nu(2-\nu)}{2D}(m_t + f_t)\right] + \beta E_t\pi_{t+1}^R + (\nu-1)u_t^R,$$

$$\pi_t^W = \delta\sigma\tilde{y}_t^W + \beta E_t\pi_{t+1}^W + u_t^W.$$

We consider only the case of $\phi = 0$ for the targeting rules for the LCP model.

3.2. Targeting Rule for World Variables

Whether markets are complete or incomplete, the same targeting rule for world variables holds in all cases:

$$\xi\pi_t^W + \tilde{y}_t^W - \tilde{y}_{t-1}^W = 0. \tag{33}$$

In the PCP model, π_t^W refers to the average producer price inflation: $\pi_t^W = (\pi_{Ht} + \pi_{Ft}^*)/2$. Under LCP, it designates the average consumer price inflation, $\pi_t^W = (\pi_t + \pi_t^*)/2$, where $\pi_t = (\nu/2)\pi_{Ht} + \big((2-\nu)/2\big)\pi_{Ft}$ and $\pi_t^* = (\nu/2)\pi_{Ft}^* + \big((2-\nu)/2\big)\pi_{Ht}^*$. Market incompleteness matters for the distribution of wealth between Home and Foreign, but Equation 33 represents a rule for stabilizing inflation and output at the global level. Of note is that the weight on inflation relative to the growth rate of output is given by ξ, the elasticity of substitution among varieties produced within a country, which is assumed to be greater than one and is typically calibrated to be much larger.[7]

Under PCP, the rule involves producer price inflation. The distortion from inflation arises because relative prices of goods produced within each country become misaligned internally with staggered price setting. Under PCP, each firm sets only a single price, so it is inflation of that price that matters. If pricing is LCP, the rules involve consumer price inflation, rather than producer price inflation. Although the distortion from inflation is still on the production side—resources are misallocated across firms as relative prices become distorted—the optimal rules involve targeting the weighted average of prices that correspond to the consumer price index.

3.3. Targeting Rules Under PCP with Complete Markets

The targeting criterion for relative variables is

$$\xi\pi_t^R + \tilde{y}_t^R - \tilde{y}_{t-1}^R = 0. \tag{34}$$

Relative inflation is defined under PCP as $\pi_t^R = (\pi_{Ht} - \pi_{Ft}^*)/2$. The relative rule (Equation 34) could be expressed as a trade-off between relative inflation and the terms of trade growth, using Equation 31:

$$\xi\pi_t^R + \frac{D}{2\sigma}\left(\tilde{s}_t - \tilde{s}_{t-1}\right) = 0.$$

This formulation highlights that in the complete markets PCP model, the relative output levels are determined only by the terms of trade. Because the terms of trade are largely driven by nominal exchange rate movements in the short run, the monetary policy maker could target the nominal exchange rate as a means of achieving the desired terms of trade change.

The two targeting rules (Equations 33 and 34) can be rewritten simply in terms of output and inflation in each country: $\xi\pi_{Ht} + \tilde{y}_t - \tilde{y}_{t-1} = 0$ and $\xi\pi_{Ft}^* + \tilde{y}_t^* - \tilde{y}_{t-1}^* = 0$. The optimal rules under cooperation are linear functions of inflation and output gap growth within each country. In fact, these are exactly the rules that emerge from the corresponding simple closed-economy New Keynesian model. In this model, under complete markets and PCP, the optimal cooperative rules are "self-oriented," in the words of Obstfeld & Rogoff (2002), and show that an optimal cooperative policy can be sustained by assigning each country's policy makers a policy rule involving only variables in its economy (see Benigno & Benigno 2006). However, this conclusion does not carry over to incomplete markets or LCP.

[7]For example, Corsetti et al. (2011) calibrate this parameter to equal 6.

