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Abstract

This chapter studies optimal monetary stabilization policy in interdependent open economies, by proposing a unified analytical framework systematizing the existing literature. In the model, the combination of complete exchange-rate pass-through ('producer currency pricing') and frictionless asset markets ensuring efficient risk sharing, results in a form of open-economy 'divine coincidence': in line with the prescriptions in the baseline New-Keynesian setting, the optimal monetary policy under cooperation is characterized by exclusively inward-looking targeting rules in domestic output gaps and GDP-deflator inflation. The chapter then examines deviations from this benchmark, when cross-country strategic policy interactions, incomplete exchange-rate pass-through ('local currency pricing') and asset market imperfections are accounted for. Namely, failure to internalize international monetary spillovers results in attempts to manipulate international relative prices to raise national welfare, causing inefficient real exchange rate fluctuations. Local currency pricing and incomplete asset markets (preventing efficient risk sharing) shift the focus of monetary stabilization to redressing domestic as well as external distortions: the targeting rules characterizing the optimal policy are not only in domestic output gaps and inflation, but also in misalignments in the terms of trade and real exchange rates, and cross-country demand imbalances.

Keywords: Currency misalignments, demand imbalances, pass-through, asset markets and risk sharing, optimal targeting rules, international policy cooperation

JEL codes: E44, E52, E61, F41, F42

1 Introduction and overview

Research in the international dimensions of optimal monetary policy has long been inspired by a set of fascinating questions, shaping the policy debate in at least two eras of progressive cross-border integration of goods, factors, and assets markets — in the years after World War I and from Bretton Woods to today. Namely, should monetary policy respond to international variables such as exchange rates, global business cycle conditions, or global imbalances beyond their influence on the domestic output gap and inflation? Do exchange rate movements have desirable stabilization and allocative properties? Or, on the contrary, should policymakers curb exchange rate fluctuations and be concerned with, and attempt to correct, currency misalignments? Are there large gains the international community could reap by strengthening cross-border monetary cooperation?

In this chapter, we revisit these classical questions by building on the choice-theoretic monetary literature encompassing the research agenda of the New Keynesian models (see, e.g., Rotemberg and Woodford 1997), the New Classical Synthesis (see, e.g., Goodfriend and King 1997), and especially the New Open Economy Macroeconomics, henceforth NOEM (see, e.g., Svensson and van Wijnbergen 1989, Obstfeld and Rogoff 1995). In doing so, we will naturally draw on a well-established set of general principles in stabilization theory, which go beyond open-economy issues. Yet, the main goal of our analysis is to shed light on monetary policy trade-offs that are inherently linked to open economies which engage in cross-border trade in goods and assets.

A general feature sharply distinguishes monetary policy analysis in open economies from its closed-economy counterpart. This consists of the need to account explicitly for different forms of heterogeneity that naturally arise in an international context, ranging from instances of *ex ante* heterogeneity across countries such as product specialization, cross-country differences in technology, preferences, currency denomination of prices, financial market development, and asset holdings, to *ex post* heterogeneity such as the asymmetric nature of shocks, as well as endogenous redistributions of wealth across countries in response to shocks. While these forms of heterogeneity enlarge the array of potential policy trade-offs relevant to the analysis, in a global equilibrium monetary policy problems are addressed using as many policy instruments as there are monetary authorities in the model economy. Along this dimension as well, however, there could be heterogeneity in objectives and policy strategies.

Building on an open-economy model which has been the workhorse for much of the literature — featuring two countries, each specialized in the production of a type of goods in different varieties[1] — we study optimal monetary policy under alternative assumptions regarding nominal rigidities and asset market structure, adopting the linear-quadratic approach developed by Woodford (2003).

A first important result consists of deriving a general expression for the open-economy New Keynesian Phillips curve, relating current inflation to expected inflation and changes in marginal costs. In an open economy, the latter (marginal costs) is a function of output gaps plus two additional terms, one accounting for misalignments in international relative prices, the other for inefficient fluctuations in aggregate demand across countries. In analogy to the definition of output gaps, we measure misalignments in terms of deviations of international relative prices from their first-best levels.[2] The term accounting for inefficient fluctuations in aggregate demand instead measures relative price- and preference-adjusted differentials in consumption demand, which generally differ from zero in the presence of financial market frictions.

This tripartite classification of factors driving the Phillips curve — output gaps, international relative price gaps, and cross-country demand imbalances — also provides the key building block for our policy analysis. Indeed, a second important result is that, together with inflation rates, the same three factors listed above are the arguments in the quadratic loss functions which can be derived for different specifications of our workhorse model. Of course, the specific way these arguments enter the loss functions vary across model specifications, reflecting different nominal and real distortions.

A well-known result from monetary theory is that stabilization policy should maintain inflation at low and stable rates, as a way to minimize the misallocation of resources due to staggered nominal price adjustment. In the baseline model with only one sector and one representative agent,

[1] The model, similarly to Chari et al. (2002), can be seen as a monetary counterpart to the international real business cycle literature after Backus, Kehoe and Kydland (1994), and, for versions including nontraded goods, Stockman and Tesar (1995). For recent evidence on monetary models of exchange rates see Engel et al. (2007).

[2] We stress that, conceptually, the efficient exchange rate is not necessarily (and in general will not be) identical to the 'equilibrium exchange rate', traditionally analyzed by international and public institutions, as a guide to policy making. 'Equilibrium exchange rates' typically refer to some notion of long-term external balance, against which to assess short-run movements in currency values (see e.g. Chinn 2010). On the contrary, the efficient exchange rate is theoretically and conceptually defined at any time horizon, in relation to a hypothetical economy in which all prices are flexible and markets are complete, in strict analogy to the notion of a welfare relevant output gap. In either case, the assessment of efficient prices and quantities, at both domestic and international levels, posits a formidable challenge to researchers.

such misallocation takes the form of price dispersion for goods which are symmetric in preferences and technology. In such a model, optimal monetary policy is characterized by a flexible inflation target, trading off fluctuations in the GDP deflator and the output gap vis-à-vis inefficient shocks — such as markup shocks (which would not be accommodated by the social planner). Conversely, the optimal target will result in the complete stabilization of the domestic GDP deflator and output gap, vis-à-vis efficient shocks — such as disturbances in productivity and tastes (which would be accommodated by the social planner) — see, e.g., Galí (2008) or Woodford (2003).

As a first step in our study, we consider a specification of the workhorse model for which the prescription guiding optimal monetary policy is identical to the one for the benchmark economy mentioned above: optimal policy is "isomorphic" to the one for baseline closed-economy models; see, e.g., Clarida Galí and Gertler (2002), henceforth CGG, and Benigno and Benigno (2006), henceforth BB. For this to be the case, it is crucial that endogenous movements in the exchange rate correct potential misalignments in the relative price between domestic and foreign goods in response to macroeconomic shocks, in accord with the classical view of the international transmission mechanism as formalized by, e.g., Friedman (1953).

Underlying the classical view, there are two key assumptions. First, frictionless asset markets provide insurance against all possible contingencies across borders. Second, producer prices are sticky in domestic currency, so that the foreign currency price of products move one-to-one with the exchange rate — the latter assumption is commonly dubbed producer currency pricing (henceforth PCP) by the literature. By virtue of perfect risk insurance and a high degree of exchange rate pass-through of import prices, as stressed by Corsetti and Pesenti (2005) and Devereux and Engel (2003), preventing price dispersion within categories of goods automatically corrects any possible misalignment in the relative prices of domestic and foreign goods — a form of "divine coincidence", in the definition of Blanchard and Galí (2007).

In relation to this baseline specification, the rest of our analysis calls attention to open-economy distortions which break the divine coincidence just defined — thus motivating optimal target rules explicitly featuring open-economy variables. In a closed-economy context, the divine coincidence breaks down in models including both price and wage rigidities, or price rigidities in multiple sectors — in which case the trade-off is between stabilizing relative prices within and across categories of goods and services, see, e.g., Erceg et al. (2000) — or introducing agents' heterogeneity, whereas policy trade-offs may then arise because of imperfect risk insurance, see, e.g., Curdia and Woodford (2009). Analogous trade-offs naturally and most plausibly arise in open economies in the form of misalignments in the terms of trade (the relative price of imports in terms of exports) or the real exchange rate (the international relative price of consumption), as well as in the form of cross-border imbalances in aggregate demand. At the core of the policy problem raised by misalignments and imbalances however lies the exchange rate in its dual role of relative price in the goods and the asset markets — which has no counterpart in a closed-economic context. In addition, inefficiencies and trade-offs with specific international dimensions result from cross-border monetary spillovers when these are not internalized by national monetary authorities — i.e., when these act noncooperatively in setting their domestic monetary stance. Except under very special circumstances, all these considerations rule out isomorphism/similarities in policy prescriptions in closed and open economies.

Under the maintained assumption of complete markets, in the first part of the chapter we characterize optimal monetary policy in the presence of distortions resulting either from nominal rigidities causing the same good to be traded at different prices across markets, or from national policymakers' failure to internalize international monetary spillovers. In the second part of the chapter, we instead reconsider the optimal policy in an incomplete market framework, focusing on the interactions between nominal and financial distortions.[3] We highlight below the main results of the chapter.

Skepticism of the classical view: local-currency price stability of imports In contrast with the classical view, recent leading contributions have emphasized the widespread evidence of local-currency stability in the price of imports, attributing asignificant portion of it to nominal rigidities. In the data, exchange rate movements appear to be only weakly reflected in import prices (a large body of studies ranges from those surveyed by Goldberg and Knetter 1997, to recent work based on individual goods data, such as Gopinath and Rigobon 2008).

Under the assumption that import prices are sticky in the local currency — a hypothesis commonly dubbed local currency pricing or LCP by the literature — the transmission of monetary policy is fundamentally different relative to the classical view. Namely, with LCP, exchange rate movements have a limited impact on the price of imports faced by consumers — pass-

[3] For a thorough analysis of the international dimensions of monetary policy, including issues in macroeconomic stabilization in response to oil shocks and in monetary control in a globalized world economy, see the excellent collection of contributions in Galí and Gertler (2009).

through is incomplete. Rather, they cause widespread inefficient deviations from the law of one price: identical goods trade at different prices (expressed in the same currency) across national markets. Exchange rates cannot realign international and domestic relative prices at their efficient level. In the last few years, the debate contrasting the international transmission mechanism and policy analysis under PCP and LCP has arguably been the main focus in the early NOEM literature (see, e.g., the discussion in Obstfeld and Rogoff 2000, Betts and Devereux 2000, and Engel 2002).

With LCP, there is no divine coincidence since cross-country output gap stabilization no longer translates into relative price stabilization. In response to productivity shocks, for instance, stabilizing marginal costs of domestic producers neither coincides with stabilizing their markups in all markets, nor it is sufficient to realign international prices. As shown by Engel (2009), the optimal policy thus will have to trade off internal objectives (output gaps and an inflation goal) with correcting misalignments. Specifically, similar to the PCP case, under LCP cooperative policymakers dislike national output gaps and inflation, as well as cross-country differences in output, to the extent that these lead to misalignments in international relative prices. Yet, relative to the PCP case, the inflation rates relevant to policymakers are different for domestic goods than for imports. The different terms in inflation reflect the fact that, with LCP, policymakers are concerned with inefficiencies in the supply of each good due to price dispersion in the domestic and in the export destination markets. In addition, the policy loss function includes a new term in deviations from the law of one price, driving misalignments in relative prices and causing inefficiencies in the level and composition of global consumption demand, a point especially stressed by the literature assuming one-period preset prices; see Devereux and Engel (2003) and Corsetti and Pesenti (2005).

The targeting rules characterizing optimal policy under LCP are generally complex, involving a combination of current and expected values of domestic variables, like the output gap and producer and consumer prices, as well as of external variables, like the real exchange rate gap. Nonetheless, they considerably simplify under two alternative conditions, that is, either the disutility of labor is linear — a case stressed by Engel (2009) — or purchasing power parity (PPP) holds in the first best — a case discussed by the early contributions to the NOEM literature such as CGG and BB. We show that either condition leads to the same clear-cut optimal policy prescriptions: in the face of efficient shocks policymakers should completely stabilize CPI inflation, the global output gap, and the real exchange rate gap at the expense of terms of trade misalignments and understabilization of relative output gaps. This implies complete stabilization of consumption around its efficient level and, only when PPP holds, complete stabilization of nominal exchange rates. The two special cases of PPP and linear disutility of labor are noteworthy, in light of the attention they receive in the literature and their analytical tractability. Yet, the strong policy prescriptions derived from their analysis should not be generalized.

Indeed, the main lesson from the LCP literature is that policymakers should pay attention to international relative price misalignments, as the exchange rate cannot be expected to correct them according to the classical view, and to consumer price inflation, since with sectoral differences in inflation there are both supply and demand distortions. In general, however, it motivates neither complete stabilization of the CPI index, even in the face of efficient shocks, since the optimal trade-off in stabilizing different components of CPI inflation do not necessarily coincide with CPI weights, nor curbing exchange rate volatility — under the optimal policy, exchange rate and terms of trade volatility can remain quite high under LCP.

Competitive devaluations and strategic interactions Policy trade-offs with an international dimension are also generated by cross-border spillovers in quantities and prices when these give rise to strategic interactions among policymakers — one of the main topics of traditional policy analysis in open economies (see, e.g., Canzoneri and Henderson 1991 and Persson and Tabellini 1995). This chapter revisits classical concerns about "competitive devaluations" in a modern framework, providing an instance of a game between benevolent national monetary authorities, each attempting to exploit the monopoly power of the country on its terms of trade to raise national welfare.

Drawing on the literature, we focus on a Nash equilibrium assuming complete markets and PCP. Depending on whether goods are complements or substitutes in preferences, domestic policymakers have an incentive to either improve or worsen their country's terms of trade, at the cost of some inflation. These results appear to support the notion that strategic terms of trade manipulation motivates deviations from domestic output gap stabilization, and thus translates into either insufficient or excessive exchange rate volatility relative to the efficient benchmark of policy cooperation (BB, and De Paoli 2009a among others). However, in a global model, much of the potential gains from national policies are offset by the reaction of monetary authorities abroad. The noncooperative allocation turns out to be suboptimal for all. Despite strategic terms of trade manipulation, the deviations from the cooperative allocation actually are quite small.[4]

Indeed, gains from international policy coordination relative to Nash in the class of models we consider may be small — they are actually zero for some configurations of parameters ruling out cross-country spillovers relevant for policymaking, (see, e.g., Corsetti and Pesenti 2005, extending this limiting result to LCP economies). The literature has recently emphasized these welfare results as a reason for skepticism about international policy cooperation (Obstfeld and Rogoff 2002, Canzoneri et al. 2005). But the issue of gauging gains from cooperation is actually wide open, especially in the presence of real and financial imperfections that may induce national central banks to play noncooperatively.

Currency misalignments and international demand imbalances New directions for monetary policy analysis are emphasized in the last part of this chapter, which widens the scope of our inquiry to inefficiencies unrelated to nominal rigidities, stemming from arguably deeper and potentially more consequential distortions. Namely, we study monetary policy tradeoffs in open economies where asset market distortions prevent the market allocation from being globally efficient. Specifically, because of distortions resulting from incomplete markets, even if the exchange rate acts as a "shock absorber" moving only in response to current and expected fundamentals, its adjustment does not necessarily contribute to achieving a desirable allocation. On the contrary, it may exacerbate misallocation of consumption and employment both domestically and globally, corresponding to suboptimal ex post heterogeneity across countries.

We first show that, relative to the case of complete markets, both the Phillips curve and the loss function generally include a welfare-relevant measure of cross-country demand imbalances. This is the gap between marginal utility differentials and the relative price of consumption — which we dub the "relative demand" gap. Such a (theoretically consistent) measure of demand imbalances is identically equal to zero in an efficient allocation. A positive gap means that the Home consumption demand is excessive (relative to the efficient allocation) at the current real exchange rate (i.e., at the current relative price of consumption). With international borrowing and lending, in addition, demand imbalances are reflected by inefficient trade and current account deficits.

[4] An open issue is the empirical relevance of terms-of-trade considerations in setting monetary policy — a similar issue is discussed in the trade literature concerning the relevance of the "optimal tariff argument".

We then show that, with incomplete markets, optimal monetary policy has an "international dimension" similar to the case of LCP: domestic goals (output gap and inflation) are traded off against the stabilization of external variables, such as the terms of trade and the demand gap. A comparative analysis of these two cases however highlights differences in the nature and size of the distortions underlying the policy trade-offs with external variables, suggesting conditions under which financial imperfections are more consequential for the conduct of monetary policy, compared to nominal price rigidities in the import sector.

We derive targeting rules showing that the optimal policy typically acts to redress demand imbalances — containing the size of external deficits — and/or correct international relative prices — leaning against overvaluation of the exchange rate — at the cost of some inflation. These targeting rules are characterized analytically for economies in financial autarky. In these economies, as stressed by Helpman and Razin (1978), Cole and Obstfeld (1991) and Corsetti and Pesenti (2001), a mechanism of risk sharing is provided by relative price adjustment affecting the valuation of a country's output. Yet we show that no parameter configuration exists for which, in the presence of both productivity and preference shocks, equilibrium terms of trade movements automatically support an efficient allocation in the absence of trade in assets — the equivalence between financial autarky and complete markets is possible only for each of these shocks in isolation.

We close the chapter by discussing the results in related work of ours (Corsetti, Dedola, and Leduc 2009b) for an economy in which households can trade an international bond, suggesting that our analytical conclusions for the case of financial autarky are a good guide to interpret the optimal policy in more general specifications of the incomplete market economy.

The text is organized as follows. In Part I, we assume complete markets, and analyze optimal policies in PCP and LCP economies under cooperation, as well as under Nash. In Part II, we allow for financial imperfection, and discuss new policy trade-offs when financial markets fail to support an efficient allocation. Analytical details of the model and its solution are provided in a web appendix.

Part I
Optimal stabilization policy and international relative prices with frictionless asset markets

In this first part of the chapter, we study optimal monetary policy in open economies in the context of a classical debate in international economics, concerning the extent to which exchange rate movements can redress the inefficiencies in the international adjustment mechanism created by nominal and monetary distortions, and foster desirable relative price adjustment across the border. To sharply focus on this issue, we follow much of the literature on the subject, and carry out our analysis assuming complete and frictionless asset markets. Under this assumption, we will contrast optimal policy prescriptions coherent with two leading views.

One important view — the classical view — is that exchange rate movements are efficient (macro) shock absorbers, fostering relative price adjustment between domestic and foreign goods in response to aggregate shocks. By way of example, in response to a country-specific positive supply shock, a fall in the international price of domestic output can efficiently occur via nominal and real depreciation, which lowers the foreign-currency prices of domestic exports while raising the domestic currency price of imports. Consistent with this view, a high sensitivity of the price of imports to the exchange rate — imported inflation — is a desirable manifestation of real price adjustment to macro disturbances.

However, in the data, exchange rate movements appear to be only weakly reflected in import prices, not only at the retail level, but also at the border. The alternative view emphasizes that a high degree of stability in the prices of imports in local currency questions the very mechanism postulated by the classical view. To the extent that a low exchange rate pass-through reflects nominal rigidities — that is, export prices are sticky in the currency of the destination market — nominal depreciation does not lower the relative price of domestic goods faced by the final buyers worldwide, hence it does not redirect demand towards them.

A further dimension of the classical debate on the role of the exchange rate in the adjustment of international relative prices in the goods market concerns the possibility that countries engage in strategic manipulation of the terms of trade — e.g. according to the logic of 'competitive devaluation.'

In such case the market allocation would not be efficient because policymakers fail to internalize cross-border monetary spillovers. On the contrary, they intentionally use monetary instrument to exploit the monopoly power that a country may have on its terms of trade, and/or their ability to affect relative prices. As a consequence, prices may be misaligned relative to the efficient allocation.

In what follows, Section 2 will first lay out our analytical framework. Section 3 and 4 will characterize optimal stabilization policy under the two contrasting views regarding the stabilizing properties of the exchange rate briefly discussed above. Section 5 will analyze a world equilibrium in the absence of international policy cooperation.

2 A baseline monetary model of macroeconomic interdependence

2.1 Real and nominal distortions in New Keynesian open-economy analysis

Our analysis builds on a two-country, two-good open-economy model which, by virtue of its analytical tractability, has become a standard reference for monetary analysis in international economics, at least since Obstfeld and Rogoff (1995) — the contribution starting the so-called New Open Economy Macroeconomics (an important precursor being Svensson and van Wijnbergen 1989). In the model, each economy is specialized in the production of one type of good supplied in many varieties, all traded across borders. Since the preferences of national consumers need not be identical, the consumption basket and therefore its price will generally be different across border. Even when the law of one price holds for each individual good/variety, the relative price of consumption — that is, the real exchange rate — will fluctuate in response to shocks, and the purchasing power parity (PPP) will fail in general. In addition, nominal rigidities can also be envisioned to bring about deviations from the law of one price at the level of individual good variety. In that case, the relative price of imports and exports will not coincide with the terms of trade.

In this workhorse model, nominal rigidities interact with three other sources of distortions. The first is monopoly power in production, as in the (closed-economy) new-Keynesian model. The other two are specific to international analysis, and consists of incentives to deviate from globally optimal policies stemming from the assumption that countries have monopoly power on their terms of trade, and imperfections in international financial markets. In the first part of the chapter, we will proceed under the assumption that financial markets are complete — so that the only policy trade-offs will be raised by distortions related to nominal rigidities and, when we look at non-cooperative policies, a country's monopoly power on its terms of trade. The policy implications of financial market imperfections will instead be analyzed in the second part of the chapter.

In this section we will lay out the model in its general form, including features from which we will abstract in the course of our analysis, but could be useful for exploring generalization of our results. Namely, in our general setup we model a demand for money balances assuming that liquidity services provides utility. For comparison with the bulk of New-Keynesian analysis, however, our analysis of the optimal policy will proceed as if our economies were de facto cashless, ignoring this component of utility. Second, our general setup account for different degree of openness (asymmetric home-bias in demand) and country size (different population). To keep our exposition as compact as possible, however, Phillips curve and optimal policy will be derived imposing symmetry in these two dimensions. Finally, while our setup below explicitly accounts for the government budget constraint, in the rest of the chapter we will abstract from fiscal spending positing $\overline{G} = 0$.

2.2 The setup

The world economy consists of two countries, dubbed H (Home) and F (Foreign). It is populated with a continuum of agents of unit mass, where the population in the segment $[0; n)$ belongs to country H and the population in the segment $(n; 1]$ belongs to country F. Each country specializes in one type of tradable good, produced in a number of varieties or brands with measure equal to population size.[5]

2.2.1 Preferences and households' decisions

The utility function of a consumer j in country H is given by

$$V^j = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[U\left(C_t^j, \zeta_{C,t}\right) + L\left(\frac{M_{t+1}^j}{P_t}, \zeta_{M,t}\right) - \frac{1}{n}\int_0^n V\left(y_t(h), \zeta_{Y,t}\right) dh \right] \right\}. \tag{1}$$

[5] A version of the workhorse model with firm entry can build on Bilbiie Ghironi and Melitz (2007).