3.4. Targeting Rules Under LCP and Complete Markets

The optimal targeting rules, assuming $\phi = 0$, are given by Equation 33 (with π_t^W defined for the LCP case) and

$$\xi\pi_t^R + \frac{\nu - 1}{D}\left(\tilde{y}_t^R - \tilde{y}_{t-1}^R\right) + \frac{\varepsilon\nu(2-\nu)}{2D}(m_t - m_{t-1}) = 0. \tag{35}$$

In contrast to the PCP case, as the economy becomes more open (as $\nu \to 1$), the relative output gaps become less important and have zero weight in the limit of full openness. But the exchange rate will matter through the m_t term because currency misalignments and pricing to market lead to misallocation of consumption, even when a complete set of contingent claims is traded. Because $m_t - m_{t-1}$ is driven largely by nominal exchange rate changes, Equation 35 can be interpreted as demonstrating that the policy maker may allow additional Home relative to Foreign inflation ($\pi_t^R > 0$) if the Home output gap is falling relative to Foreign ($\tilde{y}_t^R < \tilde{y}_{t-1}^R$) or if the Home currency is appreciating ($m_t < m_{t-1}$).

We can use Equation 31 to rewrite Equation 35 in terms of the distortion in relative Foreign to Home prices, $\tilde{s}_t$, and the pricing to market term, m_t:

$$\xi\pi_t^R + \frac{\nu - 1}{2\sigma}(\tilde{s}_t - \tilde{s}_{t-1}) + \frac{1}{2\sigma}(m_t - m_{t-1}) = 0. \tag{36}$$

Even though the relative price, s_t, is independent of monetary policy, its path will play a role in determining the trade-off between relative inflation and currency appreciation.

An intuitive way of understanding the policy trade-off is to use the consumption real exchange rate, $q_t = e_t + p_t^* - p_t$, where p_t (p_t^*) is the Home (Foreign) consumer price index. We can write

$$\xi\pi_t^R + \frac{1}{2\sigma}(\tilde{q}_t - \tilde{q}_{t-1}) = 0. \tag{37}$$

In other words, the distortions to the relative price of Foreign to Home goods and the pricing to market distortion that appear in Equation 36 can be summarized by their effects in distorting the real exchange rate from its efficient level.

3.5. Targeting Rules Under PCP with Devereux-Yetman Incomplete Markets

When markets are incomplete, the targeting rule that trades off world inflation and the world output gap (Equation 33) still holds. The second target criterion is quite complicated:

$$\xi\pi_t^R + \tilde{y}_t^R - \tilde{y}_{t-1}^R + \frac{(1-\lambda)(2-\nu)\big(\sigma(\varepsilon\nu - 1) + 1 - \nu\big)}{(1-\lambda)(2-\nu)\big(1+\nu(\varepsilon - 1)\big) - 2\lambda D}\left[\frac{\varepsilon\nu(2-\nu)}{2(\sigma+\phi D)}(f_t - f_{t-1}) + \xi\left(\frac{D+1-\nu}{\sigma+\phi D}\right)\pi_t^R\right] = 0. \tag{38}$$

The general expression is not easy to digest, and even the signs of the trade-offs implied will depend on parameter values. In the special case of Cobb-Douglas preferences over the Home and Foreign aggregates ($\varepsilon = 1$) and no home bias ($\nu = 1$), the expression in Equation 38 collapses to the same as that under complete markets (Equation 34). This reflects the well-known result that under PCP, in this special case, markets are effectively complete, even with no asset trade, because movements in the terms of trade provide insurance. From Equation 19, if there is no pricing to market ($m_t = 0$), then $f_t = 0$ when $\varepsilon = 1$ and $\nu = 1$. (If $m_t \neq 0$, we still have $f_t = 0$ if $\varepsilon = 1$ and $\sigma = 1$, irrespective of the value of ν.)