Households obtain utility from consumption and the liquidity services of holding money, while they receive disutility from contributing to the production of all domestic goods $y_t(h)$ with a separable disutility. Variables $\zeta_{C,t}$, $\zeta_{M,t}$, $\zeta_{Y,t}$ denote country specific shocks to preferences towards consumption, real money balances and production, respectively. Risk is pooled internally to the extent that agents participate in the production of all goods and receive an equal share of production revenue. We assume the following functional forms, widely used in the literature and convenient to obtain analytical characterizations (see, e.g., BB and CGG):[6]

$$\begin{aligned} U\left(C_t^j, \zeta_{C,t}\right) &= \zeta_{C,t} \frac{C_t^{j\,1-\sigma} - 1}{1-\sigma} \\ L\left(\frac{M_{t+1}^j}{P_t}, \zeta_{M,t}\right) &= \zeta_{M,t} \frac{\left(\frac{M_{t+1}^j}{P_t}\right)^{1-\rho} - 1}{1-\rho} \\ V\left(y_t(h), \zeta_{Y,t}\right) &= \frac{\zeta_{Y,t}^{-\eta} y_t(h)^{1+\eta}}{1+\eta} \end{aligned} \tag{2}$$

Households consume both types of traded goods. So $C_t(h,j)$ and $C_t(f,j)$ are the same agent's consumption of Home brand h and Foreign brand f. For each type of good, we assume that one brand is an imperfect substitute for all other brands, with constant elasticity of substitution $\theta > 1$. Consumption of Home and Foreign goods by Home agent j is defined as:

$$\begin{aligned} C_{\mathrm{H},t}(j) &\equiv \left[\left(\frac{1}{n}\right)^{1/\theta} \int_0^n C_t(h,j)^{\frac{\theta-1}{\theta}} dh\right]^{\frac{\theta}{\theta-1}}, \\ C_{\mathrm{F},t}(j) &\equiv \left[\left(\frac{1}{1-n}\right)^{1/\theta} \int_n^1 C_t(f,j)^{\frac{\theta-1}{\theta}} df\right]^{\frac{\theta-1}{\theta}} \end{aligned} \tag{3}$$

The full consumption basket, C_t, in each country is defined by the following CES aggregator

$$C = \left[a_{\mathrm{H}}^{1/\phi} C_{\mathrm{H}}^{\frac{\phi-1}{\phi}} + a_{\mathrm{F}}^{1/\phi} C_{\mathrm{F}}^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \qquad \phi > 0. \tag{4}$$

[6] We follow BB in the functional form of the disutility of labor; it could be reconciled with CGG by assuming $\zeta_{Y,t}^{-(1+\eta)}$.

where a_{H} and a_{F} are the weights on the consumption of home and foreign goods, respectively, normalized to sum to 1, and ϕ is the constant elasticity of substitution between C_{H} and C_{F}. Note that this specification generates home bias if $a_{\mathrm{H}} > \frac{1}{2}$. Also, consistent with the assumption of specialization in production, the elasticity of substitution is higher among brands produced within a country, than across types of national goods, that is, $\theta > \phi$.

As well known, the utility-based CPI is:

$$P_t = \left[a_{\mathrm{H}} P_{\mathrm{H},t}{}^{1-\phi} + (1-a_{\mathrm{H}})\, P_{\mathrm{F},t}{}^{1-\phi}\right]^{\frac{1}{1-\phi}}, \tag{5}$$

where $P_{\mathrm{H},t}$ is the price sub-index for home-produced goods and $P_{\mathrm{F},t}$ is the price sub-index for foreign produced goods, both expressed in the domestic currency:

$$P_{\mathrm{H},t} \equiv \left[\frac{1}{n}\int_0^n P_t(h)^{1-\theta} dh\right]^{\frac{1}{1-\theta}}, \qquad P_{\mathrm{F},t} \equiv \left[\frac{1}{1-n}\int_0^n P_t(f)^{1-\theta} df\right]^{\frac{1}{1-\theta}} \tag{6}$$

Foreign prices, denoted with an asterisk like all the foreign variables, are similarly defined. So, the Foreign CPI is:

$$P_t^* = \left[(1-a_{\mathrm{F}}^*)\, P_{\mathrm{H},t}^*{}^{1-\phi} + a_{\mathrm{F}}^* P_{\mathrm{F},t}^*{}^{1-\phi}\right]^{\frac{1}{1-\phi}}. \tag{7}$$

Let $\mathcal{Q}_t$ denote the real exchange rate, defined as the relative price of consumption: $\mathcal{Q}_t = \frac{\mathcal{E}_t P_t^*}{P_t}$. Even if the law of one price holds for each good individually (i.e., $P_t(h) = \mathcal{E}_t P_t^*(h)$ and $P_t(f) = \mathcal{E}_t P_t^*(f)$), differences in the optimal consumption baskets chosen by households imply that the price of consumption is not equalized across border. In other words, with different preferences, purchasing power parity (i.e., $\mathcal{Q}_t = 1$) will not hold. In addition to the real exchange rate, another international relative price of interest is the terms of trade, that is the price of imports in terms of exports. For the Home country, this can be written as $\mathcal{T}_t = \frac{P_{\mathrm{F},t}}{\mathcal{E}_t P_{\mathrm{H},t}^*}$.

From consumers' preferences, we can derive household demand for a generic good h, produced in country H, and the demand for a good f, produced in country F:

$$\begin{aligned} C_t(h,j) &= a_{\mathrm{H}} \left(\frac{P_t(h)}{P_{\mathrm{H},t}}\right)^{-\theta} \left(\frac{P_{\mathrm{H},t}}{P_t}\right)^{-\phi} C_t^j, \\ C_t(f,j) &= (1-a_{\mathrm{H}}) \left(\frac{P_t(f)}{P_{\mathrm{F},t}}\right)^{-\theta} \left(\frac{P_{\mathrm{F},t}}{P_t}\right)^{-\phi} C_t^j; \end{aligned} \tag{8}$$

assuming the law of one price holds, total demand for good h and f can then been written as:

$$y_t^d(h) = \left(\frac{P_t(h)}{P_{\mathrm{H},t}}\right)^{-\theta} \left[\left(\frac{P_{\mathrm{H},t}}{P_t}\right)^{-\phi} \left(a_{\mathrm{H}} C_t + a_{\mathrm{H}}^* \frac{1-n}{n} \mathcal{Q}_t^{\phi} C_t^*\right) + G_t\right] \tag{9}$$

$$y_t^d(f) = \left(\frac{P_t(f)}{P_{\mathrm{F},t}}\right)^{-\theta} \left[\left(\frac{P_{\mathrm{F},t}}{P_t}\right)^{-\phi} \left((1-a_{\mathrm{H}}) \frac{n}{1-n} C_t + \mathcal{Q}_t^{\phi} (1-a_{\mathrm{H}}^*) C_t^*\right) + G_t^*\right], \tag{10}$$

where G_t and G_t^* are country-specific government spending shocks, under the assumption that the public sector in the Home (Foreign) economy only consumes Home (Foreign) goods and has preferences for differentiated goods analogous to the preferences of the private sector.

2.2.2 Budget constraints and Euler equations

The individual flow budget constraint for the representative agent in the Home country can be generically written as:[7]

$$\begin{aligned} M_t + B_{\mathrm{H},t+1} + \int q_{\mathrm{H},t+1}(s_{t+1}) \mathcal{B}_{\mathrm{H},t+1}(s_{t+1}) ds_{t+1} &\leq M_{t-1} + (1+i_t) B_{\mathrm{H},t} + \mathcal{B}_{\mathrm{H},t} \\ &+ (1-\tau_t) \frac{\int P_t(h) y_t(h) dh}{n} - P_{\mathrm{H},t} T_t - P_{\mathrm{H},t} C_{\mathrm{H},t} - P_{\mathrm{F},t} C_{\mathrm{F},t}, \end{aligned}$$

where $\mathcal{B}_{\mathrm{H},t}$ is the holdings of state-contingent claims, priced at $q_{\mathrm{H},t}$, paying off one unit of domestic currency in the realized state of the world as of t, s_t, and i_t is the yield on a domestic nominal bond $B_{\mathrm{H},t}$, paid at the beginning of period t in domestic currency but known at time $t-1$, whose associated first-order conditions result in the following familiar Euler equations:

$$\frac{U_C(C_t, \zeta_{C,t})}{P_t} = (1+i_t) E_t \left[\beta \frac{U_C(C_{t+1}, \zeta_{C,t+1})}{P_{t+1}}\right], \tag{11}$$

determining the intertemporal profile of consumption and savings. Likewise, from the Foreign country analogue we obtain:

$$\frac{U_C(C_t^*, \zeta_{C,t}^*)}{P_t^*} = (1+i_t^*) E_t \left[\beta \frac{U_C(C_{t+1}^*, \zeta_{C,t+1}^*)}{P_{t+1}^*}\right]. \tag{12}$$

[7] $B_{\mathrm{H},t}$ denotes the Home agent's bonds accumulated during period $t-1$ and carried over into period t.

The government budget constraints in the Home and Foreign economy are respectively given by

$$\tau_t \int P_t(h) y_t(h) dh = P_{\mathrm{H},t} \left(nG_t + \int T_t^j \right) + \int \left(M_t^j - M_{t-1} \right), \qquad (13)$$

$$\tau_t^* \int P_t^*(f) y_t^*(f) df = P_{\mathrm{F},t}^* \left((1-n) G_t^* + \int T_t^{j*} \right) + \int \left(M_t^j - M_{t-1} \right). \quad (14)$$

Fluctuations in proportional revenue taxes τ_t (τ_t^*), or government spending G_t (G_t^*), are exogenous and completely financed by lump-sum transfers, T_t (T_t^*), made in the form of domestic (foreign) goods.

2.2.3 Price-setting decisions

Prices follow a partial adjustment rule à la Calvo-Yun. Producers of differentiated goods know the form of their individual demand functions and maximize profits taking overall market prices and products as given. In each period a fraction $\alpha \in [0; 1)$ of randomly chosen producers is not allowed to change the nominal price of the goods they produce. The remaining fraction of firms, given by $1-\alpha$ chooses prices optimally by maximizing the expected discounted value of profits. When doing so, firms face both a domestic and a foreign demand. In principle, absent arbitrage across border, firms could find it optimal to choose different prices.[8] Moreover, they may preset prices either in domestic or in foreign currency.

Price setting under PCP The NOEM literature after Obstfeld and Rogoff (1995) posits that prices are rigid in currency of the producers: firms set export prices in domestic currency, letting the foreign currency price of their product vary with the exchange rate. This hypothesis is dubbed 'producer currency pricing' or PCP. Let $\mathcal{P}_t(h)$ denote the price optimally chosen by the firm h for the domestic market at time t. To keep notation as simple as possible let $\{\mathcal{E}_t \mathcal{P}_t^*(h)\}$ denote the price chosen for the foreign market, expressed in domestic currency (under PCP, $\mathcal{E}_t$ and $\mathcal{P}_t^*(h)$ move proportionally, as exchange rate pass through on import prices is complete).

[8] See Corsetti and Dedola (2005) for an analysis of optimal pricing under an no-arbitrage constraint.

The home firm's problem can then be written as follows

$$Max_{p_t(h),\mathcal{E}_t p_t^*(h)} E_t \sum_{s=0}^{\infty} \{(\alpha\beta)^s \left\{ \begin{array}{c} \frac{U_{C,t+s}}{P_{t+s}} (1-\tau_{t+s}) \cdot \\ \left[p_t(h) \left(\frac{p_t(h)}{P_{\mathrm{H},t+s}} \right)^{-\theta} \left(\frac{P_{\mathrm{H},t+s}}{P_{t+s}} \right)^{-\phi} (a_{\mathrm{H}} C_{t+s} + G_{t+s}) \right. \end{array} \right. \tag{15}$$

$$\left. + \mathcal{E}_t p_t^*(h) \left(\frac{\mathcal{E}_t p_t^*(h)}{\mathcal{E}_{t+s} P^*_{\mathrm{H},t+s}} \right)^{-\theta} \left(\frac{P^*_{\mathrm{H},t+s}}{P^*_{t+s}} \right)^{-\phi} \left(a^*_{\mathrm{H}} \frac{1-n}{n} C^*_{t+s} \right) \right]$$

$$-V\left(y_{t+s}(h), \zeta_{Y,t+s}\right)\}$$

where revenues and costs are measured in utils and an asterisk denotes prices in Foreign currency. Let $y^d_{t+s}(h)$ be the total demand of the good at time $t+s$ under the circumstances that the prices chosen at t $\mathcal{P}_t(h)$ and $\mathcal{E}_t\mathcal{P}_t^*(h)$ still apply at $t+s$. The first-order conditions for this problems are

$$E_t \sum_{s=0}^{\infty} (\alpha\beta)^s \left\{ \left[\frac{U_{C,t+s}}{P_{t+s}} \mathcal{P}_t(h) - \frac{\theta}{(1-\tau_{t+s})(\theta-1)} V_y\left(y^d_{t+s}(h), \zeta_{Y,t+s}\right) \right] \right.$$

$$\left. \left[\left(\frac{\mathcal{P}_t(h)}{P_{\mathrm{H},t+s}} \right)^{-\theta} \left(\frac{P_{\mathrm{H},t+s}}{P_{t+s}} \right)^{-\phi} (a_{\mathrm{H}} C_t + G_t) \right] \right\} = 0$$

$$E_t \sum_{s=0}^{\infty} (\alpha\beta)^s \left\{ \left[\frac{U_{C,t+s}}{P_{t+s}} \mathcal{E}_t \mathcal{P}_t^*(h) - \frac{\theta}{(1-\tau_{t+s})(\theta-1)} V_y\left(y^d_{t+s}(h), \zeta_{Y,t+s}\right) \right] \right.$$

$$\left. \left[\left(\frac{\mathcal{E}_t \mathcal{P}_t^*(h)}{\mathcal{E}_{t+s} P^*_{\mathrm{H},t+s}} \right)^{-\theta} \left(\frac{P^*_{\mathrm{H},t+s}}{P^*_{t+s}} \right)^{-\phi} \left(a^*_{\mathrm{H}} \frac{1-n}{n} C^*_t \right) \right] \right\} = 0.$$

Note that the last term on the left hand side of each condition is the demand for the good h in the Home and Foreign market, respectively, at the price chosen at time t — these two terms indeed sum up to $y^d(h)$. Let μ_t denote the markup charged by the firm

$$\mu_t \equiv \frac{\theta}{(\theta-1)(1-\tau_{t+s})}$$

which we assume subject to shocks due to time-varying taxes on producers τ_{t+s}. The firm's problem is solved by

$$E_t \sum_{s=0}^{\infty} (\alpha\beta)^s \left[\frac{U_{C,t+s}}{P_{t,t+s}} \mathcal{P}_t(h) - \mu_t V_y\left(y^d_{t+s}(h), \zeta_{Y,t+s}\right) \right] y^d_{t+s} = 0 \tag{16}$$

$$\mathcal{E}_t \mathcal{P}_t^*(h) = \mathcal{P}_t(h) \qquad for\ all\ h$$

As demand elasticities are constant and symmetric across borders, firms will optimally choose identical prices for both their domestic and their export markets: the law of one price will hold independently of barriers to good markets integration. The above solution hence implies

$$\mathcal{E}_t P^*_{H,t} = P_{H,t} \text{ and } P_{F,t} = \mathcal{E}_t P^*_{F,t}$$

With PCP, it is easy to see that the terms of trade move one-to-one with the exchange rate, as well as with the domestic relative price of imports faced by consumers: $\mathcal{T}_t = P_{\mathrm{F},t}/\mathcal{E}_t P^*_{\mathrm{H},t} = \mathcal{E}_t P^*_{\mathrm{F},t}/P_{\mathrm{H},t} = P_{\mathrm{F},t}/P_{\mathrm{H},t}$.

Since all the producers that can choose their price set it to the same value, we obtain two equations which describe the dynamic evolution of $P_{\mathrm{H},t}$ and $P_{\mathrm{F},t}$:

$$\begin{aligned} P_{\mathrm{H},t}^{1-\theta} &= \alpha P_{\mathrm{H},t-1}^{1-\theta} + (1-\alpha)\,\mathcal{P}_t(h)^{1-\theta}, \\ P_{\mathrm{F},t}^{*1-\theta} &= \alpha^* P_{\mathrm{F},t-1}^{*1-\theta} + (1-\alpha^*)\,\mathcal{P}^*_t(f)^{1-\theta}. \end{aligned} \tag{17}$$

where α^* denotes the probability that Foreign producers do not re-optimize prices during the period.

Price setting under LCP The PCP assumption is questioned by an important strand of the literature (pioneered by Betts and Devereux 2000), subscribing the alternative view that firms preset prices in domestic currency for the domestic market, and in foreign currency for the market of destination. This hypothesis is dubbed 'local currency pricing' or LCP. Under this hypothesis, firms choose $\mathcal{P}^*_t(h)$ instead of $\mathcal{E}_t\mathcal{P}^*_t(h)$ and the first-order condition for this price is

$$E_t \sum_{s=0}^{\infty} (\alpha\beta)^s \left\{ \left[\frac{U_{C,t+s}}{P_{t+s}} \mathcal{E}_{t+s}\mathcal{P}^*_t(h) - \mu_t V_y\left(y^d_{t+s}(h), \zeta_{Y,t+s}\right)\right] \left[\left(\frac{\mathcal{P}^*_t(h)}{P^*_{\mathrm{H},t+s}}\right)^{-\theta} \left(\frac{P^*_{\mathrm{H},t+s}}{P^*_{t+s}}\right)^{-\phi} \left(a^*_{\mathrm{H}} \frac{1-n}{n} C^*_t\right)\right]\right\} = 0$$

We assume that when a firm can re-optimize, it can do so both in the domestic and export markets. With LCP, for a firm not re-optimizing its price, exchange rate pass-through is zero.

Let Δ_t denote deviations from the law of one price (LOOP): for the Home country, we can write $\Delta_{\mathrm{H},t} = \mathcal{E}_t P^*_{\mathrm{H},t}/P_{\mathrm{H},t}$. As $P^*_{\mathrm{H},t}$ and $P_{\mathrm{H},t}$ are sticky, the law of one price is violated with any movement in the exchange rate.

Specifically, nominal depreciation tends to increase the Home firms' receipts in Home currency from selling goods abroad, relative to the Home market: nominal depreciation raises $\Delta_{\mathrm{H},t}$. Because of deviations from the LOOP, the Home terms of trade $\mathcal{T}_t = P_{\mathrm{F},t}/\mathcal{E}_t P^*_{\mathrm{H},t}$ will generally be different from the domestic price of imported goods, $P_{\mathrm{F},t}/P_{\mathrm{H},t}$. The dynamic evolution of the prices indexes $P_{\mathrm{H},t}$, $P^*_{\mathrm{H},t}$, $P_{\mathrm{F},t}$ and $P_{\mathrm{F},t}$ is now described by four equations analogous to (17).[9]

2.2.4 International asset markets and exchange rate determination

Exchange rate determination crucially differs depending on the asset market structure. We contrast below the complete and the incomplete markets case, the latter including economies in financial autarky, as well as economies with a limited number of assets traded across borders.

Complete markets Under complete markets, price equalization in the state-contingent claims denominated in Home currency $\mathcal{B}_{\mathrm{H},t}$, implies the following equilibrium risk-sharing condition:

$$\beta \frac{U_C\left(C_{t+1}, \zeta_{C,t+1}\right)}{U_C\left(C_t, \zeta_{C,t}\right)} \frac{P_t}{P_{t+1}} = \beta \frac{U_C\left(C^*_{t+1}, \zeta^*_{C,t+1}\right)}{U_C\left(C^*_t, \zeta^*_{C,t}\right)} \frac{\mathcal{E}_t P^*_t}{\mathcal{E}_{t+1} P^*_{t+1}}. \qquad (18)$$

Combined with the assumption of initially zero net foreign assets, this equation can be rewritten in the well-known form:

$$\frac{C_t^{-\sigma} \zeta_{C,t}}{P_t} = \frac{(C^*_t)^{-\sigma} \zeta^*_{C,t}}{\mathcal{E}_t P^*_t} \qquad (19)$$

For given Home and Foreign monetary policy, this equation fully determines the exchange rate in both nominal and real terms. A key feature of the complete-market allocation is that, holding preferences constant, Home per capita consumption can raise relative to Foreign per capita consumption only if the real exchange rate depreciates.

[9] While we focus our analysis on symmetric economies, asymmetric pricing pattern are also plausible. A particularly interesting one follows the assumption that all export prices are preset in one currency, that is, a case of 'dollar pricing.' Using our model, the case of dollar pricing can be modelled by combining the assumption of PCP for the firms in one country, and LCP for the firms in the other. Optimal policy with dollar pricing is analyzed by Devereux et al. (2005) and Corsetti and Pesenti (2008) — see also Goldberg and Tille (2008) for evidence.

Incomplete-market economy: financial autarky In this alternative setup, the economy does not have access to international borrowing or lending. As only domestic residents hold the Home currency M_t, the individual flow budget constraint for the representative agent j in the Home country is:

$$M_t \leq M_{t-1} - P_{\mathrm{H},t}T_t + (1-\tau_t)\frac{\int P_t(h)y_t(h)dh}{n} - P_{\mathrm{H},t}C_{\mathrm{H},t} - P_{\mathrm{F},t}C_{\mathrm{F},t}. \quad (20)$$

Barring international trade in asset, under financial autarky the value of domestic production has to be equal to the level of public and private consumption in nominal terms. Aggregating private and public budget constraints, we have:

$$P_tC_t = \int P_t(h)y_t(h)dh - P_{\mathrm{H},t}G_t. \quad (21)$$

By the same token, the inability to trade intertemporally with the rest of the world imposes that the value of imports should equal the value of exports:

$$nP_{\mathrm{F},t}C_{\mathrm{F},t} = (1-n)\,\mathcal{E}_tP^*_{\mathrm{H},t}C^*_{\mathrm{H},t}. \quad (22)$$

Using the definitions of terms of trade $\mathcal{T}_t$ and real exchange rate $\mathcal{Q}_t$, we can rewrite the trade balance condition in terms of aggregate consumption:

$$n\,(1-a_{\mathrm{H}})\,\mathcal{T}_t^{1-\phi}C_t = (1-n)\,a^*_{\mathrm{H}}\mathcal{Q}_t^{\phi}C^*_t. \quad (23)$$

For given monetary policy in the two countries, it is this equation — balanced trade — that determines exchange rates.

Incomplete-market economy: trade in some assets Intermediate cases of financial markets in between the two polar cases above can be modelled by allowing for cross-border trade in a limited number of assets. Home and Foreign agents hold an international bond, B_{H}, which pays in units of Home currency and is zero in net supply. In addition they may hold other securities in the amounts α_{it}, yielding ex post returns in domestic currency R_{it}. The individual flow budget constraint for the representative agent in the Home country therefore becomes:[10]

$$M_t + B_{\mathrm{H},t+1} + \sum_i \alpha_{i,t+1} \leq M_{t-1} + (1+i_t)B_{\mathrm{H},t} + \sum_i \alpha_{i,t}R_{i,t}$$
$$+ (1-\tau_t)\frac{\int P_t(h)y_t(h)dh}{n} - P_{\mathrm{H},t}T_t - P_{\mathrm{H},t}C_{\mathrm{H},t} - P_{\mathrm{F},t}C_{\mathrm{F},t}. \quad (24)$$

[10] $B_{\mathrm{H},t}$ and α_{it} denote the Home agent's assets accumulated during period $t-1$ and carried over into period t.

In this case, price equalization across internationally traded assets will imply the following modified risk-sharing condition:

$$E_t\left[\beta\frac{U_C\left(C_{t+1},\zeta_{C,t+1}\right)}{U_C\left(C_t,\zeta_{C,t}\right)}\frac{P_t}{P_{t+1}}R_{i,t+1}\right]=E_t\left[\beta\frac{U_C\left(C^*_{t+1},\zeta^*_{C,t+1}\right)}{U_C\left(C^*_t,\zeta^*_{C,t}\right)}\frac{\mathcal{E}_{t+1}P^*_{t+1}}{\mathcal{E}_tP^*_t}R_{i,t+1}\right]. \tag{25}$$

which holds for each individual asset (or portfolio of assets). The case of international trade in one bond is easily obtained from the above imposing $\alpha_{it}=0$.

We stress two notable differences between the complete-market and the incomplete-market economy. First, while exchange rates reflect only shocks to fundamentals (thus acting as 'shock absorber') in both economies, when markets are incomplete their equilibrium value will differ from the efficient one, irrespective of nominal rigidities, due to this form of asset market frictions.

A second important difference in the equilibrium allocation with complete and incomplete markets is that international risk sharing will generally be imperfect, resulting in inefficient fluctuations in aggregate demand across countries, as shocks open a wedge between national wealth. Let D_t denote the welfare-relevant cross-country demand imbalance, defined as the following PPP-adjusted measure of cross-country demand differential:

$$\mathcal{D}_t=\left(\frac{C_t}{C^*_t}\right)^{\sigma}\left(\frac{1}{\mathcal{Q}_t}\frac{\zeta^*_{C,t}}{\zeta_{C,t}}\right) \tag{26}$$

By (19), under complete markets $\mathcal{D}_t$ is identically equal to one regardless of the shocks hitting the economy. With incomplete markets, instead, $\mathcal{D}_t$ will generally fluctuate inefficiently contingent on shocks.[11] Because of inefficient relative prices and cross-country demand fluctuations, we will see below that optimal monetary policy will differ across structures of international asset markets.

2.3 Natural and efficient allocations (Benchmark flexible-price allocations)

Allocations under flexible prices provide natural benchmarks for comparison across different equilibria under sticky prices. Without nominal rigidities,

[11] Viani (2010) provides a theoretical and empirical analysis of $\mathcal{D}_t$.

the price setting decisions simplify to:

$$\begin{aligned}
U_C\left(C_t, \zeta_{C,t}\right)\frac{P_{\mathrm{H},t}}{P_t} &= \frac{\theta}{(\theta-1)\left(1-\tau_t\right)}V_y\left(\left(\frac{P_{\mathrm{H},t}}{P_t}\right)^{-\phi}\left(a_{\mathrm{H}}C_t + a_{\mathrm{H}}^*\frac{1-n}{n}\mathcal{Q}_t^{\phi}C_t^*\right)+G_t, \zeta_{Y,t}\right) \\
\zeta_{C,t}C_t^{-\sigma}\frac{P_{\mathrm{H},t}}{P_t} &= \frac{\theta}{(\theta-1)\left(1-\tau_t\right)}\left(\frac{\left(\frac{P_{\mathrm{H},t}}{P_t}\right)^{-\phi}\left(a_{\mathrm{H}}C_t + a_{\mathrm{H}}^*\frac{1-n}{n}\mathcal{Q}_t^{\phi}C_t^*\right)+G_t}{\zeta_{Y,t}}\right)^{\eta} \qquad (27)
\end{aligned}$$

$$\begin{aligned}
U_C\left(C_t^*, \zeta_{C,t}^*\right)\frac{P_{\mathrm{F},t}^*}{P_t^*} &= \frac{\theta}{(\theta-1)\left(1-\tau_t^*\right)}V_y\left(\left(\frac{P_{\mathrm{F},t}}{P_t}\right)^{-\phi}\left(\left(1-a_{\mathrm{H}}\right)\frac{n}{1-n}C_t + \mathcal{Q}_t^{\phi}\left(1-a_{\mathrm{H}}^*\right)C_t^*\right)+G_t^*, \zeta_{Y,t}^*\right. \\
\zeta_{C,t}^*C_t^{*-\sigma}\frac{P_{\mathrm{F},t}^*}{P_t^*} &= \frac{\theta}{(\theta-1)\left(1-\tau_t^*\right)}\left(\frac{\left(\frac{P_{\mathrm{F},t}^*}{P_t^*}\right)^{-\phi}\left(\left(1-a_{\mathrm{H}}\right)\frac{n}{1-n}\mathcal{Q}_t^{-\phi}C_t + \left(1-a_{\mathrm{H}}^*\right)C_t^*\right)+G_t^*}{\zeta_{Y,t}^*}\right)^{\eta}. \qquad (
\end{aligned}$$

whereas, holding the law of one price, the terms of trade and the real exchange rate can be written as follows :

$$\begin{aligned}
\mathcal{T}_t &= \frac{P_{\mathrm{F},t}}{P_{\mathrm{H},t}} \\
\mathcal{Q}_t^{1-\phi} &= \frac{a_{\mathrm{H}}^*{P_{\mathrm{H},t}}^{1-\phi} + \left(1-a_{\mathrm{H}}^*\right){P_{\mathrm{F},t}}^{1-\phi}}{a_{\mathrm{H}}{P_{\mathrm{H},t}}^{1-\phi} + \left(1-a_{\mathrm{H}}\right){P_{\mathrm{F},t}}^{1-\phi}} \\
&= \frac{a_{\mathrm{H}}^* + \left(1-a_{\mathrm{H}}^*\right){\mathcal{T}_t}^{1-\phi}}{a_{\mathrm{H}} + \left(1-a_{\mathrm{H}}\right){\mathcal{T}_t}^{1-\phi}};
\end{aligned}$$

Throughout the chapter, the model's equilibrium conditions and constraints will be written out in log-deviations from steady-state — assuming that in steady-state the net foreign asset position is zero. Denoting with an upper-bar steady-state values, $\widehat{x}_t = \ln x_t/\overline{x}$ will represent deviations under sticky prices, while $\widetilde{x}_t = \ln x_t/\overline{x}$ will represent deviations under flexible prices. Recalling that μ denote the equilibrium markup ($\mu_t = \theta/\left(\left(\theta-1\right)\left(1-\tau_t\right)\right)$), a log-linear approximation around the steady-state of the above equations will yield:

$$\begin{aligned}
\widetilde{\mathcal{Q}}_t &= (a^*+a-1)\,\widetilde{\mathcal{T}}_t \qquad (29)\\
\widehat{\zeta}_{C,t}-\sigma\widetilde{C}_t-(1-a)\,\widetilde{\mathcal{T}}_t &= \eta\left[\begin{array}{c}\left(\widehat{G}_t-\frac{\overline{Y}-\overline{G}}{\overline{Y}}\left(\widehat{\zeta}_{Y,t}-\frac{\widehat{\mu}_t}{\eta}\right)\right)+\phi\,(1-a)\,\frac{\overline{Y}-\overline{G}}{\overline{Y}}\widetilde{\mathcal{T}}_t+\\ \left(a_{\mathrm{H}}+(1-a_{\mathrm{H}})\,\overline{\mathcal{T}}^{1-\phi}\right)^{\frac{\phi}{1-\phi}}\left(a_{\mathrm{H}}\frac{\overline{C}}{\overline{Y}}\widetilde{C}_t+a^*_{\mathrm{H}}\frac{\overline{C}^*\overline{\mathcal{Q}}^{\phi}}{\overline{Y}}\frac{1-n}{n}\left(\widetilde{C}^*_t+\phi\widetilde{\mathcal{Q}}_t\right)\right)\end{array}\right]\\
\widehat{\zeta}^*_{C,t}-\sigma\widetilde{C}^*_t+(1-a^*)\,\widetilde{\mathcal{T}}_t &= \eta\left[\begin{array}{c}\left(\widehat{G}^*_t-\frac{\overline{Y}^*-\overline{G}^*}{\overline{Y}^*}\left(\widehat{\zeta}^*_{Y,t}-\frac{\widehat{\mu}^*_t}{\eta}\right)\right)-\phi\,(1-a^*)\,\frac{\overline{Y}^*-\overline{G}^*}{\overline{Y}^*}\widetilde{\mathcal{T}}_t+\\ \left(a^*_{\mathrm{H}}\overline{\mathcal{T}}_t^{\phi-1}+(1-a^*_{\mathrm{H}})\right)^{\frac{\phi}{1-\phi}}\left(\begin{array}{c}(1-a_{\mathrm{H}})\,\frac{\overline{C}\,\overline{\mathcal{Q}}^{-\phi}}{\overline{Y}^*}\frac{n}{1-n}\left(\widetilde{C}_t-\phi\widetilde{\mathcal{Q}}_t\right)+\\ (1-a^*_{\mathrm{H}})\,\frac{\overline{C}^*}{\overline{Y}^*}\widetilde{C}^*_t\end{array}\right)\end{array}\right]
\end{aligned}$$

where a, a^*,$\overline{Y}$, $\overline{Y}^*$, $\overline{G}$, and $\overline{G}^*$ are defined as follows:

$$\begin{aligned}
1-a^* &= \frac{a^*_{\mathrm{H}}}{a^*_{\mathrm{H}}+\left(1-a^*_{\mathrm{H}}\right)\overline{\mathcal{T}}^{1-\phi}},\qquad 1-a=\frac{(1-a_{\mathrm{H}})\,\overline{\mathcal{T}}^{1-\phi}}{a_{\mathrm{H}}+(1-a_{\mathrm{H}})\,\overline{\mathcal{T}}^{1-\phi}}\\
\widehat{G}_t &= \frac{G_t-\overline{G}}{\overline{Y}},\qquad \overline{Y}=\left[a_{\mathrm{H}}+(1-a_{\mathrm{H}})\,\overline{\mathcal{T}}^{1-\phi}\right]^{\frac{\phi}{1-\phi}}\left[\left(a_{\mathrm{H}}\overline{C}+\frac{1-n}{n}a^*_{\mathrm{H}}\overline{C}^*\overline{\mathcal{Q}}^{\phi}\right)+\overline{G}\right]\\
\widehat{G}^*_t &= \frac{G^*_t-\overline{G}^*}{\overline{Y}^*},\quad \overline{Y}^*=\left[a^*_{\mathrm{H}}\overline{\mathcal{T}}^{\phi-1}+(1-a^*_{\mathrm{H}})\right]^{\frac{\phi}{1-\phi}}\left[\left(\frac{n}{1-n}(1-a_{\mathrm{H}})\,\overline{\mathcal{Q}}^{-\phi}\overline{C}+(1-a^*_{\mathrm{H}})\,\overline{C}^*\right)+\overline{G}^*\right]
\end{aligned}$$

To solve for the world competitive allocation, we need a further equation, characterizing exchange rate determination. As discussed above, the equilibrium will crucially differ depending on the structure of international financial markets. With complete markets, the relevant equation is (19), which in log-linearized form becomes

$$\widetilde{\mathcal{Q}}_t=\left(\widehat{\zeta}^*_{C,t}-\widehat{\zeta}_{C,t}\right)+\sigma\left(\widetilde{C}_t-\widetilde{C}^*_t\right) \qquad (30)$$

For the case of financial autarky, instead, the relevant equation is (23), which becomes

$$\widetilde{\mathcal{Q}}_t=\frac{a^*+a-1}{\phi\,(a^*+a)-1}\left(\widetilde{C}_t-\widetilde{C}^*_t\right) \qquad (31)$$

Observe that, relative to the case of complete markets (19), the real exchange rate is still proportional to the ratio of consumption across countries. Yet, under financial autarky, the proportionality coefficient, rather than being equal to σ the (inverse of the) intertemporal elasticity, is a function of ϕ, the trade elasticity, and of a_{H}, the degree of home bias in consumption.

Moreover, shocks to marginal utility do not enter directly into this relation. In light of these two observations, it is easy to see that the two conditions indeed coincide if there are no preference shocks, and $\sigma = \frac{a^*+a-1}{\phi(a^*+a)-1}$, in which case the equilibrium movements of international prices in response to shocks perfectly insure national households against country-specific macro risk. We will return on this point in the last section of the chapter.

The system of equations (29) and either (30) or (31) provides a synthetic representation of macroeconomic interdependence in a global equilibrium under either complete asset markets, or international financial autarky, mapping all the shocks in the four endogenous variables $\left(\widetilde{\mathcal{Q}}_t, \widetilde{C}_t, \widetilde{C}_t^* \text{ and } \widetilde{\mathcal{T}}_t\right)$.

Following the monetary literature, the *natural-rate* allocation is defined as the decentralized market allocation in which all prices are flexible (derived above). A second allocation of interest is the one that would be chosen by a benevolent planner. In our model, by the first welfare theorem, this *efficient* allocation is equivalent to the decentralized equilibrium with flexible prices *and* complete markets, in which markups levels and fluctuations are neutralized with appropriate subsidies ($\mu_t = 0$), so that $U_C(\cdot)\frac{P_{\mathrm{H},t}}{P_t} = V_y(\cdot)$ and $U_C^*(\cdot)\frac{P_{\mathrm{F},t}^*}{P_t^*} = V_y^*(\cdot)$. In what follows, we will denote the efficient allocation (corresponding to (a) complete markets, (b) flexible prices and (c) production subsidies such that $\mu_t = 0$) with a superscript '*fb*'.

In general, the international transmission of shocks can be expected to be shaped by a large set of structural characteristics of the economy, ranging from financial market development and integration, to vertical interactions between producers and retailers, which are not accounted for by our workhorse model. One advantage of the workhorse model specified in this section is that, with complete markets and flexible prices, it yields an admittedly special, yet intuitive and parsimonious benchmark characterization of the international transmission, stressing output linkages.

In each country, both the natural-rate output (defined under flexible prices) and the efficient level of output (which with complete markets coincides with the natural rate without markup shocks) are functions of output in the other country. To see this most clearly, impose symmetry ($n = 1 - n$ and $a_{\mathrm{H}} = 1 - a_{\mathrm{H}}^*$), and derive the expressions relating output to the terms of trade and fundamental shocks. For the first-best allocation, we have

$$
\begin{aligned}
(\eta+\sigma)\,\widetilde{Y}_{H,t}^{fb} &= \left[2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\right]\left(\widetilde{\mathcal{T}}_t^{fb}\right) - \left(1-a_{\mathrm{H}}\right)\left(\widehat{\zeta}_{C,t} - \widehat{\zeta}_{C,t}^*\right) + \widehat{\zeta}_{C,t} + \eta\widehat{\zeta}_{Y,t} \qquad (32)\\
(\eta+\sigma)\,\widetilde{Y}_{F,t}^{fb} &= \left[2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\right]\left(-\widetilde{\mathcal{T}}_t^{fb}\right) + \left(1-a_{\mathrm{H}}\right)\left(\widehat{\zeta}_{C,t} - \widehat{\zeta}_{C,t}^*\right) + \widehat{\zeta}_{C,t}^* + \eta\widehat{\zeta}_{Y,t}^*
\end{aligned}
$$

whereas the terms of trade can in turn be written as a function of relative output and preference shocks

$$\left[4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}\right]\widetilde{\mathcal{T}}_{t}^{fb}=\sigma\left(\widetilde{Y}_{H,t}^{fb}-\widetilde{Y}_{F,t}^{fb}\right)-\left(2a_{\mathrm{H}}-1\right)\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right) \tag{33}$$

Based on the above three equations, the literature has emphasized the terms of trade channel of transmission, through which foreign shocks, such as gains in productivity $\widehat{\zeta}_{Y,t}^{*}$, affect the level of activity in the Home country, $\widetilde{Y}_{H,t}^{fb}$ via movements in relative prices. It is easy to see that, through this channel, the Home and Foreign output will move either in the same or in the opposite direction depending on whether $\sigma\phi<1$, or $\sigma\phi>1$.

In the parameterization of the workhorse model, as is well known, when the intra-temporal elasticity ϕ is higher than the inter-temporal elasticity $1/\sigma$, the two goods are substitute in the Pareto-Edgeworth sense: if $\phi\sigma>1$, the marginal utility from consuming the Home good is decreasing in the consumption of the foreign good. The opposite is true if $\phi\sigma<1$, the two goods are complements. A key implication is that a depreciation of the Home terms of trade increases (in case of substitutability) or decreases (complementarity) the world demand for Home goods[12] — generating negative (positive) comovements in output.[13]

However, note that the value of $\sigma\phi$ alone does not fully characterize the cross-border output spillovers. To see this, set $\sigma=\phi=1$ in the above expression. While the first-best levels of output become insulated from terms of trade movements, national outputs remain interdependent, as they respond to preference shocks abroad independently of the terms-of-trade channel. In turn, the terms of trade now change one-to-one with output differential, but also move proportionally to the differential in preference shocks independently of output movements:

$$\sigma=\phi=1 \qquad => \qquad \widetilde{\mathcal{T}}_{t}^{fb}=\left(\widetilde{Y}_{H,t}^{fb}-\widetilde{Y}_{F,t}^{fb}\right)-\left(2a_{\mathrm{H}}-1\right)\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right)$$

Note that similar considerations apply to the natural-rate allocation, whereas $\widetilde{Y}_{H,t}^{fb}$ in the above equations is replaced with

$$\widetilde{Y}_{H,t}=\widetilde{Y}_{H,t}^{fb}+\frac{\widehat{\mu}_{t}}{(\eta+\sigma)} \tag{34}$$

[12] In light of this observation, one could interpret the parameter governing the 'marginal propensity to import' in the Mundell-Fleming model as stressing complementarity between domestic and foreign goods.

[13] From a planner perspective, complementarity means that an increase in the supply of one good makes the other good more socially valuable, hence providing a welfare rationale for positive co-movements in output.

As already stated at the beginning of this section, for the sake of analytical tractability, in the rest of this chapter we will focus on a version of the model in which openness and population are symmetric across countries, abstracting from fiscal policy altogether (setting $G = 0$). We will also ignore utility from liquidity services.

2.4 The open-economy Phillips curve

Allocations with nominal rigidities are characterized below by deriving counterparts to the New-Keynesian Phillips curve (NKPC) in our open-economy model. This is accomplished by log-linearizing the equations for the price setting decisions ((16) with PCP, and (**??**) with LCP) and the evolution for the price indexes ((17) with PCP and their counterparts with LCP). While the specific form of the NKPC will of course vary with the specification of price setting as well as of the international asset markets, it is nonetheless useful to write a general expression, encompassing different cases.

We start by writing Home inflation of the domestically produced good as a function of expected inflation and current marginal costs (corresponding to the expression in squared brackets below):

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)} \left[\sigma \widehat{C}_t - \widehat{\zeta}_{C,t} + \eta \left(\widehat{Y}_{H,t} - \widehat{\zeta}_{Y,t} \right) + \widehat{\mu}_t + (1-a_{\mathrm{H}}) \left(\widehat{\mathcal{T}}_t + \widehat{\Delta}_{\mathrm{H},t} \right) \right]$$

The expression for the marginal cost already sheds light on how macroeconomic interdependence can affect the dynamics of domestic prices: the level of activity in the foreign country is bound to affect marginal costs to the extent that it affects, given openness $1 - a_{\mathrm{H}}$, domestic consumption and international relative prices, here expressed in terms of changes in the terms of trade and deviations from the law of one price (for the Home good): $\widehat{\mathcal{T}}_t + \widehat{\Delta}_{\mathrm{H},t}$.

Now, the aggregate demand for domestic output (9) in log-linear form is

$$\widehat{Y}_{H,t} = \widehat{C}_t + (1-a_{\mathrm{H}}) \left[\phi \left(\widehat{\mathcal{T}}_t + \widehat{\mathcal{Q}}_t \right) - \left(\widehat{C}_t - \widehat{C}_t^* \right) \right]. \tag{35}$$

Using the definition of $\mathcal{D}_t$ (26)

$$\widehat{\mathcal{D}}_t = \sigma \left(\widehat{C}_t - \widehat{C}_t^* \right) - \widehat{\mathcal{Q}}_t - \left(\widehat{\zeta}_{C,t} - \widehat{\zeta}_{C,t}^* \right) \tag{36}$$

to substitute out the consumption differential, we can also express Home aggregate demand as follows:

$$\sigma \widehat{C}_t = \sigma \widehat{Y}_{H,t} - (1-a_{\mathrm{H}}) \left[\sigma\phi \widehat{\mathcal{T}}_t + (\sigma\phi - 1) \widehat{\mathcal{Q}}_t - \widehat{\mathcal{D}}_t - \left(\widehat{\zeta}_{C,t} - \widehat{\zeta}_{C,t}^* \right) \right].$$

Combining this with the equation (32) for the first-best output $\widetilde{Y}_{H,t}^{fb}$, we can finally derive the open-economy NKPC in its general form:

$$\begin{aligned} \pi_{H,t} &= \beta E_t \pi_{H,t+1} + \\ & \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)} \left\{ \begin{array}{c} (\eta+\sigma)\left(\widehat{Y}_{H,t} - \widetilde{Y}_{H,t}^{fb}\right) + \widehat{\mu}_t + \\ -(1-a_{\mathrm{H}}) \cdot \left[(\sigma\phi - 1)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}_t^{fb} + \widehat{\mathcal{Q}}_t - \widetilde{\mathcal{Q}}_t^{fb}\right) - \widehat{\Delta}_{\mathrm{H},t} - \widehat{\mathcal{D}}_t\right] \end{array} \right\} \end{aligned} \tag{37}$$

In the closed-economy counterpart of our model ($a_{\mathrm{H}} = 1$), the expression above coincides with the Phillips curve in the baseline New-Keynesian specification with only one sector: inflation is a function of expected inflation, the gap between output and its efficient level, usually dubbed the welfare relevant output gap, and markup shocks.

In open economies ($a_{\mathrm{H}} < 1$), however, inflation responds to additional factors. First, there are cross-country misalignments in international relative prices of goods ($\widehat{\mathcal{T}}_t + \widehat{\Delta}_{\mathrm{H},t}$) as well as in the relative price of consumption, $\widehat{\mathcal{Q}}_t$, both measured with respect to their efficient levels $\widetilde{\mathcal{T}}_t^{fb}$ and $\widetilde{\mathcal{Q}}_t^{fb}$. For future reference, note that the relative price terms drop out from the NKPC in the particular case in which $\sigma\phi = 1$. Second, there is the welfare-relevant measure of cross-country demand $\widehat{\mathcal{D}}_t$. Since $\widehat{\mathcal{D}}_t = 0$ in the efficient allocation with perfect risk sharing, $\widehat{\mathcal{D}}_t$ can be referred to as a relative demand imbalance. As discussed below, these two additional factors, not present in the canonical close-economy Phillips curve, will concur in shaping fundamental trade-offs among different objectives of monetary stabilization in open economy.