In the case in which all asset trade is shut off ($\lambda = 0$), the expression is equivalent to one derived in Corsetti et al. (2010):

$$\xi\pi_t^R + \tilde{y}_t^R - \tilde{y}_{t-1}^R + \frac{(\sigma(\varepsilon\nu - 1) + 1 - \nu)}{(1 + \nu(\varepsilon - 1))}\left[\frac{\varepsilon\nu(2-\nu)}{2(\sigma + \phi D)}(f_t - f_{t-1}) + \xi\left(\frac{D + 1 - \nu}{\sigma + \phi D}\right)\pi_t^R\right] = 0. \tag{39}$$

To get some intuition of how market incompleteness affects the inflation targeting incentive, consider the case of no home bias, $\nu = 1$, so that perfect risk sharing requires $c_t = c_t^*$. With balanced trade, one finds that $c_t - c_t^* = (\varepsilon - 1)s_t$. Assuming an elasticity of substitution greater than one, when Foreign prices rise relative to Home prices (s_t rises), Home output rises, which increases the consumption power of Home households. In turn, one obtains $s_t = (y_t - y_t^*)/\varepsilon$ because as Home output rises, its relative price falls. Thus,

$$f_t = \sigma(c_t - c_t^*) = \frac{2\sigma(\varepsilon - 1)}{\varepsilon}y_t^R = \frac{2\sigma(\varepsilon - 1)}{\varepsilon}\left(\tilde{y}_t^R + \bar{y}_t^R\right). \tag{40}$$

As Home output rises, f_t rises because Home has more income and can consume more. The loss function (Equation 27) in this case ($\nu = 1$) can be written, using Equation 40, as

$$\Psi_t \propto \left(\frac{1}{\varepsilon} + \phi\right)\left(\tilde{y}_t^R\right)^2 + (\sigma + \phi)\left(\tilde{y}_t^W\right)^2 + \sigma\left(\frac{\varepsilon - 1}{\varepsilon}\right)^2\left(\left(\tilde{y}_t^R + \bar{y}_t^R\right)\right)^2 + \frac{\xi}{2\delta}\left((\pi_{Ht})^2 + (\pi_{Ft}^*)^2\right).$$

The Phillips curves (Equations 23 and 24) are now given by

$$\pi_{Ht} = \delta\left[\left(\frac{1}{\varepsilon} + \phi\right)\tilde{y}_t^R + (\sigma + \phi)\tilde{y}_t^W + \frac{\sigma(\varepsilon - 1)}{\varepsilon}\left(\tilde{y}_t^R + \bar{y}_t^R\right)\right] + \beta E_t\pi_{Ht+1} + u_t,$$

$$\pi_{Ft}^* = \delta\left[-\left(\frac{1}{\varepsilon} + \phi\right)\tilde{y}_t^R + (\sigma + \phi)\tilde{y}_t^W - \frac{\sigma(\varepsilon - 1)}{\varepsilon}\left(\tilde{y}_t^R + \bar{y}_t^R\right)\right] + \beta E_t\pi_{Ft+1}^* + u_t^*.$$

A marginal increase in $\tilde{y}_t^R$, holding inflation constant, increases the loss by $2(1/\varepsilon + \phi)\tilde{y}_t^R + 2\sigma((\varepsilon - 1)/\varepsilon)^2 y_t^R$ when there is no asset trade, but only by $2(1/\varepsilon + \phi)\tilde{y}_t^R$ when markets are complete. The second term appears because higher y_t^R worsens the consumption distortion. The effect on π_t^R of a marginal increase in $\tilde{y}_t^R$ is $2\delta[1/\varepsilon + \phi + (\sigma(\varepsilon - 1))/\varepsilon]$, whereas the effect under complete markets is only $\delta[1/\varepsilon + \phi]$. The greater effect of higher output on inflation comes because under no asset trade, when Home output rises, Home consumption increases, and home labor supply declines relative to Foreign. This works to push up Home wages and hence Home relative to Foreign inflation. The targeting rule in this case is

$$\xi\pi_t^R + \tilde{y}_t^R - \tilde{y}_{t-1}^R + \frac{\sigma(\varepsilon - 1)^2}{2\varepsilon(1 + \phi\varepsilon)}\left(y_t^R - y_{t-1}^R\right) + \xi\frac{\sigma(\varepsilon - 1)}{1 + \phi\varepsilon}\pi_t^R = 0. \tag{41}$$