It is worth pointing out that some of these trade-offs have an obvious counterpart in a closed-economy model with two sectors, in which the parameter a_{H} would index the weight of the two goods in consumption. With a representative agent, the Phillips curve for sectoral inflation (see, e.g., Woodford 2003, chapter 3) is also a function of the efficient gap of the relative price between the two goods, $\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}_t^{fb}$ in our notation. A number of differences nonetheless arise because in the canonical closed-economy model there is one representative agent supplying labor inputs to the two sectors, while in an open-economy setting, there are multiple agents with generally different preferences, supplying good-specific labor inputs. So, in addition to the fact that in closed-economy analyses the output gap is usually referred to as aggregate output, the coefficient multiplying relative prices is a function of labor elasticity, that is, $\eta\phi + 1$, instead of $1 - \sigma\phi$. Furthermore, price discrimination and deviations from the law of one price $\widehat{\Delta}_{\mathrm{H},t}$ are only conceivable in a heterogenous-agent economy. In comparing the two settings, a final important issue refers to the possibility of aggregating multiple agents into a world representative agent — as discussed below, this will require either the assumption of complete markets within and across borders, or some restrictions on preferences and shocks.

3 The classical view: divine coincidence in open economies

3.1 Exchange rates and efficient international relative price adjustment

In this section, we characterize optimal stabilization policy under the maintained hypotheses that markets are complete, and prices are sticky in the currency of the producers, so that in foreign markets the local-currency price of exports varies in each period with the movement in the exchange rate. This insures that the same product sells for the same price across markets – ruling out deviations from the law of one price, in our notation $\widehat{\Delta}_{\mathrm{H},t} = \widehat{\Delta}_{\mathrm{F},t} = 0$.

With complete pass-through, a monetary expansion which causes nominal depreciation raises the price of imports in domestic currency, and lowers the price of export in foreign currency, making domestic products cheaper worldwide: both $P_{F,t}/P_{H,t}$ and its foreign counterpart rise. These movements in relative prices within each market translate into weaker terms of trade for the Home country: as both $P^*_{F,t}$ and $P_{H,t}$ are sticky, $\mathcal{T}_t = \mathcal{E}_t P^*_{F,t}/P_{H,t}$ and $\mathcal{E}_t$ move in the same direction. Nominal exchange rate movements have 'expenditure switching effects', as Home depreciation switches domestic and foreign demand in favor of the Home goods.

The notion that nominal depreciation causes a fall in the relative international price of tradables accords well with the classical model of international monetary transmission, viewing exchange rate movements as a substitute for product price flexibility in fostering international relative price adjustment vis-à-vis macroeconomic shocks. However, for relative price adjustment via exchange rate to be efficient, as implicitly envisioned by the classical view, a high pass-through on import prices is not enough. Efficiency also require perfect risk sharing. This observation can be best appreciated by combining the two log-linearized equations for demand for goods produced in each country ((35) and its foreign counterpart) as to obtain:

$$\begin{aligned}\widehat{Y}_{H,t}-\widehat{Y}_{F,t} &= 4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\widehat{\mathcal{T}}_t+\left(2a_{\mathrm{H}}-1\right)\left(\widehat{C}_t-\widehat{C}_t^{*}\right)\\ &= 4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\widehat{\mathcal{T}}_t+\left(\frac{2a_{\mathrm{H}}-1}{\sigma}\right)\left(\widehat{\mathcal{D}}_t+\widehat{\mathcal{Q}}_t+\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right)\right)\end{aligned}$$

whereas we have imposed the law of one price consistent with the PCP assumption, and in the second line we have made use of (36). From the above expression, it is easy to verify that, holding the perfect risk sharing condition $\widehat{\mathcal{D}}_t=0$, the equilibrium relation between the terms of trade and relative output is identical to the one derived under the first-best allocation (33):

$$\left[4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\sigma\phi+\left(2a_{\mathrm{H}}-1\right)^2\right]\widehat{\mathcal{T}}_t=\sigma\left(\widehat{Y}_{H,t}-\widehat{Y}_{F,t}\right)-\left(2a_{\mathrm{H}}-1\right)\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right) \tag{38}$$

It follows that, once monetary policy closes output gaps, international prices will correspondingly align to their efficient level too. This will not be true, in general, if the PCP assumption is not complemented by the complete-market assumption, so that $\widehat{\mathcal{D}}_t\neq 0$.

The implications for inflation dynamics of the international transmission mechanism in the case of PCP and complete markets are summarized by the following two Phillips curves, one tracing the dynamics of inflation in Home currency for the good produced at Home, the other the dynamics of inflation in foreign currency for the good produced in the Foreign country:

$$\begin{aligned}&\pi_{H,t}-\beta E_t\pi_{H,t+1}=\\ &\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\left[(\eta+\sigma)\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)+\widehat{\mu}_t-(1-a_{\mathrm{H}})\,2a_{\mathrm{H}}\,(\sigma\phi-1)\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}_t^{fb}\right)\right]\end{aligned}$$

$$\begin{aligned}&\pi_{F,t'}^{*}-\beta E_t\pi_{F,t+1}^{*}=\\ &\frac{(1-\alpha^{*}\beta)(1-\alpha^{*})}{\alpha^{*}(1+\theta\eta)}\left[(\eta+\sigma)\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)+\widehat{\mu}_t^{*}+(1-a_{\mathrm{H}})\,2a_{\mathrm{H}}\,(\sigma\phi-1)\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}_t^{fb}\right)\right]\end{aligned}$$

By improving the Home terms of trade, an increase in foreign output can increase or reduce Home marginal costs (the term in squared brackets) and thus Home inflation, depending on whether $\sigma\phi$ is above or below unity. Intuitively, as argued by CGG 2002 p. 887, an improvement in the terms of trade means a fall in the price of imports — everything else equal, this reduces Home wages. Under perfect risk sharing, however, a higher foreign output translate into higher Home consumption for given relative prices — this raises marginal costs, as it increases the marginal rate of substitution between consumption and leisure. The second effect prevails if the two goods are substitutes: higher foreign output raises home marginal costs.

With complete markets and nominal rigidities in the currency of the producers, the natural output gap can be obtained from the efficient one simply subtracting markup shocks (simply use (34)):

$$\widehat{Y}_{H,t} - \widetilde{Y}_{H,t} = \widehat{Y}_{H,t} - \left[\widetilde{Y}^{fb}_{H,t} + \widehat{\mu}_t / (\eta + \sigma)\right]. \tag{39}$$

It is then straightforward to rewrite the above Phillips curves in terms of the *natural* output (and international price) gaps, instead of *welfare-relevant* gaps. By doing so, it becomes apparent that policies keeping the natural gaps completely closed at zero at all times in both countries can support the flexible-price allocation. This is because, as monetary policy expands in response to a positive productivity shock or to a negative markup shock (hitting symmetrically all firms in a country), the exchange rate depreciates exactly as much as it is required to move the international relative price of Home output to its flexible-price level (see (38), — in close accord to the classical adjustment mechanism envisaged in the well-known contribution by Friedman (1953).

We nonetheless stress two observations. First, the exchange rate does not stabilize prices independently of the way monetary policy is conducted. Specifically, the international relative prices adjust to their flexible-price allocation level only if monetary policy leans against (natural) output gaps. Second, a flex-price equilibrium is not necessarily efficient — e.g. it will not be so in the presence of markup shocks. We will explore these issues in greater detail below.

3.2 Optimal policy

We characterize the optimal monetary policy by analyzing cooperative welfare-maximizing policies under commitment. We take a timeless perspective and, for analytical convenience, focus on the case in which monopolistic distortions in production are offset by appropriately chosen subsidies. This implies that, in a cooperative solution, the steady-state is efficient, and we can derive a quadratic approximation of the objective function for the cooperative problem without using second order approximations to the competitive equilibrium conditions (see Benigno and Woodford 2006).

With complete markets and PCP, the arguments of the loss function consists of deviations of output from the efficient benchmark (the welfare-relevant output gaps) and inflation in either country, plus a relative price gap, measuring the deviations of international prices from their efficient level — the latter term can be expressed using either the terms of trade or the real exchange rate (or even using the difference between output gaps combining (38) and (33), a point further discussed below).

Assuming symmetry for simplicity, the purely quadratic flow loss ℓ_t^{CM-PCP} is proportional to the following expression (see BB and CGG):

$$\ell_t^{CM-PCP} \ltimes -\frac{1}{2}\left\{\begin{array}{c} (\sigma+\eta)\left(\widetilde{Y}_{H,t}^{fb}-\widehat{Y}_{H,t}\right)^2+(\sigma+\eta)\left(\widetilde{Y}_{F,t}^{fb}-\widehat{Y}_{F,t}\right)^2+ \\ \frac{\theta\alpha\left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)}\pi_{H,t}^2+\frac{\theta\alpha^*\left(1+\theta\eta\right)}{\left(1-\alpha^*\beta\right)\left(1-\alpha^*\right)}\pi_{F,t}^{*2}+ \\ -2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\frac{\left(\sigma\phi-1\right)}{\sigma}\left(4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^2\right)\left(\widetilde{\mathcal{T}}_t^{fb}-\widehat{\mathcal{T}}_t\right)^2 \end{array}\right\}, \tag{40}$$

where all the gaps are derived relative to the flex-price benchmark ignoring markup shocks, as these would not be accommodated by the social planner. The terms in inflation in the loss reflect the fact that benevolent policymakers are concerned with inefficiencies in the supply of goods, due to price dispersion in the domestic and in the export destination markets, similarly to the closed-economy case. Note that, when there are no deviations from PPP, i.e., $a_{\mathrm{H}}=\frac{1}{2}$, the above loss coincides with the one derived by BB: the coefficient in front of terms of trade deviations simplifies to $\frac{\sigma\phi-1}{2}\phi$.[14]

The optimal policy is characterized by the first-order conditions for the optimal policy problem under commitment, with respect to inflation:

$$\begin{aligned} \pi_{H,t} &: \quad 0=-\theta\frac{\alpha\left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)}\pi_{H,t}-\gamma_{H,t}+\gamma_{H,t-1} \\ \pi_{F,t}^* &: \quad 0=-\theta\frac{\alpha^*\left(1+\theta\eta\right)}{\left(1-\alpha^*\beta\right)\left(1-\alpha^*\right)}\pi_{F,t}^*-\gamma_{F,t}^*+\gamma_{F,t-1}^*, \end{aligned} \tag{41}$$

where $\gamma_{H,t}$ and $\gamma_{F,t}^*$ are the multipliers associated with the Phillips curves — whose lags appear reflecting the assumption of commitment; and with

[14] For a small open economy limit of the same analysis see Galí and Monacelli 2005 and Faia and Monacelli 2008.

respect to output:

$$\widehat{Y}_{H,t} \quad : \quad 0=\left[(\sigma+\eta)\left(\widetilde{Y}_{H,t}^{fb}-\widehat{Y}_{H,t}\right)-2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\left(\widetilde{\mathcal{T}}_{t}^{fb}-\widehat{\mathcal{T}}_{t}\right)\right]+ \tag{42}$$

$$\left[\eta+\sigma-\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\,\sigma}{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}}\right]\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\gamma_{H,t}+$$

$$\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\,\sigma}{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}}\frac{(1-\alpha^{*}\beta)(1-\alpha^{*})}{\alpha^{*}(1+\theta\eta)}\gamma_{F,t}^{*}$$

$$\widehat{Y}_{F,t} \quad : \quad 0=\left[2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\left(\widetilde{\mathcal{T}}_{t}^{fb}-\widehat{\mathcal{T}}_{t}\right)+(\sigma+\eta)\left(\widetilde{Y}_{F,t}^{fb}-\widehat{Y}_{F,t}\right)\right]+$$

$$\left[\eta+\sigma-\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\,\sigma}{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}}\right]\frac{(1-\alpha^{*}\beta)(1-\alpha^{*})}{\alpha^{*}(1+\theta\eta)}\gamma_{F,t}^{*}+$$

$$\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\,\sigma}{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}}\gamma_{H,t},$$

where we have used the equilibrium relation (38) between terms of trade and relative output, and imposed the appropriate initial conditions consistent with taking a timeless perspective (see Woodford (2003)).

Summing and subtracting the above first-order conditions, optimal policy can be conveniently expressed in terms of targeting rules by substituting out the Lagrange multipliers from the first-order conditions relative to output. In the tradition of open-economy macro, it is natural to express the targeting rules in cross-country sum

$$0=\left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)\right]+\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}_{F,t-1}^{fb}\right)\right] \tag{43}$$
$$+\,\theta\left(\pi_{H,t}+\pi_{F,t}^{*}\right)$$

and cross-country differences:

$$0 = (\sigma+\eta)\left\{\begin{array}{c}\left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)\right]-\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}_{F,t-1}^{fb}\right)\right]\\+\theta\left(\pi_{H,t}-\pi_{F,t}^{*}\right)\end{array}\right\} \tag{44}$$
$$+4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)(\sigma\phi-1)\left\{\begin{array}{c}\frac{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}}{\sigma}\left[\left(\widehat{\mathcal{T}}_{t}-\widetilde{\mathcal{T}}_{t}^{fb}\right)-\left(\widehat{\mathcal{T}}_{t-1}-\widetilde{\mathcal{T}}_{t-1}^{fb}\right)\right]\\+\theta\left(\pi_{H,t}-\pi_{F,t}^{*}\right)\end{array}\right\}$$

Under cooperation, the optimal monetary policy faces a global trade-off between stabilizing changes in world output gaps and world producers' inflation (also corresponding to world CPI inflation, because of PCP), as well as a cross-border trade-off between stabilizing output gaps and inflation at country level, and stabilizing relative inflation and international relative prices around their efficient level.

From (38) and (33), however, it follows that under complete markets and PCP the gap in the terms of trade and the output gap are linearly related to each other:

$$\frac{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma+\left(2a_{\mathrm{H}}-1\right)^{2}}{\sigma}\left[\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}_t^{fb}\right)\right]=\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)$$

implying no trade-off between stabilizing international relative prices and stabilizing output gaps across countries. We therefore have an important open-economy instance of 'divine coincidence' among potentially contrasting objectives. Indeed, combining the above expressions, the optimal cooperative policy can be decentralized in terms of two targeting rules expressed in domestic objectives only:

$$\begin{aligned}\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)+\theta\pi_{H,t} &= 0 \\ \left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}_{F,t-1}^{fb}\right)+\theta\pi_{F,t}^{*} &= 0.\end{aligned} \tag{45}$$

In conjunction with the Phillips curves, these rules suggest a key result: the optimal policy prescription in this benchmark open-economy model with PCP and complete markets is identical to the one in the baseline closed-economy one-sector model with flexible wages (see the chapter by Woodford in this Handbook).[15] Note that under these conditions foreign shocks are relevant to domestic policymaking only to the extent that they influence domestic output gap and inflation. The optimal policy prescription draws a crucial distinction between efficient and inefficient shocks.[16]

In response to shocks of the efficient shocks, such as productivity and preference shocks, the flex-price allocation is efficient: policymakers minimize the loss by setting GDP-deflator inflation identically equal to zero, so as

[15] In a closed-economy framework, a trade-off between output gap and inflation stabilization arises, for instance, because of multiple sectors (see e.g. Aoki 2001), or the presence of a cost channel (see e.g. Ravenna and Walsh 2006).

[16] While the optimal target criteria have been expressed as flexible inflation targets, they can alternatively be expressed in the form of output-gap-adjusted price level targets, as shown in the chapter by Woodford. A target criterion of this form makes it clear that the regime is one under which a rational long-run forecast of the price level never changes, stressing the role of optimal monetary policy as a nominal anchor to manage and guide expectations.

to keep the (welfare-relevant) output gap closed at all times. Under the optimal policy, the nominal and real exchange rates fluctuate with these shocks and adjust international relative prices without creating any policy trade-off: the terms of trade are at their (efficient) flexible-price level. By way of example, under the optimal policy trend-stationary productivity gains in one country are matched by an expansion of domestic monetary policy, stabilizing domestic prices while in turn causing nominal and real depreciation — the country's terms of trade weakens exactly as they would under flexible prices. Under the optimal policy, the behavior of the world economy in response to these shocks is completely characterized by the benchmark allocation described in Section 2.

Conversely, in response to inefficient — such as markup — shocks, the optimal policy reflects fundamental trade-offs between output gap, inflation and relative price stabilization. As stressed by the new-Keynesian literature, markup shocks create a wedge between efficient and natural output. In the closed-economy counterpart of our model, the optimal policy prescribes partial accommodation, letting output fall and inflation rise temporarily in the short-run, while simultaneously committing to a persistent contractionary policy in the future (see Galí 2008, Woodford 2003). The same is true in open economies.

While the optimal targeting rule are the same as in the baseline New Keynesian closed-economy model, in interdependent economies, the response of output gaps and inflation to fundamental shocks will generally be shaped by cross-border spillovers. The sign and magnitude of these spillovers will in turn affect the implementation of the optimal policy. By way of example, consider the optimal response to markup shocks. Combining the targeting rules with the Phillips curves yields the following characterization of the optimal path of output in the two countries:

$$\begin{aligned}
\left(\widehat{Y}_{H,t+1}-\widehat{Y}_{H,t}\right) &= \left[\beta^{-1}+\theta\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}(\eta+\sigma)\right]\left(\widehat{Y}_{H,t}-\widehat{Y}_{H,t-1}\right)+ \\
&\quad \theta\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\left\{\widehat{\mu}_t-(1-a_{\mathrm{H}})\,2a_{\mathrm{H}}\frac{(\sigma\phi-1)\left(\widehat{Y}_{H,t}-\widehat{Y}_{F,t}\right)}{4(1-a_{\mathrm{H}})\,a_{\mathrm{H}}\phi\sigma+(2a_{\mathrm{H}}-1)^2}\right\} \\
\left(\widehat{Y}_{F,t+1}-\widehat{Y}_{F,t}\right) &= \left[\beta^{-1}+\theta\frac{(1-\alpha^*\beta)(1-\alpha^*)}{\alpha^*(1+\theta\eta)}(\eta+\sigma)\right]\left(\widehat{Y}_{F,t}-\widehat{Y}_{F,t-1}\right)+ \\
&\quad \theta\frac{(1-\alpha^*\beta)(1-\alpha^*)}{\alpha^*(1+\theta\eta)}\left\{\widehat{\mu}_t^*+(1-a_{\mathrm{H}})\,2a_{\mathrm{H}}\frac{(\sigma\phi-1)\left(\widehat{Y}_{H,t}-\widehat{Y}_{F,t}\right)}{4(1-a_{\mathrm{H}})\,a_{\mathrm{H}}\phi\sigma+(2a_{\mathrm{H}}-1)^2}\right\}
\end{aligned} \tag{46}$$

It is apparent that cross-country output spillovers depend on $\sigma\phi$. Posit a favorable markup shock in the Home economy, $\widehat{\mu}_t < 0$. According to the first equation above, by accommodating in part such a shock, the Home policymakers let domestic output increase (and domestic GDP inflation fall), causing the Foreign country's terms of trade to worsen. These domestic developments affect the Foreign economy. If goods are substitutes, i.e., $\sigma\phi > 1$, the Home terms-of-trade depreciation driven by higher Home output raises the marginal costs of foreign producers. According to the second equation, the Home expansion indeed translates into the equivalent of an adverse cost-push shock abroad – Foreign output falls, opening a negative output gap, while Foreign producer prices rise. Under the optimal policy, the Foreign monetary authorities counteract the rise in inflation, with the result of feeding the Home terms of trade appreciation.[17] The comovements between national output gap, inflation and monetary stance are negative.

Figure I.1
International transmission of a decline in Home markups under the optimal policy with Producer Currency Pricing and complete markets

These results are illustrated by the right-hand column of Figure I.1, showing, for the Home and the Foreign country, the response of output, GDP inflation, and the terms of trade (proportional to the real exchange rate) to a favorable markup shock in the Home economy, under the assumption of PCP and complete markets. The differences between the case of substitutability ($\sigma\phi > 1$) discussed above, and that of complementarity ($\sigma\phi < 1$), shown by the graphs on the left-hand column of the Figure, are apparent. With complementarity, a favorable markup shock $\widehat{\mu}_t < 0$ causes output gaps to rise and inflation to fall on impact worldwide — comovements are positive. This is because Foreign marginal costs and prices drop with the expansion in Home output — the Foreign economy experiences a favorable cost-push shock. As the Foreign monetary authorities optimally accommodate such shock by expanding, they partly offset the initial terms of trade movement — everything else equal, the Home terms of trade depreciation is slightly milder with $\sigma\phi < 1$ than with $\sigma\phi > 1$.

[17] Observe that in equilibrium there will be a feedback from the drop in Foreign output onto Home output — akin to a favorable markup shock (see the first equation), thus going in the same direction of the initial cost-push impulse on inflation. These effects are quantitatively small however.

In the literature, some contributions have used the complete-market model as a benchmark to assess how openness affects the slope of the IS curve and the Phillips curve. CGG, for instance, notes that, when output spillovers are negative (goods are substitute), openness raises the semi-elasticity of aggregate demand with respect to the interest rate (see also Clarida 2009): central banks get more 'bang' out of every basis point by which it changes interest rates. The case of positive spillovers (goods are complement) is instead closer to the prediction of traditional frameworks such as the Mundell-Fleming model, that openness induces 'leakages' of aggregate demand in favor of foreign output and employment. Central banks thus get less 'bang' on aggregate demand out of interest rate movements.

Similarly, under complete markets, changes in domestic output have less of an impact on marginal costs, as the domestic consumption index (and therefore marginal utility) does not move one-to-one with domestic production, and its cost varies with the terms of trade. When goods are substitutes, the former (income) effect dominates the latter, resulting in a flatter Phillips curve. When goods are complements, openness makes the Phillips curve steeper.

While stark and intuitive, however, these results derived under complete markets and PCP are not an exhaustive characterization of the way in which openness and globalization of real and financial markets affect the slopes of the IS and the NKPC. More general results can be derived from more comprehensive specifications of the model — a promising area for further research.[18]

4 Skepticism on the classical view: local currency price stability of imports

4.1 Monetary transmission and deviations from the law of one price

In the previous section, import prices were assumed to move one-to-one with the exchange rate (as a simplification, at the border as well as at retail level). This is seemingly at odds with the finding of empirical studies, which document that import prices are rather stable in local currency. While the observed local-currency price stability of imports arguably reflects to a large

[18] For a debate on the effect of globalization on the inflation process, see Ball (2006), Bean (2007), Rogoff (2003) and Sbordone (2009) among others, as well as the literature after early empirical work includes Romer (1993).

extent local costs, especially at the consumer level, and destination-specific markup adjustment — that is, real factors —, many authors have embraced the idea that price stickiness nonetheless plays an important role in explaining this evidence. In this section we discuss the international transmission mechanism and the optimal policy design under the assumption that import prices are subject to nominal-pricing distortions in the currency of the market of destination — an hypothesis commonly labelled 'local currency pricing' or LCP. For simplicity, we will consider the extreme assumption that nominal distortions are the *only* factor explaining import price stability — thus abstracting from real determinants. Also for simplicity, we will impose perfect symmetry in parameters' value, including the probability of resetting prices ($\alpha = \alpha^*$) so that, up to a first-order approximation, deviations from the law of one price will be symmetric across countries $\widehat{\Delta}_{\mathrm{H},t} = \widehat{\Delta}_{\mathrm{F},t} = \widehat{\Delta}_t$.

With LCP, the law of one price does not generally hold, since when export prices are sticky in local currency, exchange rate fluctuations drive the domestic-currency price of exports away from the price firms charge in the domestic market. Rather than raising the domestic price of imports, nominal depreciation of the Home currency increases the Home firms' revenue from selling a unit of goods abroad relative to the Home market, corresponding to a rise in $\Delta_{\mathrm{H},t} = \mathcal{E}_t P^*_{\mathrm{H},t}/P_{\mathrm{H},t}$. Thus, for any given volume of sales in foreign currency, Home depreciation raises the corresponding revenues in domestic currency accruing to the exporting firms. Since the relative price of imports faced by national consumers, $P_{F,t}/P_{H,t}$ and $P^*_{F,t}/P^*_{H,t}$, are little responsive to exchange rate movements, nominal depreciation tends to improve, rather than worsen, the terms of trade of a country, as it increases the purchasing power of domestic residents for any level of economic activity.

Exchange rate pass-through is on average far from complete: it is positive for the firms which re-optimize prices during the period, as these optimally pass some of the marginal cost movements onto local prices, compensating for exchange rate movements; it is zero for the prices charged by the other firms, which do not re-optimize during the period. For the first group of firms, nominal depreciation reduces their prices relative to foreign products — ceteris paribus, this works towards worsening the country's terms of trade. For the other firms, nominal depreciation instead raises the local-currency revenue from selling goods abroad at an unchanged price — this works towards improving the country's terms of trade. Which effect prevails will depend on the degree of price stickiness (Corsetti, Dedola, and Leduc 2008b). Thus, while nominal depreciation will always be associated with real depreciation, it can either weaken or improve the terms of trade of the country as a whole. Different from the classical view, nominal exchange rate movements cannot be expected to have 'expenditure switching effects:' nominal depreciation does not necessarily make goods produced in the country cheaper worldwide, thus re-allocating demand in favor of them.

The real exchange rate and the terms of trade no longer move in direct proportion to each other, as nominal depreciation also causes deviations from the law of one price

$$\widehat{\mathcal{Q}}_t = (2a_{\mathrm{H}} - 1)\,\widehat{\mathcal{T}}_t + a_{\mathrm{H}}\left(\widehat{\Delta}_{\mathrm{H},t} + \widehat{\Delta}_{\mathrm{F},t}\right) = (2a_{\mathrm{H}} - 1)\,\widehat{\mathcal{T}}_t + 2a_{\mathrm{H}}\widehat{\Delta}_t, \qquad (47)$$

where because of symmetry in the probability $\alpha = \alpha^*$, $\widehat{\Delta}_{\mathrm{H},t} = \widehat{\Delta}_{\mathrm{F},t} = \widehat{\Delta}_t$. LCP has thus key implications for the transmission mechanism. Specifically, even if markets are complete, the equilibrium relation between relative output and international prices is not identical to the first best, because of deviations from the law of one price:

$$\left[4a_{\mathrm{H}}\,(1 - a_{\mathrm{H}})\,\sigma\phi + (2a_{\mathrm{H}} - 1)^2\right]\left(\widehat{\mathcal{T}}_t - \widehat{\mathcal{T}}_t^{fb}\right) =$$
$$\sigma\left[\left(\widehat{Y}_{H,t} - \widetilde{Y}_{H,t}^{fb}\right) - \left(\widehat{Y}_{F,t} - \widetilde{Y}_{F,t}^{fb}\right)\right] - \left[4a_{\mathrm{H}}\,(1 - a_{\mathrm{H}})\,\sigma\phi + 2a_{\mathrm{H}}\,(2a_{\mathrm{H}} - 1)\right]\widehat{\Delta}_t$$

By way of example, if Home monetary policy eases in response to a positive productivity shock and closes the output gap, the ensuing nominal depreciation of the Home currency will bring about deviations from the law of one price, preventing the Home terms of trade from adjusting to their efficient (flex-price) level.

Cross-border monetary spillovers are quite different from the PCP case. Rearranging aggregate demand under LCP, write

$$\widehat{C}_t = \widehat{Y}_{H,t} - \frac{1 - a_{\mathrm{H}}}{\sigma}\left[2a_{\mathrm{H}}\phi\sigma\left(\widehat{\mathcal{T}}_t + \widehat{\Delta}_t\right) - \widehat{\mathcal{Q}}_t - \left(\widehat{\zeta}_{C,t} - \widehat{\zeta}^*_{C,t}\right)\right] \qquad (48)$$

First, nominal appreciation now strengthens the real exchange rate, but tends to weaken the terms of trade, with opposite effects on consumption: consumption spillovers are less positive than under PCP. Second, consumption responds to international relative prices even when $\sigma\phi = 1$. In other words, monetary spillovers play an important role in shaping macroeconomic interdependence, independently of the distinction between goods complementarity and substitutability, which is instead central to understanding spillovers in the PCP economy.

There are now four relevant NK Phillips curves, one for each combination of goods (H or F) and destination market (with or without a star *). These four Phillips curves now track the behaviour of inflation at consumer price level, in local currency:

$$\pi_{H,t} - \beta E_t \pi_{H,t+1} =$$
$$\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\left[(\sigma+\eta)\left(\widehat{Y}_{H,t} - \widetilde{Y}^{fb}_{H,t}\right) + \widehat{\mu}_t - (1-a_{\mathrm{H}})\left[2a_{\mathrm{H}}(\sigma\phi-1)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}^{fb}_t + \widehat{\Delta}_t\right) - \widehat{\Delta}_t\right]\right]$$
$$= \pi^*_{H,t} - \beta E_t \pi^*_{H,t+1} - \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\widehat{\Delta}_t,$$

$$\pi^*_{F,t} - \beta E_t \pi^*_{F,t+1} =$$
$$+\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\left[(\sigma+\eta)\left(\widehat{Y}_{F,t} - \widetilde{Y}^{fb}_{F,t}\right) + \widehat{\mu}^*_t + (1-a_{\mathrm{H}})\left[2a_{\mathrm{H}}(\sigma\phi-1)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}^{fb}_t + \widehat{\Delta}_t\right) - \widehat{\Delta}_t\right]\right]$$
$$= \pi_{F,t} - \beta E_t \pi_{F,t+1} + \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)}\widehat{\Delta}_t,$$

whereas the inflation differential between Home produced goods and imports is related to changes in the terms of trade and in the deviations from the law of one price by the following identity:

$$\pi_{F,t} - \pi_{H,t} = \widehat{\mathcal{T}}_t - \widehat{\mathcal{T}}_{t-1} + \widehat{\Delta}_t - \widehat{\Delta}_{t-1}, \tag{49}$$

an identity which is to be included as an additional constraint in the policy problem solved below.

To appreciate the difference relative to the PCP case, suppose that monetary authorities target zero inflation for domestically produced goods $\pi_{H,t} = 0$, which requires no change in producers' marginal costs under all contingencies. The Phillips curves above together with (**??**) suggest that closing output gap will be ineffective towards this goal. Rather, a target of zero inflation could only be pursued at the cost of variability in output gaps and inefficient misalignment and dispersion in prices (including deviations from the LOOP) across all categories of goods.

Moreover, with LCP, a Home depreciation has an asymmetric effect on the price dynamics of domestically produced goods in domestic and foreign currency. A Home depreciation also makes foreign consumer price inflation (π^*_H and π^*_F) larger than the domestic one (π_H and π_F.)

4.2 Optimal policy: trading off inflation with domestic and international relative price misalignment

With LCP, the flow loss function under cooperation and commitment, as shown by Engel 2009, is proportional to:

$$\ell_t^{CM-LCP} \ltimes -\frac{1}{2}\left\{\begin{array}{c} (\sigma+\eta)\left(\widetilde{Y}_{H,t}^{fb}-\widehat{Y}_{H,t}\right)^2+(\sigma+\eta)\left(\widetilde{Y}_{F,t}^{fb}-\widehat{Y}_{F,t}\right)^2+ \\ \dfrac{\theta\alpha\,(1+\theta\eta)}{(1-\alpha\beta)\,(1-\alpha)}\left[a_{\mathrm{H}}\pi_{H,t}^2+(1-a_{\mathrm{H}})\,\pi_{H,t}^{*2}+a_{\mathrm{H}}\pi_{F,t}^{*2}+(1-a_{\mathrm{H}})\,\pi_{F,t}^2\right]+ \\ -\dfrac{2a_{\mathrm{H}}\,(1-a_{\mathrm{H}})\,(\sigma\phi-1)\,\sigma}{4a_{\mathrm{H}}\,(1-a_{\mathrm{H}})\,\phi\sigma+(2a_{\mathrm{H}}-1)^2}\left[\left(\widetilde{Y}_{H,t}^{fb}-\widehat{Y}_{H,t}\right)-\left(\widetilde{Y}_{F,t}^{fb}-\widehat{Y}_{F,t}\right)\right]^2+ \\ \dfrac{2a_{\mathrm{H}}\,(1-a_{\mathrm{H}})\,\phi}{4a_{\mathrm{H}}\,(1-a_{\mathrm{H}})\,\phi\sigma+(2a_{\mathrm{H}}-1)^2}\widehat{\Delta}_t^2 \end{array}\right\}. \tag{50}$$

Comparing this and the loss function under PCP (40), cooperative policymakers still dislike national output gaps and inflation, as well as cross-country differences in output gaps, to the extent that these lead to misalignments in international relative prices. Yet, relative to the PCP case, the relevant inflation rates are measured at consumer level, and thus differ across domestic goods and imports. In addition, there is a new term reflecting deviations from the law of one price.

The four different terms in inflation in the loss function reflect the fact that, with LCP, policymakers are concerned with inefficiencies in the supply of each good, due to price dispersion in the domestic and in the export destination markets. Observe that in our symmetric specification, the quadratic inflation terms are weighted according to the corresponding shares in the consumption basket.[19]

Furthermore, because of the presence of a term in Δ_t, losses from misalignments in relative prices would arise even if output could be brought to its efficient level. Deviations from the law of one price lead to inefficiencies in the level and composition of global consumption demand, a point especially stressed by the LCP literature assuming one-period preset prices — see, e.g., Devereux and Engel (2003) and Corsetti and Pesenti (2005).

The optimal policy is characterized by the following first-order conditions

[19] In more general specifications with asymmetries in nominal rigidities and thus in Phillips Curve parameters, it will not be possible to aggregate national CPI inflation components according only to the CPI weights.

for inflation

$$\pi_{H,t} \quad : \quad 0 = -\theta \frac{\alpha \left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)} a_{\mathrm{H}} \pi_{H,t} - \gamma_{H,t} + \gamma_{H,t-1} - \gamma_t \tag{51}$$

$$\pi^*_{H,t} \quad : \quad 0 = -\theta \frac{\alpha \left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)} \left(1-a_{\mathrm{H}}\right) \pi^*_{H,t} - \gamma^*_{H,t} + \gamma^*_{H,t-1}$$

$$\pi_{F,t} \quad : \quad 0 = -\theta \frac{\alpha \left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)} \left(1-a_{\mathrm{H}}\right) \pi_{F,t} - \gamma_{F,t} + \gamma_{F,t-1} + \gamma_t$$

$$\pi^*_{F,t} \quad : \quad 0 = -\theta \frac{\alpha \left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)} a_{\mathrm{H}} \pi^*_{F,t} - \gamma^*_{F,t} + \gamma^*_{F,t-1},$$

for output

$$\begin{aligned}
\widehat{Y}_{H,t} \quad : \quad & 0 = \left(\sigma+\eta\right)\left(\widetilde{Y}^{fb}_{H,t} - \widehat{Y}_{H,t}\right) - \frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\sigma}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2}\left[\left(\widetilde{Y}^{fb}_{H,t} - \widehat{Y}_{H,t}\right) - \left(\widetilde{Y}^{fb}_{F,t} - \widehat{Y}_{F,t}\right)\right] + \\
& + \left[\left(\sigma+\eta\right)\left(\gamma_{H,t}+\gamma^*_{H,t}\right)\right] \\
& - \frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\sigma}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2} \frac{\left(1-\alpha\beta\right)\left(1-\alpha\right)}{\alpha\left(1+\theta\eta\right)}\left[\left(\gamma_{H,t}+\gamma^*_{H,t}\right) - \left(\gamma_{F,t}+\gamma^*_{F,t}\right)\right] + \\
& + \frac{\sigma\left(\beta E_t \gamma_{t+1} - \gamma_t\right)}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2},
\end{aligned} \tag{52}$$

$$\begin{aligned}
\widehat{Y}_{F,t} \quad : \quad & 0 = \left(\sigma+\eta\right)\left(\widetilde{Y}^{fb}_{F,t} - \widehat{Y}_{F,t}\right) + \frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\sigma}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2}\left[\left(\widetilde{Y}^{fb}_{H,t} - \widehat{Y}_{H,t}\right) - \left(\widetilde{Y}^{fb}_{F,t} - \widehat{Y}_{F,t}\right)\right] + \\
& + \left[\left(\sigma+\eta\right)\left(\gamma_{F,t}+\gamma^*_{F,t}\right)\right] + \\
& + \frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\sigma}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2} \frac{\left(1-\alpha\beta\right)\left(1-\alpha\right)}{\alpha\left(1+\theta\eta\right)}\left[\left(\gamma_{H,t}+\gamma^*_{H,t}\right) - \left(\gamma_{F,t}+\gamma^*_{F,t}\right)\right] + \\
& - \frac{\sigma\left(\beta E_t \gamma_{t+1} - \gamma_t\right)}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2},
\end{aligned}$$

and for deviations from the LOOP:

$$\begin{aligned}
\widehat{\Delta}_t \quad : \quad & 0 = -\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2}\widehat{\Delta}_t + \\
& \frac{\left(1-\alpha\beta\right)\left(1-\alpha\right)}{\alpha\left(1+\theta\eta\right)} \frac{1}{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2} \cdot \\
& \frac{1}{2}\left[\begin{array}{c} \left(4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2\right)\left(\gamma_{H,t}+\gamma_{F,t} - \left(\gamma^*_{F,t}+\gamma^*_{H,t}\right)\right) + \\ -\left(2a_{\mathrm{H}}-1\right)\left(\gamma_{H,t}+\gamma^*_{H,t} - \gamma_{F,t} - \gamma^*_{F,t}\right) \end{array}\right] \\
& - \left\{\frac{2a_{\mathrm{H}}-1}{4\left(1-a_{\mathrm{H}}\right)a_{\mathrm{H}}\phi\sigma + \left(2a_{\mathrm{H}}-1\right)^2}\right\}\left(\beta E_t \gamma_{t+1} - \gamma_t\right)
\end{aligned} \tag{53}$$

where $\gamma_{H,t}$ and $\gamma^*_{H,t}$ ($\gamma_{F,t}$ and $\gamma^*_{F,t}$) are the multiplier associated with the

Home (Foreign) Phillips curves (**??**) — whose lags appear reflecting the assumption of commitment, and γ_t is the multiplier associated with the additional constraint arising under LCP (49).

As before, we can summarize these conditions by deriving two targeting criteria, one expressed in terms of global objectives, the other in terms of relative objectives. The first targeting criterion is readily obtained by summing the first-order conditions with respect to output and inflation rates:

$$0 = \left[\left(\widehat{Y}_{H,t} - \widetilde{Y}^{fb}_{H,t}\right) - \left(\widehat{Y}_{H,t-1} - \widetilde{Y}^{fb}_{H,t-1}\right) + \left(\widehat{Y}_{F,t} - \widetilde{Y}^{fb}_{F,t}\right) - \left(\widehat{Y}_{F,t-1} - \widetilde{Y}^{fb}_{F,t-1}\right)\right] + \theta\left[a_{\mathrm{H}}\pi_{H,t} + (1-a_{\mathrm{H}})\,\pi_{F,t} + (1-a_{\mathrm{H}})\,\pi^*_{H,t} + a_{\mathrm{H}}\pi^*_{F,t}\right]. \tag{54}$$

Similarly to the PCP economy, the policymakers seek to stabilize a linear combination of changes in the world output gap and world price inflation. Under LCP, however, the latter is defined using consumer prices only — under PCP, instead, world inflation could be expressed using either consumer or producer prices.

Obtaining the second targeting criterion under LCP is more involved. An instructive way to write this criterion in its general form consists of combining a difference equation in the multiplier γ_t, obtained using the first order conditions for $\widehat{Y}_{H,t}$, $\widehat{Y}_{F,t}$ and $\widehat{\Delta}_t$ and inflation to eliminate the other multipliers:

$$\begin{aligned} &-2\,(2a_{\mathrm{H}}-1)\,\eta\frac{(1-\alpha\beta)\,(1-\alpha)}{\alpha\,(1+\theta\eta)}\left(\beta E_t\gamma_{t+1}-\gamma_t\right) = \\ &\quad\frac{(1-\alpha\beta)\,(1-\alpha)}{\alpha\,(1+\theta\eta)}\left(1+\frac{4a_{\mathrm{H}}\,(1-a_{\mathrm{H}})\,\phi\sigma+(2a_{\mathrm{H}}-1)^2}{\sigma}\eta\right)\cdot \\ &\quad\left\{\begin{array}{c} (2a_{\mathrm{H}}-1)\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}^{fb}_t\right)+2a_{\mathrm{H}}\widehat{\Delta}_t+ \\ \sigma\theta\left[\left(a_{\mathrm{H}}\widehat{p}_{H,t}+(1-a_{\mathrm{H}})\,\widehat{p}_{F,t}\right)-\left((1-a_{\mathrm{H}})\,\widehat{p}^*_{H,t}+a_{\mathrm{H}}\widehat{p}^*_{F,t}\right)\right] \end{array}\right\}, \end{aligned}$$

with a solution for the same multiplier, given by

$$-2\left(2a_{\mathrm{H}}-1\right)\eta\frac{\left(1-\alpha\beta\right)\left(1-\alpha\right)}{\alpha\left(1+\theta\eta\right)}\gamma_t = \tag{55}$$

$$\left(2a_{\mathrm{H}}-1\right)\eta\left\{\begin{array}{c}\theta\left[\left(a_{\mathrm{H}}\pi_{H,t}+\left(1-a_{\mathrm{H}}\right)\pi^*_{H,t}\right)-\left(\left(1-a_{\mathrm{H}}\right)\pi_{F,t}+a_{\mathrm{H}}\pi^*_{F,t}\right)\right]+\\ \left[\left(\widehat{Y}_{H,t}-\widetilde{Y}^{fb}_{H,t}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}^{fb}_{H,t-1}\right)\right]-\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}^{fb}_{F,t}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}^{fb}_{F,t-1}\right)\right]\end{array}\right\}+$$
$$\left(2a_{\mathrm{H}}-1\right)\left[\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}^{fb}_t\right)-\left(\widehat{\mathcal{T}}_{t-1}-\widetilde{\mathcal{T}}^{fb}_{t-1}\right)\right]+2a_{\mathrm{H}}\left(\widehat{\Delta}_t-\widehat{\Delta}_{t-1}\right)+$$
$$\sigma\theta\left[\left(a_{\mathrm{H}}\pi_{H,t}+\left(1-a_{\mathrm{H}}\right)\pi_{F,t}\right)-\left(\left(1-a_{\mathrm{H}}\right)\pi^*_{H,t}+a_{\mathrm{H}}\pi^*_{F,t}\right)\right].$$

Observe that, contrary to the PCP case, the relative criterion generally combines both a flexible inflation target and a price level target in terms of consumer prices, also adjusted to take into account relative price misalignments rather than the output gap. Moreover, the targeting rule will generally include the differential between GDP deflators across countries $\left(\left(a_{\mathrm{H}}\pi_{H,t}+\left(1-a_{\mathrm{H}}\right)\pi^*_{H,t}\right)-\left(\left(1-a_{\mathrm{H}}\right)\pi_{F,t}+a_{\mathrm{H}}\pi^*_{F,t}\right)\right)$, in addition to the differential in CPI inflation $\left(\left(a_{\mathrm{H}}\pi_{H,t}+\left(1-a_{\mathrm{H}}\right)\pi_{F,t}\right)-\left(\left(1-a_{\mathrm{H}}\right)\pi^*_{H,t}+a_{\mathrm{H}}\pi^*_{F,t}\right)\right)$.

Under LCP, cross-country differentials in good-specific inflation are optimally traded offs with cross-country differentials in output gaps and relative price misalignments, including deviations from the law of one price. Thus, while optimal policy still pursues global CPI inflation targeting and world output gap stabilization (according to the global criterion), global stabilization generally comes at the expense of the stabilization of national CPI inflation and output gaps, as well as international prices.[20]

While the expression for the relative targeting criterion is not immediately intuitive, it greatly simplifies under two alternative assumptions: either a linear disutility of labor ($\eta = 0$) — the case stressed by Engel (2009) — or purchasing power parity in the first best, reflecting identical preferences across goods ($a_{\mathrm{H}} = 1/2$) — a case discussed by the early contributions to the NOEM literature such as CGG and BB. Under either condition, the multiplier γ drops from the targeting criterion, simplifying the analytical characterization of the optimal policy (for instance, there is no longer a trade-off between stabilizing the GDP and the CPI inflation differential).

[20] It is instructive to compare the above expression with optimal targeting criteria derived in models with multiple sectors, or featuring both price and wage rigidities (e.g. Giannoni and Woodford 2009). A common feature is that the targets pursued by monetary authorities involve linear combinations of current and expected changes in output gaps and inflation.