The term involving $y_t^R - y_{t-1}^R$ arises because of the effect of differential output growth on relative consumption growth, and the final term involving π_t^R reflects the effects of consumption imbalances on relative inflation. Note that under this target criterion, the policy maker wants to have not only small values of growth in the relative output gap, but also small values of growth in the actual relative output. Any differential in Home relative to Foreign output growth may serve to further distort consumption allocations under incomplete markets. Also, under complete markets, 1 percentage point of inflation is traded against ξ percentage points in the growth rate of the relative output gap. Incomplete markets add the final two terms, in which 1 percentage point of inflation weighs against $2\xi\varepsilon/(\varepsilon - 1)$ points of growth in relative output (not the output gap).

Because under PCP $\tilde{y}_t^R$ is just proportional to $\tilde{s}_t$ (Equation 31) and f_t is proportional to s_t (Equation 29), we can also interpret the target criteria in Equation 38 as a trade-off involving inflation and the terms of trade, which in turn are largely driven by the exchange rate under PCP.

3.6. Targeting Rules Under LCP with Devereux-Yetman Incomplete Markets

Under LCP and with Devereux-Yetman incomplete markets, the targeting rules are Equation 33 and

$$\xi\pi_t^R + \frac{\nu - 1}{D}\left(\tilde{y}_t^R - \tilde{y}_{t-1}^R\right) + \frac{\varepsilon\nu(2-\nu)}{2D}\left(f_t + m_t - (f_{t-1} + m_{t-1})\right) = 0. \qquad (42)$$

The sum $f_t + m_t$ is the deviation from perfect risk sharing. Under our notation, there are two possible sources of deviations: pricing to market, m_t, and the deviation arising from incompleteness of markets, f_t. But the two sources of deviation do not matter individually. Policy makers need only be concerned with their sum. It is clear comparing Equation 42 to the policy criterion under complete markets (Equation 36) that pricing to market when a complete set of contingent claims is traded matters in the policy trade-offs only because of its role in confounding risk sharing.

An important thing to note about the criterion in Equation 42 is that the degree of market completeness, as indexed by λ, does not figure into the policy trade-offs. This fact, and the fact that f_t and m_t can influence the policy choice only through their sum, arises because the terms of trade are independent of monetary policy under LCP, determined by Equation 32 when $\phi = 0$. As a result, an increase in $m_t + f_t$ of one unit, from Equation 31, always leads to an increase in $\tilde{y}_t^R$ of $(\nu - 1)/D$ units.

In the case of incomplete markets, the relative policy criterion can no longer be expressed as a simple trade-off between relative inflation and home real depreciation, as in Equation 37. Instead,

$$\xi\pi_t^R + \frac{1}{2\sigma}\left(\tilde{q}_t - \tilde{q}_{t-1} + f_t - f_{t-1}\right) = 0,$$

so the policy maker trades off inflation with the change in $\tilde{q}_t + f_t$. Still, from Equation 29, the policy maker can only influence the incomplete markets distortion, f_t, by targeting the deviation from the law of one price, m_t, which in turn can be accomplished through exchange rate targeting.

3.7. Targeting Rules Under PCP with Non-State-Contingent Bonds Traded[8]

Corsetti et al. (2011) find that when only interest-bearing bonds are traded, the world target criterion (Equation 33) is the same as under complete markets. Then there is a criterion for relative variables:

[8]As is well known, the linearized version of the model presented here does not have a stable nonstochastic steady state. Some additional element to the model must be introduced—such as an endogenous utility discount factor, or an exogenous cost of holding bonds—analogous to those in Schmitt-Grohe & Uribe (2003). The targeting rules presented in this section ignore the role of those elements. The implied path of bond accumulation may therefore not be stationary.