Specifically, using equation (47), the relative targeting criterion can be expressed as a function of CPI inflation differentials and the real exchange rate gap only:

$$0 = \sigma^{-1}\left[\left(\widehat{\mathcal{Q}}_t - \widetilde{\mathcal{Q}}_t^{fb}\right) - \left(\widehat{\mathcal{Q}}_{t-1} - \widetilde{\mathcal{Q}}_{t-1}^{fb}\right)\right] + \theta \left[\begin{array}{c} \left(a_{\mathrm{H}}\pi_{H,t} + \left(1 - a_{\mathrm{H}}\right)\pi_{F,t}\right) \\ -\left(\left(1 - a_{\mathrm{H}}\right)\pi^*_{H,t} + a_{\mathrm{H}}\pi^*_{F,t}\right) \end{array}\right] \quad (56)$$

Under either $\eta = 0$ or $a_{\mathrm{H}} = 1/2$, the two targeting criteria — in sum and difference — lead to clearcut policy prescriptions, spelled out by Engel (2009) in his discussion of the case of linear disutility of labor. Namely, in response to efficient shocks, the optimal policy stabilizes the global welfare-relevant output gap together with CPI inflation in each country. With zero CPI inflation, in turn, satisfying the relative criterion coincides with correcting misalignments in the real exchange rate.[21]

The latter result — optimal real exchange rate stabilization — helps shedding light on recurrent claims in the literature that, under LCP, policy-makers should be concerned with stabilizing consumption deviations from their efficient level. This is apparent from the targeting rule above, as with complete markets, we can use the perfect risk-sharing condition to substitute out the real exchange rate for relative consumption. The relative targeting criterion indeed emphasizes the optimal trade off between minimizing differences in inflation rates, and containing misallocation of consumption across countries. In response to efficient shocks, stabilization of (national) CPI inflation implies that cross-country consumption differentials are also stabilized (see, e.g., Corsetti and Pesenti 2005).

Using the following equilibrium relation between international relative prices — real exchange rates, the terms of trade and deviations from the law of one price — and relative output,

$$\sigma^{-1}\left[\left(2a_{\mathrm{H}} - 1\right)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}_t^{fb}\right) + 2a_{\mathrm{H}}\widehat{\Delta}_t\right] - \left[\left(\widehat{Y}_{H,t} - \widetilde{Y}_{H,t}^{fb}\right) - \left(\widehat{Y}_{F,t} - \widetilde{Y}_{F,t}^{fb}\right)\right] = \quad (57)$$

$$\sigma^{-1}\left[2\left(1 - a_{\mathrm{H}}\right)\left(2a_{\mathrm{H}} - 1\right)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}_t^{fb}\right) + 2\left(1 - a_{\mathrm{H}}\right)2a_{\mathrm{H}}\widehat{\Delta}_t - 4a_{\mathrm{H}}\left(1 - a_{\mathrm{H}}\right)\phi\sigma\left(\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}_t^{fb}\right) + \widehat{\Delta}_t\right)\right]$$

the relative targeting criterion could also be written in a form more similar

[21] To see this, rearrange the Phillips curves (**??**) into global CPI inflation and cross-country CPI inflation differentials. Under efficient shocks global CPI inflation is always zero when the global output gap is closed. Relative CPI inflation is also zero under either PPP or linear disutility of labor when the real exchange rate gap is closed.

to its counterpart for the PCP economy (44):

$$0 = \left[\left(\left(\widehat{Y}_{H,t} - \widetilde{Y}^{fb}_{H,t} \right) - \left(\widehat{Y}_{H,t-1} - \widetilde{Y}^{fb}_{H,t-1} \right) \right) - \left(\left(\widehat{Y}_{F,t} - \widetilde{Y}^{fb}_{F,t} \right) - \left(\widehat{Y}_{F,t-1} - \widetilde{Y}^{fb}_{F,t-1} \right) \right) \right] + \tag{58}$$

$$\theta \left[\left(a_{\mathrm{H}} \pi_{H,t} + (1 - a_{\mathrm{H}}) \pi_{F,t} \right) - \left((1 - a_{\mathrm{H}}) \pi^{*}_{H,t} + a_{\mathrm{H}} \pi^{*}_{F,t} \right) \right] +$$

$$- 2 (1 - a_{\mathrm{H}}) \sigma^{-1} \begin{bmatrix} \left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}^{fb}_t \right) - \left(\widehat{\mathcal{T}}_{t-1} - \widetilde{\mathcal{T}}^{fb}_{t-1} \right) + \\ 2a_{\mathrm{H}} (\phi\sigma - 1) \left(\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}^{fb}_t \right) - \left(\widehat{\mathcal{T}}_{t-1} - \widetilde{\mathcal{T}}^{fb}_{t-1} \right) + \widehat{\Delta}_t - \widehat{\Delta}_{t-1} \right) \end{bmatrix}$$

As was the case for the PCP economy, the policy trade-off is between stabilizing internal objectives (output gaps and an inflation goal) across countries, and stabilizing international relative prices. However, as argued above, with LCP cross-country output gap stabilization no longer translates into terms of trade stabilization. In response to productivity shocks, for instance, stabilizing the marginal cost of domestic producers neither coincides with stabilizing their markups in all markets, nor is sufficient to realign international product prices. It is apparent that LCP breaks the 'divine coincidence' in open economy.

Furthermore, note that with no home bias in consumption preferences ($a_{\mathrm{H}} = 1/2$), the efficient real exchange rate is obviously constant — PPP would hold under flexible prices. When PPP is efficient, real exchange rate stabilization implies a constant nominal exchange rate. Indeed, according to the second targeting criterion (56), keeping the nominal exchange rate fixed corrects real exchange rate misalignment — in a PPP environment the sole cause of deviations from the law of one price — at the same time ruling out cross-country misallocation in consumption. In this case, a fixed exchange rate is indeed implied by the optimal policy in response to efficient shocks, although not to markup shocks. Unless PPP is efficient, however, optimal policy under LCP will not imply keeping the nominal exchange rate fixed (a point stressed by Duarte and Obstfeld 2008; see also Corsetti 2006 and Sutherland 2005).

It is worth stressing that the clearcut prescriptions of strict CPI inflation targeting and complete stabilization of real exchange rate misalignments — specific to economies in which either PPP is efficient or $\eta = 0$ — do not imply an overall efficient allocation, as apparent from equation (58). Under LCP, global stabilization is generally achieved at the cost of cross-country and domestic inefficiency, that is, inefficient cross-country output gap differentials, terms of trade misalignments and deviations from the law of one price.

For general specifications of the model (with $\eta > 0$ and efficient deviations from PPP), the optimal policy prescriptions are less clear-cut, reflecting the complexity of the trade-offs among competing objectives accounted for by the cross-country targeting criterion (**??**). The main lessons from the analysis of optimal policy can nonetheless be ummarized as follows. The presence of LCP entails that policymakers should pay more attention to consumer price inflation components (domestic goods and import inflation), rather than GDP deflator inflation, and to international relative price misalignments. Yet, it motivates neither complete CPI stabilization within countries, nor policies containing real exchange rate volatility.

To provide further insights on the optimal policy under LCP, we show impulse-responses to different shocks for the general case with home bias in consumption and $\eta > 0$. We start by reproducing in Figure I.2 the same exercise of optimal stabilization of markup shocks as in Figure I.1. The striking difference between these figures is that, with LCP, alternative values of $\sigma\phi$ are much less relevant for the direction of cross-border spillovers. With import prices sticky in local currency, the Home expansion in response to a favorable markup shock in one country creates positive output spillovers independently of the sign of $\sigma\phi$: in the figure, output comovements are always positive; CPI (but also GDP deflator) inflation comovements are always negative. Yet the magnitude of $\sigma\phi$ still determines the response of marginal costs to change in terms of trade and deviations from the law of one price, and thus the optimal monetary policy stance. At the margin, the movement in international prices is still slightly larger if $\sigma\phi > 1$, compared to the complementarity case, as was the case with PCP. Relative to the PCP economy, however, international relative prices move in opposite directions: when the Home real exchange rate depreciates, the terms of trade strengthen.

Figure I.2
International transmission of an exogenous decline in Home markups under the optimal policy with Local Currency Pricing and complete markets

Figure I.3 depicts impulse responses under the optimal policy to Home shocks to productivity and preference (demand), for the benchmark calibration in Table I.1. Even if these shocks are efficient, with LCP the optimal policy cannot fully stabilize them. A positive productivity shock in the Home economy (the graphs on the left-hand column of the Figure) opens a negative output gap and translates into negative GDP deflator inflation in the Home economy. The allocation in the Foreign country is once again determined by monetary spillovers, rather than by elasticity parameters (it is assumed that $\sigma\phi > 1$). In response to the Home productivity shock, a Home expansion raises domestic demand, depreciating the exchange rate in real and nominal terms, but improving the terms of trade in excess of their efficient levels. The Home expansion translates into excessive demand for the foreign goods: the Foreign output gap turns positive, so does the Foreign GDP deflator inflation. Observe that the rise in Foreign good prices in Home currency is large enough to cause some overall CPI inflation in the Home country (despite the fall in the domestic GDP deflator). However, the CPI is stabilized to a much larger extent than the GDP deflator.

The pattern of impulse responses is just the opposite for the case of a positive Home preference shock, depicted on the right-hand column in the Figure. The Home monetary authorities react to the inflationary consequences of higher domestic demand by contracting, thus appreciating the currency. With LCP, however, a Home appreciation causes weaker terms of trade, despite the stronger demand for Home output. Foreign output falls. Once again, import prices move the CPI opposite relative to the GDP deflator, corresponding to negative inflation in the Home economy. Note that, for either shock, the optimal policy induces a negative correlation of output and CPI inflation across border.

Figure I.3
International transmission of Home productivity and preference shocks under the optimal policy with Local Currency Pricing and complete markets

4.3 Discussion

Optimal stabilization and macro volatility To complement our analytical characterization of the optimal policy under PCP and LCP, we carry out numerical exercises shedding light on the implications of pursuing the optimal policy for the volatility of macro variables of interest. The parameters underlying our exercises are shown in Table I.1. Results are shown in Table I.2, reporting the standard deviation of inflation rates for the CPI and the GDP deflator, output gaps, markups, and international prices (relative to output). The table contrasts PCP and LCP economies under complete markets, assuming either efficient shocks only or efficient and inefficient shocks together.

Table I.1 and I.2 here

With an efficient steady-state, the optimal policy under PCP reproduces the flexible-price efficient allocation if there are only shocks to productivity and preferences: markups, the output gap, and GDP-deflator inflation are all perfectly stabilized. Monetary authorities are inward-looking in the sense that they focus exclusively on stabilizing the prices of domestic products in domestic currency, by virtue of the fact that, with the optimal policy in place, import prices fluctuate with the exchange rate to realign relative prices. For this reason, monetary authorities should instead never respond to "imported inflation." At an optimum, CPI inflation remains quite volatile. In the presence of markup shocks, however, monetary authorities optimally trade-off stabilization of markups and inflation, with stabilization of output gaps.

Compare these results with those reported for the LCP economy. Relative to the PCP case, it is apparent that the optimal policy no longer fully stabilizes the domestic output gap, whether or not shocks are efficient. The volatility of CPI inflation is lower than that of the GDP-deflator inflation. This stems from the fact that the optimal policy attempts to stabilize a weighted average of domestic and foreign-goods markups. Compared to the PCP case, the optimal policy lowers the volatility of the terms of trade, but not that of the real exchange rate, which can actually be more volatile in the LCP than in the PCP economy.

The latter result deserves a comment. The impulse responses in Figure 3 suggest that, under the optimal policy, the *gap* between market and efficient real exchange rates is stabilized by more than the corresponding gap in the terms of trade. In other words, the policymakers are relatively more concerned with stabilizing the real exchange rate than the terms of trade. Yet, from Table I.2 it is apparent that the volatility of the former is larger than that of the latter in equilibrium. The two observations are obviously consistent. Together they stress once again that what matters for policymakers are welfare-relevant gaps, rather than variables in level. Specifically, the lower volatility of the terms of trade is explained by the fact that LCP induces a negative covariance between the market and the efficient level of the terms of trade — such a covariance is instead positive for the real exchange rate.[22]

Sources of Local Currency Price Stability of Imports The analysis of optimal policy contrasting PCP and LCP raises issues in the extent to which the local currency price stability of imports can be considered

[22] See Svensson (2002) for an analysis of flexible inflation targeting, and its implications on exchange rate volatility.in a small open economy context.

evidence in favor of nominal frictions, as postulated by LCP, instead of reflecting optimal markup adjustment by firms (for an analysis of the latter, see, e.g., Atkeson and Burstein 2008, Bergin and Feenstra 2000 Dornbusch 1987, Krugman 1987, and Ravn et al. 2007), or the incidence of local costs in final prices (see, e.g., Burstein et al. 2005).[23] If rooted in real factors, local currency price stability is not necessarily incompatible with the classical view attributing expenditure switching effects to exchange rate movements (a point stressed by Obstfeld 2002).

Different sources of local currency price stability can interact in determining the degree of exchange rate pass-through. In previous work of ours (Corsetti and Dedola 2005 and Corsetti, Dedola, and Leduc 2009a), we have shown how local costs and distributive trade can affect the demand elasticity faced by exporters at the dock,[24] making it market-specific (hence creating an incentive for cross-border price discrimination), and increasing in the dock price (thus leading to incomplete exchange rate pass-through independently of nominal rigidities).[25] According to this model, even in the absence of nominal frictions, exporters pass through to local prices only a fraction of the change in marginal costs in local currency induced by exchange rate movements.

In turn, allowing for nominal rigidities affecting both producers and retailers in the same model does not necessarily lower pass-through — nominal rigidities at retail levels can actually raise the producers' incentive to raise local prices in response to exchange rate shocks. Real and (several layers of) nominal rigidities in turn create trade-offs between price stability and relative price adjustment, which need to be addressed by optimal stabilization

[23] Several empirical and theoretical works have shed light on the importance of real factors in muting the adjustment of prices vis-à-vis marginal costs fluctuations driven by the exchange rate (see, e.g., Goldberg and Verboven 2001, Goldberg and Hellerstein 2007, and Nakamura and Zerom 2009).

[24] It is well understood that, even if exchange rate pass-through is complete, the incidence of local costs can lower the elasticity of import prices at the retail level As stressed by Burstein, Eichenbaum, and Rebelo (2007), suppose that import prices at the dock move one-to-one with the exchange rate — the exchange rate pass-through correctly defined is complete — but 50 percent of the retail prices is distribution margin, mostly covering local costs. A 1 percent depreciation of the currency will then affect the final price of the imported good only by 1/2 percent.

[25] In our work we have modelled upstream monopolists selling their tradable goods to downstream firms, which combine them with local inputs before reaching the consumer, assuming that the two (tradable goods and local inputs) are not good substitutes in the downstream firms' production The same principle nonetheless can be applied to models where intermediate imported inputs are assembled using local inputs.

policies.[26]

Endogeneity of LCP and the role of monetary policy A small but important strand of literature has emphasized the need to treat the currency denomination of exports as an endogenous choice by profit maximizing firms. Bacchetta and Van Wincoop (2005), Devereux, Engel, and Storgaard (2004), and Friberg (1998) have developed models where firms can choose whether to price exports in domestic or in foreign currency, knowing that price updates will be subject to frictions. A number of factors — from the market share of exporters to the incidence of distribution and the availability of hedging instruments — potentially play a crucial role in this choice (see Engel 2006 for a synthesis).

Taylor (2000) and Corsetti and Pesenti (2002) specifically discuss the role of monetary policy in this choice. The former links low pass-through to a low inflation environment (see however Campa and Goldberg 2005 for evidence). The latter stresses the systematic effects of monetary policy stabilization on the covariance between exporters' marginal costs and their revenues from the foreign market. The key argument can be intuitively explained as follows: consider a firm producing in a country where monetary policy is relatively noisy, that is frequent nominal shocks tend to simultaneously raise nominal wages and depreciate the exchange rates. In this environment, by choosing LCP, a firm can secure that, whenever an unexpected monetary expansion causes nominal wages and thus its marginal cost to rise, its export revenues in domestic currency will correspondingly increase per effect of the nominal depreciation — with clear stabilizing effects on the firm's markup. The opposite will be true for a foreign firm exporting to the same country. By choosing PCP this firm can insulate its revenue, and therefore its markup, from monetary noise.

We have seen above that benevolent policymakers choose their optimal policy differently depending on the degree of exchange rate pass-through (PCP versus LCP). Firms, in turn, will choose optimal pass-through also taking into account monetary policy. So, monetary policy and firms' pricing strategies depend on each other, raising the possibility of interesting interaction in general equilibrium.[27]

[26] For a small open-economy analysis see Monacelli (2005).

[27] Chang and Velasco (2006) reconsider the mechanism in Corsetti and Pesenti (2002), to explain the way monetary policy can affect the choice of the currency denomination of debt.

Price indexes An important issue raised by the LCP literature concerns the price index to be targeted by policymakers. LCP provides an argument to use an index closer to the CPI than to the GDP deflator — depending on the weight of imports in the consumption basket, but also on differences in the degree of nominal distortions across the domestic and the import sector (see, e.g., Smets and Wouters 2002).[28]

Similar considerations apply to PCP economies producing both traded and nontraded goods whose prices are subject to nominal rigidities — complete stabilization of the GDP deflator is therefore not attainable. Despite PCP, under the optimal policy these economies behave pretty much like the LCP economy in a key dimension: markups and output gaps are not stabilized fully in response to efficient shocks. Under a standard calibration of sectoral shocks, real exchange rate volatility can actually be lower than in the LCP case. The optimal price target is however still defined in terms of a (now composite) GDP deflator only.

A relatively unexplored direction of research consists of allowing for (staggered) wage contracts on top of price rigidities. As there is now a feedback from "imported inflation" into optimal wage setting, sticky wages might provide an argument for deviating from targeting the GDP deflator, and somewhat stabilize import prices even under PCP.

5 Deviations from policy cooperation and concerns with "competitive devaluations"

5.1 Benefits and costs from strategic manipulation of the terms of trade

A classical question in international monetary policy concerns the gains from policy cooperation — reflecting the magnitude of cross-border monetary and real spillovers as well as the modalities of strategic interactions among independent policymakers. In this section, we analyze this issue by keeping the assumption of complete markets and focusing on the Nash equilibrium in the class of models analyzed by, e.g., BB, with the GDP inflation rate as the policy instrument. As for the case of cooperative policymakers, we again characterize the optimal policy under commitment, assuming that appropriately chosen subsidies ensure efficiency of the steady-state.

As amply discussed in the literature, the allocations under international

[28] For an analysis of similar issues in a currency union, see Benigno (2004) and Lombardo (2006). Adao et al. (2009) extends the analysis to optimal monetary and fiscal policy.

policy cooperation and Nash are not necessarily different, but happen to coincide under some special but noteworthy cases. One such special case is discussed by Obstfeld and Rogoff (2002) and Corsetti and Pesenti (2005), specifying a model with symmetric Cobb-Douglas aggregator of consumption, logarithmic preferences, no government expenditure, and, only productivity shocks.[29] More generally, Cobb-Douglas preferences and logarithmic utility in this list can be replaced by the condition $\sigma\phi = 1$; as discussed above, this condition implies that, under PCP, there are no cross-border supply spillovers via the influence of terms of trade movements on marginal costs with complete markets.[30]

Another special case is suggested by the literature based on Mundell-Fleming (see, e.g., Canzoneri and Henderson 1991 and Persson and Tabellini 1995), concerning gains from cooperation when shocks are global and symmetric across countries. In the workhorse model, however these gains are zero only in special cases — i.e., global shocks only affect productivity provided government spending is zero. In general (e.g. with markup shocks), even symmetric disturbances produce cross-country spillovers and thus create room for improving welfare via cooperative policies.

With the exception of a few special cases, cooperative policies will generally be welfare improving. A specific source of gains from cooperation is the elimination of strategic manipulation of the terms of trade. In the traditional literature, a key argument in favor of cooperation indeed consists of preventing "competitive devaluations," that is, attempts by one country to manipulate the terms of trade in order to steal markets from foreign competitors, to the benefit of domestic employment and output. Over the years, the modern literature has thoroughly revisited the same argument, using the expected utility of the representative consumer as the welfare criterion.

One feature differentiates the modern from the conventional analysis. By analyzing the welfare incentive for policymakers to manipulate international prices, the modern literature makes it clear that these incentives can go either way, depending on macroeconomic interdependence — they do not exclusively make domestic products cheaper. An intuitive account of the gains from terms of trade manipulation is as follows. Assume that our baseline model is in steady-state, and markups are zero per effect of appropriate subsidies. Consider now the effect of a contraction in the production of domestic goods, improving a country's terms of trade. When

[29] See also Benigno and Benigno (2003) and Corsetti (2006).

[30] As noted by BB, the absence of cross-border *supply* spillovers per se does not rule out gains from cooperation: in fact these materialize in the presence of, e.g., markup shocks because of the interdependence of consumption utilities.

goods are substitutes, the fall in domestic production reduces the disutility of labor, without much effect on the utility from consumption. This is because, at better terms of trade, domestic households can now acquire more units of foreign goods, which are good substitutes for the domestic one — an argument which follows the same logic of the "optimal tariff" in trade theory. The opposite is true when goods are complements. In this case, utility increases with a marginal increase in domestic production, even if the country's terms of trade worsen. As the extra production is exchanged for foreign goods, a higher consumption of imports raises the marginal utility from consuming domestically produced goods. Note that these effects disappear when goods are independent, namely $\sigma\phi = 1$.[31]

From the vantage point of a country, the macroeconomic advantages from strategic manipulation of terms of trade can be fully appreciated in analyses of small open economies facing a downward sloping demand for their domestic products since in this case the analysis can abstract from strategic interactions with the rest of the world (see, e.g., De Paoli 2009a). In a symmetric Nash equilibrium, instead, a country's attempt to manipulate terms of trade is in large part self-defeating, as such attempt is matched by the policy response of the other country: in the noncooperative equilibrium all players end up being worse off relative to the cooperative one. In general, output gaps will not be closed in equilibrium; there will instead be either overproduction or underproduction.[32]

[31] The influence of monetary policy on a country's real international prices has important implications as regards the incentives faced by discretionary policymakers. Although the chapter focuses on the case of full commitment, it is appropriate to discuss these incentives, if only briefly. In closed economy New Keynesian model, it is well understood that monopolistic distortions in production create an incentive for discretionary policymakers to engineer surprise monetary expansions, as to bring output closer to its efficient level. In an open economy, however, the country as a whole has also monopoly power on its terms of trade: by causing depreciation, a surprise monetary expansion also worsens the international price of domestic output. For this reason, as discussed by Corsetti and Pesenti (2001) and Tille (2001), discretionary policymakers will trade-off monopolistic distortions in production and in the country's terms of trade. Depending on the relative magnitude of these distortions, a discretionary policymaker may have the incentive to either engineer a surprise devaluation, although smaller than needed to make the economy produce its efficient level of output, or even to engineer an ex-post appreciation.

[32] As shown by Corsetti and Pesenti (2001) and (2005), Obstfeld and Rogoff (2002), national policymakers can manipulate the country's terms of trade by affecting the *level* of prices set on average by firms, via the influence of their monetary rules on the statistical distribution of marginal costs and revenues (see Broda 2006 for evidence).

5.2 Optimal stabilization policy in a global Nash equilibrium

In order to characterize noncooperative policy, the modern intertemporal approach emphasizes the need to model fully specified dynamic games. Hence the literature faces several important challenges, as regards the definition of equilibria (e.g., open- or closed-loop, discretion or commitment) and policy instruments (inflation, price level, output gaps), as well as the feasibility of analytical solutions (complete and incomplete markets, distorted steady-states) and implementation issues (interest rates or money) — each passage pointing to promising although difficult avenues of research.[33] In what follows, we focus on one of the few cases which has been fully worked out by the literature. This is a two-country, open-loop Nash equilibrium under PCP, with GDP deflator inflation rates as the policy instrument; see BB for the analysis of an economy in which PPP holds. Revisiting this contribution, we carry out numerical experiments presenting new results on the real exchange rate behavior.

Figure I.4
Nash Gaps Following a Home Productivity Shock

The Nash policy from the vantage point of each country is characterized under commitment, positing an efficient steady-state via appropriate subsidies. The calibration is the same as in Table I.1. Results are shown in Figure I.4. This figure reports the difference in impulse responses to a positive productivity shock in the Home country between the cooperative case to the Nash-equilibrium. The two columns report results for different degrees of substitutability between domestic and foreign goods, always assuming home bias in preferences: positing $\sigma = 2$, the column on the left corresponds to the case of complementarity for $\phi = .3$ so that $\phi\sigma < 1$, the column on the right to the case of substitutability for $\phi = .7$, so that $\phi\sigma > 1$ (the two allocations coincide in the case of independence, as discussed).

Relative to the efficient terms of trade/real exchange rate depreciation in the cooperative allocation, noncooperative policies lead to more or less

[33] Sims (2009) argues that even state-of-the-art exercises such as Coenen et al. (2009), provide only prototype analysis of strategic monetary interactions, for several reasons: (i) the features of the Nash equilibria studied depend crucially on many aspects of the game, especially which variables each player treats as given when choosing the player's own moves; (ii) the reliance on equally unrealistic open-loop strategies (in which the entire past and future of the other central bank's instrument is taken as given) or ad-hoc (closed-loop) strategies like simple rules; (iii) the lack of key features like valuation effects with incomplete markets.

depreciation in response to the shock, depending on the size of $\phi\sigma$. This suggests that, with strategic interactions, exchange rate volatility will tend to be lower in the case of substitutability and higher in the case of complementarity.[34] An instance of excessive ('competitive') devaluation is detectable for the case of complementarity ($\sigma\phi < 1$) — in the other case ($\sigma\phi > 1$) the Home country enjoys the benefits of real appreciation, relative to the cooperative policy benchmark. Correspondingly, under Nash the movements in the real rate relative to the efficient allocation go in opposite directions in either country.

In the case of $\sigma\phi < 1$ — corresponding to excessive depreciation — Home output overshoots its flex-price level, so that the Home output gap is opportunistically understabilized in response to productivity shocks. In the case of $\sigma\phi > 1$ the Home output gap is instead overstabilized: by keeping output short of the flex-price level, the Home country can save on labor efforts and raise consumption utils by acquiring foreign goods (which are good substitutes for domestic ones) at better terms of trade. In either case, output gaps are not zero: because of the associated price dispersion and relative price misalignment, the Nash allocation is clearly welfare-dominated by price stability.

Figure I.5
Nash Gaps Following an Exogenous Decline in Home Markups

Similar patterns characterize the optimal response under Nash to a favorable markup shock in the Home economy, shown in Figure I.5. Both the Home and the Foreign monetary stances are inefficiently expansionary in response to such a shock, to a degree that varies across parameter configurations. With goods substitutability, the Home terms of trade depreciation causes Foreign output to fall. With goods complementarity, even though the Home terms of trade deviates by less with respect to the efficient allocation (thus depreciating by more), a stronger global demand drives up Foreign output. Conditional on markup shocks, the volatility of international prices is again higher in the latter case.

In either figure, observe that the difference between the two allocations is strikingly small. In welfare terms, the gains from cooperation are close

[34] Interestingly, De Paoli (2009) notes that, in a noncooperative equilibrium, a small country adopting a fixed exchange rate regime may increase its welfare, relative to regimes involving some degree of exchange rate flexibility. This is the case for a high enough elasticity of substitution.

to zero.[35] Indeed, the literature has presented numerical assessments of the benchmark model under complete markets which do not generate appreciable quantitative welfare gains from coordinating policies, relative to optimal stabilization pursued by independent policymakers (engaging in strategic manipulation of terms of trade). An important instance is Obstfeld and Rogoff (2002), who forcefully stress the limited size of welfare gains as a novel and independent argument feeding intellectual skepticism on the virtue of international policy coordination — supporting instead the principle of "keeping one's house in order" as the foundation for an efficient global economic order.

Yet the debate over the gains from policy coordination is far from settled. Gains may be significant in the presence of lack of commitment (see Cooley and Quadrini 2003) or inefficient shocks and real distortions, creating policy-relevant trade-offs which potentially enlarge the scope for policy conflicts above and beyond strategic terms of trade manipulation[36] — magnifying inefficiencies from strategic interaction (see, for instance, Pappa 2004 and Canzoneri et al. 2005).

Part II
Currency misalignments and cross-country demand imbalances

In the first part of this chapter, we analyzed complete-market economies in which optimal monetary policy redresses domestic nominal distortions implementing the flexible price allocation vis-á-vis efficient shocks, and by doing so it also corrects misalignments in the exchange rate — in its dual role of assets and goods price.[37] Relaxing the assumption of complete markets, we now study economies in which the flexible price allocation results in ineffi-

[35] In our calibration, in terms of steady-state consumption, the gains from cooperation are essentially zero for productivity, taste, and markup shocks. The gains of cooperation following markup shocks are about an order of magnitude bigger relative to the other two shocks, but always tiny. To wit, with $\phi = 1$ and no home bias, they amount to a mere 0.000263 percent of steady-state consumption.

[36] Admittedly, the literature has not (yet) settled on the question as of whether terms of trade manipulation as a principle driving monetary policy is empirically relevant. To some extent, this debate echoes the corresponding debate in the trade literature, concerning the empirical relevance of the "optimal tariff" argument.

[37] See e.g. the discussion in Devereux and Engel (2007), who develop a model with news shocks after Beaudry and Portier (2006).

cient levels of consumption and employment, both globally and within countries, as well as real currency misalignments, even when exchange rates only reflect fundamentals. These inefficiencies create relevant trade-offs for policymakers, raising issues about the extent to which monetary policy should lean again misalignments and global demand imbalances.

In what follows, we first focus on the analytically convenient case of financial autarky, and derive closed-form expressions characterizing the equilibrium allocation, the policy loss function, and the optimal targeting rules. In light of this intuition, we then delve into numerical analysis of economies where agents can borrow and lend internationally.

6 Macroeconomic interdependence under asset market imperfections

6.1 The natural allocation under financial autarky

The key consequence of asset market imperfections and frictions for monetary policy is that the flexible-price allocation does not generally coincide with the first-best allocation. To elaborate on this point, it is convenient to focus on the special case of financial autarky, for which a number of results can be derived analytically. In such a setup, households and firms do not have access to international borrowing or lending, nor to any other type of cross-border financial contracts; consequently, there is no opportunity to share risk across borders through asset diversification. As under complete markets, we proceed assuming that the distribution of wealth across agents is initially symmetric.

Barring international trade in assets, the value of domestic production has to be equal to the level of public and private consumption in nominal terms. By the same token, the inability to trade intertemporally with the rest of the world imposes that the value of aggregate imports should equal the value of aggregate exports. Using the definitions of terms of trade $\mathcal{T}_t$ and the real exchange rate $\mathcal{Q}_t$, we can rewrite the trade balance condition in terms of aggregate consumption and the real exchange rate in log-linear terms, similar to equation (31):

$$(2a_{\rm H}\phi - 1)\,\widetilde{\mathcal{Q}}_t = (2a_{\rm H} - 1)\left(\widetilde{C}_t - \widetilde{C}_t^*\right). \tag{59}$$

Proceeding as in Section 2, it is possible to show that under flexible prices, Home and Foreign output will obey the following relations:

$$(\eta+\sigma)\,\widetilde{Y}_{H,t} = (\sigma-1)\,(1-a_{\rm H})\,\widetilde{\mathcal{T}}_t + \eta\widehat{\zeta}_{Y,t} + \widehat{\zeta}_{C,t} + \widehat{\mu}_t \tag{60}$$

$$(\eta+\sigma)\,\widetilde{Y}_{F,t} = (\sigma-1)\,(1-a_{\rm H})\left(-\widetilde{\mathcal{T}}_t\right) + \eta\widehat{\zeta}^*_{Y,t} + \widehat{\zeta}^*_{C,t} + \widehat{\mu}^*_t, \tag{61}$$

whereas the terms of trade in turn can be written as a function of relative output:

$$(1-2a_{\rm H}\,(1-\phi))\,\widetilde{\mathcal{T}}_t = \widetilde{Y}_{H,t} - \widetilde{Y}_{F,t}. \tag{62}$$

Comparing these expressions with their first-best counterparts (32) and (33), it is clear that the transmission of shocks will generally be very different under financial autarky, depending on the values of preference parameters such as σ and ϕ. For instance, because of imperfect risk sharing, a shock that increases the relative supply of domestic output can now appreciate the terms of trade and the real exchange rate, for a low enough trade elasticity, i.e., for $\phi < \frac{2a_{\rm H}-1}{2a_{\rm H}}$.[38] Such appreciation would not be possible if markets were complete (see (33)).

6.2 Domestic and global implications of financial imperfections

As shown in the previous section of the chapter, with PCP and complete markets, markup shocks always move the economy away from the efficient allocation, creating welfare-relevant trade-offs between output and price stability. The same will obviously be true under financial autarky. Under financial autarky, however, the economy will generally be away from its first-best allocation also in response to efficient shocks.

The literature has paid attention to a few special but informative exceptions, whereas, despite imperfect capital markets, the flexible-price allocation is equal to the first-best allocation. This equivalence is possible by virtue of the mechanism discussed by Helpman and Razin (1978) and Cole and Obstfeld (1991): under some parameter configurations, terms of trade movements in response to shocks maintain the relative value of domestic to foreign output constant, automatically delivering risk insurance, even in the absence of trade in assets.[39]

[38] As discussed by Corsetti and Dedola (2005) and Corsetti, Dedola, and Leduc (2008a), for a sufficiently low ϕ, the possibility of multiple equilibria arises.

[39] Empirically, however, terms of trade fluctuations tend to be larger than relative output fluctuations. On the business cycle properties of terms of trade, see early evidence by Mendoza 1995.

The flexible-price allocation under financial autarky will be efficient if and only if the following condition holds:

$$\widetilde{\mathcal{D}}_t = \left[\sigma\left(\widetilde{C}_t - \widetilde{C}_t^*\right) - \widetilde{\mathcal{Q}}_t\right] - \left(\widehat{\zeta}_{C,t} - \widehat{\zeta}_{C,t}^*\right) = 0. \tag{63}$$

Expressing the endogenous variables in terms of relative output:

$$\widetilde{\mathcal{Q}}_t = (2a_{\mathrm{H}} - 1)\,\widetilde{\mathcal{T}}_t = \frac{2a_{\mathrm{H}} - 1}{1 - 2a_{\mathrm{H}}(1-\phi)}\left(\widetilde{Y}_{H,t} - \widetilde{Y}_{F,t}\right), \tag{64}$$

$$\left(\widetilde{C}_t - \widetilde{C}_t^*\right) = (2a_{\mathrm{H}}\phi - 1)\,\widetilde{\mathcal{T}}_t = \frac{2a_{\mathrm{H}}\phi - 1}{1 - 2a_{\mathrm{H}}(1-\phi)}\left(\widetilde{Y}_{H,t} - \widetilde{Y}_{F,t}\right), \tag{65}$$

and rearranging, (63) can be rewritten as:

$$\frac{\sigma(2a_{\mathrm{H}}\phi - 1) - (2a_{\mathrm{H}} - 1)}{1 - 2a_{\mathrm{H}}(1-\phi)}\left(\widetilde{Y}_{H,t} - \widetilde{Y}_{F,t}\right) - \left(\widehat{\zeta}_{C,t} - \widehat{\zeta}_{C,t}^*\right) = 0. \tag{66}$$

Clearly, this condition cannot be satisfied in the presence of both preference and technology shocks, when these are uncorrelated. In general, there is no parameter configuration for which the flexible-price allocation under financial autarky can be expected to coincide with the first best, even when all shocks are efficient.

The efficient and the financial autarky allocations can instead coincide for each efficient shock in isolation. Assuming technology shocks only, this would be the case when parameters satisfy the following:

$$\sigma\phi = 1 + \frac{1-\phi}{2a_{\mathrm{H}}\phi - 1}. \tag{67}$$

Note that, for $\phi = 1$ — the Cobb-Douglas aggregator of domestic and foreign goods — efficiency requires utility from consumption to be logarithmic ($\sigma = 1$) — the case of macroeconomic independence ($\sigma\phi = 1$). This parameter configuration has been amply analyzed by the monetary policy literature in an open economy, after its characterization by Corsetti and Pesenti (2001).

When the above condition is violated, in response to fundamental technology shocks, the terms of trade and the real exchange rate will be misaligned relative to the efficient allocation, even under flexible prices, while consumption will be suboptimally allocated across countries. A useful result follows from the fact that when $\sigma \geq 1$, the sign of deviations from the above equality indicates whether relative Home aggregate demand is too high or too low, relative to the efficient benchmark, in response to productivity gains in one country. Namely, in the face of positive technology shocks in the domestic economy, Home aggregate demand will be too high for $\phi \geq 1$, leading to a cross-country demand imbalance and domestic overheating — a term that in our context is defined as excessive demand and activity relative to the efficient equilibrium. It will be too low for $1 > \phi > \frac{2a_{\rm H} - 1}{2a_{\rm H}}$. Correspondingly, the real exchange rate misalignment will take the form of overvaluation or undervaluation, respectively.

For a large home bias in consumption, the case $\phi < \frac{2a_{\rm H} - 1}{2a_{\rm H}}$ also becomes relevant for our analysis. This case is extensively analyzed in Corsetti, Dedola, and Leduc (2008a) who characterize it as a "negative transmission:" a positive technology shock associated with excessive relative aggregate demand in the country experiencing it and real overvaluation — brought about by an *appreciation* of the country's real exchange rate.

The conditions under which the flex-price and the first-best allocation coincide are different in response to preference shocks. Writing out (66) in terms of these shocks only we have

$$[\sigma(2a_{\rm H}\phi - 1) - (2a_{\rm H} - 1)]\,[(\sigma + \eta)(1 - 2a_{\rm H}(1 - \phi)) - 2(1 - a_{\rm H})(\sigma - 1)] = 1. \tag{68}$$

Note that a necessary condition for the above equality to hold is

$$\sigma\phi \neq 1 + \frac{1 - \phi}{2a_{\rm H}\phi - 1},$$

implying that efficiency under preference shocks is incompatible with efficiency under technology shocks (see (67)). In general, as for the case of technology shocks, the sign of the deviation from the above equality indicates whether relative aggregate demand is too high or too low in one country, with respect to the efficient benchmark, leading to a cross-country demand imbalance and domestic overheating under a policy of strict price stability that reproduces the flex-price allocation.

6.3 Optimal policy: trading off inflation with demand imbalances and misalignments

We now proceed to characterize optimal monetary policy in economies with incomplete markets *and* nominal rigidities — focusing on the case of PCP. Under financial autarky and PCP, the NK Phillips curves for the Home and

Foreign GDP deflator inflation are:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)} \left\{ \begin{array}{c} (\eta+\sigma)\left(\widehat{Y}_{H,t} - \widetilde{Y}^{fb}_{H,t}\right) + \widehat{\mu}_t + \\ -(1-a_{\mathrm{H}}) \cdot \left[2a_{\mathrm{H}}(\sigma\phi-1)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}^{fb}_t\right) - \widehat{\mathcal{D}}_t\right] \end{array} \right\} \quad (69)$$

$$\pi^*_{F,t} = \beta E_t \pi^*_{F,t+1} + \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\theta\eta)} \left\{ \begin{array}{c} (\eta+\sigma)\left(\widehat{Y}_{F,t} - \widetilde{Y}^{fb}_{F,t}\right) + \widehat{\mu}^*_t + \\ +(1-a_{\mathrm{H}}) \cdot \left[2a_{\mathrm{H}}(\sigma\phi-1)\left(\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}^{fb}_t\right) - \widehat{\mathcal{D}}_t\right] \end{array} \right\}.$$

With incomplete markets, the last term $\widehat{\mathcal{D}}_t$ will generally not be zero, responding to fundamental shocks.

The monetary policy trade-offs associated with financial autarky and PCP are synthesized by the following flow loss function, derived under the standard assumptions of cooperation and an efficient nonstochastic steady-state:

$$\ell^{FA-PCP} \ltimes -\frac{1}{2} \left\{ \begin{array}{c} (\sigma+\eta)\left(\widetilde{Y}^{fb}_{H,t} - \widehat{Y}_{H,t}\right)^2 + (\sigma+\eta)\left(\widetilde{Y}^{fb}_{F,t} - \widehat{Y}_{F,t}\right)^2 + \\ \frac{\theta\alpha(1+\theta\eta)}{(1-\alpha\beta)(1-\alpha)}\pi^2_{H,t} + \frac{\theta\alpha^*(1+\theta\eta)}{(1-\alpha^*\beta)(1-\alpha^*)}\pi^{*2}_{F,t} + \\ -2a_{\mathrm{H}}(1-a_{\mathrm{H}})(\sigma\phi-1)(1-2a_{\mathrm{H}}(1-\phi))\left(\widetilde{\mathcal{T}}^{fb}_t - \widehat{\mathcal{T}}_t\right)^2 + \\ \frac{2a_{\mathrm{H}}(1-a_{\mathrm{H}})(\phi-1)}{\sigma(2a_{\mathrm{H}}\phi-1)-(2a_{\mathrm{H}}-1)} \left[\underbrace{(\sigma(2a_{\mathrm{H}}\phi-1)-(2a_{\mathrm{H}}-1))\widehat{\mathcal{T}}_t - \left(\widehat{\zeta}_{C,t} - \widehat{\zeta}^*_{C,t}\right)}_{\widehat{\mathcal{D}}_t} \right]^2 \end{array} \right\}. \quad (70)$$

The loss function under financial autarky differs from its counterpart with complete markets (40) in two respects. First, the coefficient on the terms of trade gap has an additional term, because of the different equilibrium relation between relative output and international relative prices, dictated by the requirement of a balanced trade. Second, in addition to deviations from the efficient level of domestic output and the terms of trade, the loss function also depends on the deviations from the efficient cross-country allocation of aggregate demand, $\widehat{\mathcal{D}}_t$. In general, the objective function thus includes well-defined trade-offs among policy objectives that are specific to heterogeneous agent economies: strict inflation targeting will not be optimal, even in response to efficient shocks.

Taking, as before, a timeless perspective, the optimal cooperative policy is characterized by the following first-order conditions for inflation:

$$\pi_{H,t} \quad : \quad 0=-\theta\frac{\alpha\left(1+\theta\eta\right)}{\left(1-\alpha\beta\right)\left(1-\alpha\right)}\pi_{H,t}-\gamma_{H,t}+\gamma_{H,t-1} \tag{71}$$

$$\pi^*_{F,t} \quad : \quad 0=-\theta\frac{\alpha^*\left(1+\theta\eta\right)}{\left(1-\alpha^*\beta\right)\left(1-\alpha^*\right)}\pi^*_{F,t}-\gamma^*_{F,t}+\gamma^*_{F,t-1},$$

where $\gamma_{H,t}$ and $\gamma^*_{H,t}$ are the multipliers on the Phillips curves — whose lags appear reflecting the assumption of commitment — and for output

$$\begin{aligned}\widehat{Y}_{H,t} \quad : \quad & 0=\left(\sigma+\eta\right)\left(\widetilde{Y}^{fb}_{H,t}-\widehat{Y}_{H,t}\right)-2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\left(\widetilde{\mathcal{T}}^{fb}_t-\widehat{\mathcal{T}}_t\right) \\ & -\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\phi-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\widehat{\mathcal{D}}_t+ \\ & -\frac{\left(1-\alpha\beta\right)\left(1-\alpha\right)}{\alpha\left(1+\theta\eta\right)}\left[\sigma+\eta-\frac{\left(1-a_{\mathrm{H}}\right)\left(\sigma-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\right]\gamma_{H,t}+ \\ & +\frac{\left(1-\alpha^*\beta\right)\left(1-\alpha^*\right)}{\alpha^*\left(1+\theta\eta\right)}\frac{\left(1-a_{\mathrm{H}}\right)\left(\sigma-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\gamma^*_{F,t},\end{aligned} \tag{72}$$

$$\begin{aligned}\widehat{Y}_{F,t} \quad : \quad & 0=\left(\sigma+\eta\right)\left(\widetilde{Y}^{fb}_{F,t}-\widehat{Y}_{F,t}\right)+2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\left(\widetilde{\mathcal{T}}^{fb}_t-\widehat{\mathcal{T}}_t\right)+ \\ & +\frac{2a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\phi-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\widehat{\mathcal{D}}_t+ \\ & -\frac{\left(1-\alpha\beta\right)\left(1-\alpha\right)}{\alpha\left(1+\theta\eta\right)}\frac{\left(1-a_{\mathrm{H}}\right)\left(\sigma-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\gamma_{H,t}+ \\ & -\frac{\left(1-\alpha^*\beta\right)\left(1-\alpha^*\right)}{\alpha^*\left(1+\theta\eta\right)}\left[\sigma+\eta-\frac{\left(1-a_{\mathrm{H}}\right)\left(\sigma-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\right]\gamma^*_{F,t},\end{aligned}$$

whereas we have used the fact that both terms of trade $\widehat{\mathcal{T}}_t$ and $\widehat{\mathcal{D}}_t$ are linear functions of relative output.