$$\xi\pi_t^R + \tilde{y}_t^R - \tilde{y}_{t-1}^R + \left(\frac{\sigma(\varepsilon\nu - 1) + 1 - \nu}{1 + \nu(\varepsilon - 1)}\right)\frac{\varepsilon\nu(2-\nu)}{2(\sigma + \phi D)}(f_t - f_{t-1}) = 0. \tag{43}$$

There are two interesting comparisons to make. In the first, in Equation 43, compared to the target criteria under complete markets (Equation 34), we see that the policy maker puts a positive weight on changes in relative consumption. Specifically, recall from Equation 15 that

$$f_t - f_{t-1} = \sigma\left(c_t - c_{t-1} - \left(c_t^* - c_{t-1}^*\right)\right) + (1-\nu)(s_t - s_{t-1}).$$

The relationship in Equation 43 states that if, for example, $f_t - f_{t-1} < 0$, perhaps because Home consumption growth is below Foreign consumption growth, then policy makers may tolerate relatively high Home inflation to boost Home consumption.

The second comparison is with Equation 39, the target criteria when international financial markets are completely closed. Careful comparison of the two expressions in Equations 39 and 43 shows that when there are no capital flows, the policy maker puts a higher weight on inflation. The policy maker must pay attention to the fact that when $f_t - f_{t-1} < 0$, to boost current consumption, Home output must increase, which worsens Home inflation. When it is possible to trade a non-state-contingent bond, the welfare gain from any given increase in Home output and inflation is greater because the consumption increase that it affords can be spread over time.

3.8. Targeting Rules Under LCP with Non-State-Contingent Bonds Traded

In this case, the optimal targeting rules are the same as in the Devereux-Yetman model of incomplete financial markets, when $\phi = 0$. As noted in that case, the rules (Equations 33 and 42) do not depend on the degree of market incompleteness.

4. DISCUSSION AND CONCLUSION

It may be helpful to rewrite the targeting rules as price-level rules rather than inflation rules, as Gali (2008) suggests. For example, under incomplete markets and LCP, the relative rule in Equation 42 can be expressed as

$$\xi\left(p_t^R - p_{-1}^R\right) + \frac{\nu - 1}{D}\tilde{y}_t^R + \frac{\varepsilon\nu(2-\nu)}{2D}(f_t + m_t) = 0, \tag{44}$$

where we assume that the rule is adopted at time 0. Then the policy maker commits to a policy that aims to move the relative price level at any time t toward the value relative prices took at time -1, p_{-1}^R, but trades off that commitment with concerns about output gaps, risk sharing, and pricing to market.[9] The global policy maker will allow the Home relative price to be above target, $p_t^R > p_{-1}^R$, for three reasons: The Home output gap is low relative to the Foreign output gap, $\tilde{y}_t^R < 0$; the Home currency is overvalued, $m_t < 0$; or, even given output levels, the Home consumption level is low, so $f_t < 0$. In practice, $f_t < 0$ may imply Home is running a trade surplus. Under LCP, a currency depreciation will not influence the terms of trade but may still lead to an increase in f_t by raising revenues earned on exports. From Equation 44, it is clear that the weight given to

[9]In deriving our optimal target criteria, we have implicitly also imposed a constraint on policy in period 0. Under these conditions, committing to achieve Equation 44 from period 0 onward is then equivalent to committing to Equation 42, for example. Readers are referred to Benigno & Woodford (2012) and Giannoni & Woodford (2010) for an elaboration on these constraints.

open-economy concerns, f_t and m_t, is greater the openness of the economy (the closer to zero home bias, $\nu = 1$) and the greater the elasticity of substitution between Home and Foreign aggregates.

This analysis provides some general guidelines for welfare-based optimal monetary policy in a very simple context, but implementation in the real world is of course much more difficult. It may be problematic to measure f_t and m_t. The degree of pricing to market, m_t, might seem simple to gauge based on differences in purchasing power of any given currency across countries. The model analyzed here, however, abstracts from the role of distribution services. These services represent true resource costs, and they may lead to differences in consumer prices for identical goods across countries that efficiently reflect these costs. In other words, differences in consumer prices may not reflect inefficient pricing to market and price stickiness, but rather differences in local labor and other costs of distribution. A calculation of the true degree of pricing to market then must correct for differences in the cost of distribution (see Burstein & Gopinath 2014 for a recent survey of work on pricing to market).

Measuring deviations from risk sharing is possibly even more difficult. The model presented here made an important simplifying assumption—that the wealth of Home and Foreign households is equal at the time the monetary authority commits to a policy rule, so that it is natural to treat Home and Foreign households' utility identically. It is less clear what the objective function should be when there is not equal wealth. Additionally, because preferences differ, it is not straightforward to measure aggregate consumption levels.

The policies analyzed here under incomplete markets are aimed at correcting the distortion of too little consumption insurance. Monetary policy can substitute for missing insurance markets, subject to the constraints put on monetary policy by competing objectives. However, as with any insurance, moral hazard problems arise. It would not be easy for countries to come to an agreement to help a country with low consumption levels by depreciating its currency if there was a widely held view that the low consumption level was caused by insufficient effort to earn income by the country—because of low labor effort, inefficient government policies, etc. A global monetary agreement would require some assessment of the degree to which the inequalities in consumption, first, are temporary reflections of the business cycle rather than permanent wealth differentials and, second, have exogenous causes rather than being the result of household choices or government policies that are subject to moral hazard.

The analysis of optimal monetary policy in the global context presented here implicitly assumes that other policy tools are not available. This assumption is plausible for policies aimed at correcting distortions that arise over the short run because of slow adjustment of prices and wages. Fiscal policy and other economic policies are clumsier to implement because they require a political and bureaucratic process that can be cumbersome. But persistent global imbalances may be better addressed by spending and tax policy or capital controls. There has been an expanding literature in open-economy macroeconomics that considers the roles of fiscal policy and capital controls in conjunction with monetary policy in an open-economy environment (see, e.g., Gopinath et al. 2011, Devereux & Yetman 2012, Farhi & Werning 2012, Cook & Devereux 2013).

Some other recent literature has been concerned with important asymmetries. Schmitt-Grohe and Uribe (2012a,b) show how asymmetries in nominal rigidities, particularly that nominal wages are much more rigid in the downward direction, can have profound implications for the assessment of exchange rate policies. Cook & Devereux (2013) and Devereux & Yetman (2012) examine the consequences of the zero lower bound on nominal interest rates in two-country models.

In the simple model analyzed here, trade imbalances matter for monetary policy because they lead to deviations from efficient risk sharing. Certainly, in recent years, another major concern with global imbalances is the implication for debt sustainability. Countries that acquire too much debt may be forced to reduce spending to meet their debt obligations, which may magnify the drop in consumption levels during economic downturns. In the open economy, there are potentially conflicting implications for exchange rate policy. On the one hand, currency depreciation may help alleviate the debt problem because a depreciation may improve the trade balance and reduce the need for foreign borrowing. On the other hand, countries that face international borrowing constraints are often forced to borrow in foreign currency. A depreciation of the borrower's currency will increase the value of the debt obligation in the borrower's currency, which may worsen the financial constraint. Recently, Fornaro (2013) and Ottonello (2013) examine monetary policy in this environment but reach somewhat conflicting conclusions on the implications for how policy should control exchange rates. The exact policy conclusions depend on the details of the model—which prices or wages are sticky, and the nature of the constraint on borrowers.

The analysis of welfare-based optimal monetary policy in open economies is still in the early stages. There are many interesting issues to be explored, especially when financial markets are incomplete. The analysis to date does suggest a role for exchange rates in an optimal monetary policy rule. As globalization proceeds, these considerations may call for greater international monetary policy coordination, with a focus on exchange rates and imbalances.

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The author is not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

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