Summing up and taking the difference of the first-order conditions, optimal policy could be expressed implicitly in terms of a global targeting rule that is identical to the one derived under complete markets and PCP (43):

$$\begin{aligned}0 \quad = \quad & \left[\left(\widehat{Y}_{H,t}-\widetilde{Y}^{fb}_{H,t}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}^{fb}_{H,t-1}\right)\right]+\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}^{fb}_{F,t}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}^{fb}_{F,t-1}\right)\right] \\ & +\theta\left(\pi_{H,t}+\pi^*_{F,t}\right)\end{aligned} \tag{73}$$

and the following cross-country rule:

$$
\begin{aligned}
0 \quad = \quad & (\sigma+\eta)\left\{ \begin{array}{c} \left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)\right]-\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}_{F,t-1}^{fb}\right)\right] \\ +\theta\left(\pi_{H,t}-\pi_{F,t}^{*}\right) \end{array} \right\} \\
& 4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\left[\begin{array}{c} \left[\left(\widehat{\mathcal{T}}_{t}-\widetilde{\mathcal{T}}_{t}^{fb}\right)-\left(\widehat{\mathcal{T}}_{t-1}-\widetilde{\mathcal{T}}_{t-1}^{fb}\right)\right] \\ -\dfrac{(\sigma-1)}{2a_{\mathrm{H}}\left(\sigma\phi-1\right)}\dfrac{\theta}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\left(\pi_{H,t}-\pi_{F,t}^{*}\right) \end{array} \right]+ \\
& \frac{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\phi-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\left(\widehat{\mathcal{D}}_{t}-\widehat{\mathcal{D}}_{t-1}\right)
\end{aligned} \tag{74}
$$

$$
\begin{aligned}
0 \quad = \quad & (\sigma+\eta)\left\{ \begin{array}{c} \left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)\right]-\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}_{F,t-1}^{fb}\right)\right] \\ +\theta\left(\pi_{H,t}-\pi_{F,t}^{*}\right) \end{array} \right\} \\
& 4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\sigma\phi-1\right)\left[\begin{array}{c} \left[\left(\widehat{\mathcal{T}}_{t}-\widetilde{\mathcal{T}}_{t}^{fb}\right)-\left(\widehat{\mathcal{T}}_{t-1}-\widetilde{\mathcal{T}}_{t-1}^{fb}\right)\right] \\ -\dfrac{(\sigma-1)}{2a_{\mathrm{H}}\left(\sigma\phi-1\right)}\dfrac{\theta}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\left(\pi_{H,t}-\pi_{F,t}^{*}\right) \end{array} \right]+ \\
& \frac{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\phi-1\right)}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\left(\widehat{\mathcal{D}}_{t}-\widehat{\mathcal{D}}_{t-1}\right)
\end{aligned} \tag{75}
$$

Comparing this expression to the targeting criterion derived under complete markets (44), observe that only the first two terms in output gaps and inflation differentials are identical. In line with the differences already pointed out in our discussion of the loss functions, the incomplete markets rule depends on an additional term in $\widehat{\mathcal{D}}_t$, and the coefficient of the term in relative prices and inflation differentials reflects misalignments due to balanced trade. Because of these misalignments, even under the special conditions implying no misallocation in cross-country demand ($\widehat{\mathcal{D}}_t = 0$), the trade-off between relative inflation and relative prices will generally not be proportional to that between relative output gaps and relative inflation in the face of either supply or demand shocks (either (67) or (68)).

Useful insights on the international dimensions of the monetary policy trade-offs can be gained by comparing the above targeting rules under incomplete markets and PCP with the ones derived under complete markets and LCP — emphasized by the literature as a case where the deviation from the divine coincidence is specifically motivated by openness-related distortions (nominal rigidities in the import sectors). For the sake of tractability, we carry out this comparison imposing the simplifying assumption $\eta = 0$.

We first rewrite the above decentralized targeting rule (74) replacing the terms of trade with the real exchange rate:

$$
\begin{aligned}
0 \quad = \quad & \left\{ \begin{array}{c} \left[\left(\widehat{Y}_{H,t}-\widetilde{Y}^{fb}_{H,t}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}^{fb}_{H,t-1}\right)\right]-\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}^{fb}_{F,t}\right)-\left(\widehat{Y}_{F,t-1}-\widetilde{Y}^{fb}_{F,t-1}\right)\right] \\ +\dfrac{\theta}{\sigma}\dfrac{1}{1-2a_{\mathrm{H}}\left(1-\phi\right)}\left[2a_{\mathrm{H}}\left(\sigma\phi-1\right)-\left(\sigma-2\right)\right]\left(\pi_{H,t}-\pi^{*}_{F,t}\right) \end{array} \right\} \quad (76) \\
& \frac{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)}{2a_{\mathrm{H}}-1}\left(\frac{\sigma\phi-1}{\sigma}\right)\left[\left(\widehat{\mathcal{Q}}_{t}-\widetilde{\mathcal{Q}}^{fb}_{t}\right)-\left(\widehat{\mathcal{Q}}_{t-1}-\widetilde{\mathcal{Q}}^{fb}_{t-1}\right)\right]+ \\
& \frac{4a_{\mathrm{H}}\left(1-a_{\mathrm{H}}\right)\left(\phi-1\right)}{\sigma\left[1-2a_{\mathrm{H}}\left(1-\phi\right)\right]}\left(\widehat{\mathcal{D}}_{t}-\widehat{\mathcal{D}}_{t-1}\right)
\end{aligned}
$$

as to make it directly comparable with the analogous targeting rule with LCP and complete markets (**??**). Looking at the two expressions, it is apparent that in either case optimal monetary policy has an international dimension: domestic goals (inflation and output gaps) are traded off against the stabilization of external variables. These external variables include the real exchange rate and, for the economy under financial autarky, the demand gap. However, at least two differences stand out. The first one concerns the coefficients of similar terms. In the economy with complete markets and LCP, the coefficients of the inflation term and the real exchange rate gap are $\theta > 0$ and $\sigma > 0$, respectively. In the economy analyzed in this section, the corresponding coefficients also depend on the degree of home bias a_{H} and on the elasticities σ and ϕ, and can have either sign. This confirms the idea that openness and elasticities are likely to play a key role in shaping policy trade-offs in open economies when markets are incomplete.

The second difference concerns the implications of the new term $\widehat{\mathcal{D}}_t$ capturing demand imbalances, which, recalling that $\widetilde{\mathcal{D}}^{fb}_t = 0$, could be decomposed into two components, the terms of real exchange rate misalignments and cross-country consumption gaps:

$$
\widehat{\mathcal{D}}_t - \widetilde{\mathcal{D}}^{fb}_t = \sigma\left(\left(\widehat{C}_t - \widetilde{C}^{fb}_t\right) - \left(\widehat{C}^{*}_t - \widetilde{C}^{*fb}_t\right)\right) - \left(\widehat{\mathcal{Q}}_t - \widetilde{\mathcal{Q}}^{fb}_t\right).
$$

In our analysis of the economy with LCP and complete markets, we have seen that, if $\eta = 0$, we can write the trade-off with relative (CPI) inflation *either* in terms of the cross-country consumption gap, *or* in terms of the real exchange rate misalignment — these are proportional to each other. A similar result does not arise with incomplete markets, since, in this case, real exchange rate misalignments depend on both the cross-country consumption gaps, and the output gap differentials as follows:

$$4(1-a_{\rm H})\,a_{\rm H}\phi\sigma\left(\widehat{\mathcal{Q}}_t-\widetilde{\mathcal{Q}}_t^{fb}\right)=(2a_{\rm H}-1)\,\sigma\left[\begin{array}{c}\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)\\-(2a_{\rm H}-1)\left(\left(\widehat{C}_t-\widetilde{C}_t^{fb}\right)-\left(\widehat{C}_t^{*}-\widetilde{C}_t^{*fb}\right)\right)\end{array}\right].$$

Hence, the non-inflation terms in the targeting rule (76) are always a function of both components of the demand gap. The intuition for such a difference is straightforward: in contrast to the case of complete markets, closing the real exchange rate misalignments under financial autarky does not automatically redress the relative consumption gap, thus posing a trade-off for optimal monetary policy.

Further insights can be gained by combining the target criteria, rewriting them in terms of decentralized rules specific to each country — again for $\eta = 0$. Focusing on the Home country, the decentralized rule in the incomplete-market, PCP economy is:

$$\begin{aligned}0 \;=\;& \theta\pi_{H,t}+\left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)\right]+\\&\frac{1/2}{2(1-a_{\rm H})-\sigma(1-2a_{\rm H}\phi)}\left[\begin{array}{c}4a_{\rm H}(1-a_{\rm H})(\sigma\phi-1)(1-2a_{\rm H}(1-\phi))+\\\left(4(1-a_{\rm H})a_{\rm H}\phi\sigma+(2a_{\rm H}-1)^2\right)(2a_{\rm H}(2-\phi(1+\sigma))+(\sigma-1))\end{array}\right].\\&\sigma^{-1}\left[\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}_t^{fb}\right)-\left(\widehat{\mathcal{T}}_{t-1}-\widetilde{\mathcal{T}}_{t-1}^{fb}\right)\right]+\\&\frac{1/2}{2(1-a_{\rm H})-\sigma(1-2a_{\rm H}\phi)}\left[\begin{array}{c}4a_{\rm H}(1-a_{\rm H})(\phi-1)+\\(2a_{\rm H}-1)(2a_{\rm H}(2-\phi(1+\sigma))+(\sigma-1))\end{array}\right]\sigma^{-1}\left(\widehat{\mathcal{D}}_t-\widehat{\mathcal{D}}_{t-1}\right)\end{aligned}$$

It is useful to write out the corresponding rule under complete markets and LCP as follows:

$$\begin{aligned}0 \;=\;& \theta\left(a_{\rm H}\pi_{H,t}+(1-a_{\rm H})\pi_{F,t}\right)+\left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)-\left(\widehat{Y}_{H,t-1}-\widetilde{Y}_{H,t-1}^{fb}\right)\right]+\\&-(1-a_{\rm H})\,2a_{\rm H}(\sigma-1)\,\sigma^{-1}\left(\widehat{\Delta}_t-\widehat{\Delta}_{t-1}\right)+\\&-(1-a_{\rm H})(2a_{\rm H}(\sigma-1)+1)\,\sigma^{-1}\left[\left(\widehat{\mathcal{T}}_t-\widetilde{\mathcal{T}}_t^{fb}\right)-\left(\widehat{\mathcal{T}}_{t-1}-\widetilde{\mathcal{T}}_{t-1}^{fb}\right)\right].\end{aligned}$$

Comparing the two expressions above, it is apparent that optimal monetary policy trades off output gaps and inflation against the stabilization of the terms of trade, and either deviations from the law of one price for the LCP complete-market economy, or the demand gap for the economy under financial autarky and PCP. Interestingly, however, these trade-offs are shaped by different parameters, particularly concerning the coefficients multiplying the external variable objectives, which can be quite large in the financial autarky economy, particularly under parameterizations for which $\sigma(1-2a_{\rm H}\phi)$ is close to $2(1-a_{\rm H})$ in value. This suggests that the trade-offs with external variables related to incomplete market distortions can be significant, compared to the ones related to multiple nominal distortions, as thoroughly investigated in related work of ours (Corsetti, Dedola, and Leduc 2009b).

To conclude our analysis, it is worth commenting on the optimal policy under a special parameterization of the model assuming log utility and a Cobb-Douglas consumption aggregator, that is, $\sigma = \phi = 1$, recurrent in the literature after Corsetti and Pesenti (2005). Using our analytical results, it is easy to verify that, under PCP, the expressions for the target criteria under financial autarky and complete markets coincide, without however implying the same allocation outcomes. The reason for the discrepancy in allocations is that, while the two targeting criteria are formally identical, the welfare-relevant output gaps behave differently across the two market structures. As already shown above, under financial autarky and $\sigma = \phi = 1$ the flexible price allocation is only efficient in response to productivity shocks, not to preference shocks.

To wit, using the Phillips curves, it is easy to verify that, if $\sigma = \phi = 1$, keeping inflation at zero in response to preference shocks implies inefficient output gaps:

$$\begin{aligned}(1+\eta)\left[\left(\widehat{Y}_{H,t}-\widetilde{Y}_{H,t}^{fb}\right)\right] &= (1-a_{\rm H})\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right), \\ (1+\eta)\left[\left(\widehat{Y}_{F,t}-\widetilde{Y}_{F,t}^{fb}\right)\right] &= (1-a_{\rm H})\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right),\end{aligned} \tag{77}$$

whereas by (66)), under the relevant parameterization, $\widehat{\mathcal{D}}_t$ is equal to the negative of the preference shock differential $\left(\widehat{\zeta}_{C,t}-\widehat{\zeta}_{C,t}^{*}\right)$, and thus is independent of policy. Inefficient output gaps in turn translate into terms of trade and real exchange rate misalignments. Namely, under financial autarky, (62) implies that a positive Home output differential — whatever its origin — cannot but weaken the country's terms of trade. Conversely, in the first-best allocation, a positive Home output differential resulting from a shock to Home preferences is associated with stronger Home terms of trade — since the terms of trade also respond directly to such a shock:

$$\widetilde{\mathcal{T}}_t^{fb} = \left(\widetilde{Y}_{H,t}^{fb}-\widetilde{Y}_{F,t}^{fb}\right)-(2a_{\rm H}-1)\,\widehat{\zeta}_{C,t} = -\frac{\eta}{1+\eta}(2a_{\rm H}-1)\,\widehat{\zeta}_{C,t}.$$

In light of (**??**), it immediately follows that the resulting misalignment is of the same sign as the preference shocks:

$$\widehat{\mathcal{T}}_t - \widetilde{\mathcal{T}}_t^{fb} = \frac{1}{1+\eta}\left[1+\eta\left(2a_{\mathrm{H}}-1\right)\right]\widehat{\zeta}_{C,t}.$$

As stressed by Devereux (2004), even though the exchange rate would respond to fundamental shocks, acting as a shock absorber, it will not foster an efficient allocation.

Thus, a monetary stance geared to implementing the flexible price allocation in response to *all* efficient shocks cannot be optimal, as is the case with complete markets. On the contrary, the optimal policy will respond similarly to preference shocks as it does to markup shocks— accommodating them in relation to the degree of openness of the economy.[40]

6.4 International borrowing and lending

The analytical results derived for the case of financial autarky provide an effective interpretive key to study economies with trade in some assets. Figure I.4 showa impulse responses to shocks to preferences under the optimal policy. The figures contrast, under PCP, the financial-autarky economy characterized above with an economy in which households can trade internationally a noncontingent bond denominated in Home currency.

Figure II.1
Home Preference Shock and Optimal Policy under Alternative Financial Structures

Consider first the response to a positive shock to Home preferences for current consumption. In a first best allocation, such a shock would tend to increase both Home and Foreign output in relation to openness, and have a direct effect on international prices, causing a Home real appreciation. There would be no demand imbalance. The extent of inefficiencies in the incomplete-market economies is apparent from Figure II.1. Whether or not international borrowing and lending is possible, the optimal policy has to

[40]Note that, under the relevant parameterization, the terms of trade drop out of the loss function: monetary authorities trade off output gap and inflation stabilization only. Nonetheless, the optimal policy does redress — at least in part — the misalignments in relative prices. As explained above, under financial autarky international price misalignments result from the fact that the terms of trade only respond to output differentials, according to (62). Since the optimal policy at Home and abroad moves to close domestic output gaps — the monetary stance has the opposite sign in the two countries — this joint action tends to contain output differentials, and hence the suboptimal real depreciation.

trade off competing domestic and external goals. As a result, the output gap is positive in the Home country, negative in the Foreign country. The excessive differential in outputs across countries maps into misalignments in international prices: the real exchange rate and thus the terms of trade are inefficiently weak. The demand gap is overall negative, pointing to a negative imbalance — at the current real exchange rate — in relative Home consumption. This is in turn mirrored by an inefficiently high level of real net exports. Note that, by pursuing a tighter Home monetary stance, relative to the stance consistent with the efficient allocation, the Home monetary authorities react to the misalignment and the negative demand imbalances. The optimal policy aims at containing the differences in output gaps and strengthening the Home real exchange rate, thus reducing the relative demand gap at the cost of some negative GDP inflation (positive in the Foreign country).

The qualitative responses in the figure are the same across market structures, particularly concerning the monetary stance. Introducing borrowing and lending does not change the fundamental transmission channels through which optimal policy redresses the inefficiencies in the economy. It is worth stressing that these channels affect the fundamental valuation of output via relative price adjustment — rather than involving any systematic attempt to manipulate the ex post value of nominal bonds via inflation and depreciation, as to make returns contingent on the state of the economy.[41]

However, the size of the deviations from the first best allocation is substantially smaller in the bond economy. This reflects the fact that, under the adopted parameterization, international trade in bonds allows households to self insure against temporary shocks, thus limiting the deviations from the first-best in the incomplete market economy with flexible prices.[42] Yet, even in this economy, the optimal policy can still achieve a welfare-improving allocation by trading off some movements in inflation and output gaps for smaller movements in currency misalignments and demand gaps.

[41] The empirical role of valuation effects in the international adjustment has been analyzed by Gourinchas and Rey (2007) and Lane and Milesi-Ferretti (2004), among others. The interactions between these effects and monetary policy, within incomplete market framework and endogenous portfolio decisions, is an important topic for future research.

[42] For a discussion of the risk-insurance properties of international trade in bonds with temporary and permanent shocks see Baxter and Crucini (1995).

6.5 Discussion

In this section of this chapter, we have argued that incomplete asset markets create new and potentially important policy trade-offs, in line with the notion that misalignments can and are likely to arise independently of nominal and monetary distortions, and that frictions in financial markets lead to cross-country demand imbalances.[43] In the economies discussed above, the optimal policy consists of reacting to shocks to correct consumption and employment both within and across borders, typically addressing overappreciation and underappreciation of exchange rates.

Optimal monetary policy in open-economy models with incomplete markets is the subject of a small but important strand of the literature. Among these contributions, we have already mentioned Devereux (2004), who builds an example of economies under financial autarky hit by demand shocks in which, even when the exchange rate is a fundamental shock absorber, it may in fact be better to prevent exchange rate adjustment altogether.[44] The reason is the same as the one discussed above: with incomplete international financial markets, the flexible-price allocation is inefficient. Under PCP, Benigno (2009) finds large gains accruing from cooperative policies relative to the flexible price allocation in economies whereby the nonstochastic steady-state is assumed to be asymmetric because of positive net foreign asset holdings by one country.[45] Similar to the analysis in this chapter, the working paper version of this paper, Benigno (2001), characterizes welfare differences between cooperative policies and the flexible price allocation in economies with incomplete markets but no steady-state asymmetries. Benigno (2001, 2009), however, assumes purchasing power parity, hence abstracts from misalignments which are instead central to more recent contributions.[46]

Welfare costs from limited international asset trade are discussed by Devereux and Sutherland (2008), who posit a model in which markets are effectively complete under flexible prices and with no random elements in

[43] See, e.g., Lahiri, Singh, and Vegh (2007) for a model studing optimal exchange rate regimes with segmented asset markets under flexible prices.

[44] A long-standing view is that the exchange rate may be driven by non-fundamental, see, e.g., Jeanne and Rose (2002) and Bacchetta and Van Wincoop (2006).

[45] For an early contribution on the topic, see Dellas (1988).

[46] Other contributions have looked at the optimal policy in a small open-economy, incomplete markets framework — see, e.g., De Paoli (2009b). A related literature focuses on optimized simple rules. In Kollmann (2002), for instance, exchange rate volatility is driven by exogenous shocks to the model's uncovered interest parity (UIP) relation: a policy of complete currency stabilization that eliminates these shocks would be optimal for very open economies, but not for the kind of relatively less open economies we study.

monetary policy. In their analysis, strict inflation targeting also closes misalignments and attains the efficient allocation vis-à-vis technology shocks — in accord with the results in the first part of the chapter. In Corsetti, Dedola, and Leduc (2009b), we reconsider the same issue in standard open macro models with incomplete markets, pointing out that inward-looking monetary policies like strict inflation targeting may well result in (rather than correcting) misalignments in exchange rates. We characterize monetary policy trade-offs arising in incomplete-market economies, identifying conditions under which optimal monetary policy redresses these inefficiencies, achieving significant welfare gains. The size or even the sign of the gaps in relative demand and international prices shaping policy trade-offs in open economies can vary significantly with the values of preference parameters such as σ and ϕ, the degree of openness, the nature and persistence of shocks, and especially the structure of financial markets.

7 Conclusions

This chapter has addressed the question of how optimal monetary policy should be conducted in interdependent open economies, proposing a unified analytical framework to systematize the existing literature, and pointing to new directions of research.

According to received wisdom, the answer to our question is that macroeconomic interdependence is relevant to the optimal monetary conduct only to the extent that it affects domestic output gaps and inflation. Therefore, the optimal policy prescriptions are the same as the ones derived in the baseline monetary model abstracting from openness and can be readily applied in terms of the same targeting rules in output gaps and GDP inflation. As shown in this chapter, however, such answer turns out to be a good guide to policy making only under two key special conditions — a high responsiveness of import prices to the exchange rate, and frictionless international financial markets supporting the efficiency of the flexible price allocation. Under general conditions, optimal policy instead does require policy makers to trade offs domestic and external gaps, i.e., to redress misalignments in international relative prices and cross-country demand imbalances.

Stressing the empirical evidence questioning a high responsiveness of import prices to the exchange rate, a large body of literature explores the policy implications of stickiness in the price of imports in local currency. In this case, there is an optimal trade off between output gaps and misalignments in domestic and international relative prices induced by multiple nominal distortions. The focus of policymakers naturally shifts from GDP deflator inflation, to CPI inflation, and onto real exchange rate stabilization, containing deviations from the law of one price.

Similarly, trade-offs between output gaps and the terms of trade emerge when policymakers do not internalize international monetary spillovers, and engage in cross-country strategic interactions. Reflecting traditional models of competitive devaluation, the modern paradigm emphasizes the incentives for national policymakers to manipulate the terms of trade to raise national welfare, that arise in the absence of international policy coordination.

But, in addition to the two cases above extensively discussed in the literature, a third important source of policy trade-offs with an international dimension are induced by financial imperfections. Key lessons for monetary policy analysis can be learnt from models in which asset markets do not support the efficient allocation — in line with the notion that misalignments can occur independently of nominal and monetary distortions, and indeed can be expected to occur per effects of large distortions in financial markets.

Our analysis focuses on standard open-economy models where restrictions to cross-border trade in assets result in significant misallocation of consumption and employment within countries, associated with international demand imbalances and exchange rate misalignments. Although the exchange rate responds to fundamentals, acting as a "shock absorber", currency misalignments contribute to drive a wedge between the efficient and the market outcomes, globally and domestically. Optimal monetary policy thus should target a combination of inward-looking variables such as output gap and inflation, with currency misalignment and cross-country demand misallocation, by leaning against the wind of misaligned exchange rates and international imbalances.

This analysis points to largely unexplored areas of research, focusing on the design of monetary policy in models with explicit financial distortions as a complement or an alternative to what we have done in this chapter. From an open-economy perspective, the goal is to foster the understanding of the inherent link between financial distortions and misalignments, wealth and demand imbalances, which distort market outcomes both within and across countries, and thus have potentially important implications for the optimal design of monetary policies.

References

[1] Adao, Bernardino, Isabel Correia, and Pedro Teles, "On the relevance of exchange rate regimes for stabilization policy," *Journal of Economic Theory*, 144(4): 1468-1488 (2009).

[2] Aoki, Kosuke, "Optimal Monetary Policy Response to Relative Price Changes," *Journal of Monetary Economics* 48: 55-80 (2001).

[3] Atkeson, Andrew, and Ariel Burstein, "Pricing to Market, Trade Costs, and International Relative Prices," *American Economic Review*.98(5): 1998-2031 (2008).

[4] Bacchetta, Philippe, and Eric Van Wincoop, "A Theory of the Currency Denomination of International Trade," *Journal of International Economics* 67(2): 295-319 (2005).

[5] Bacchetta, Philippe, and Eric Van Wincoop, "Can information heterogeneity explain the exchange rate determination puzzle?" *American Economic Review* 96(3): 552-576 (2006).

[6] Backus, David K., Patrick J. Kehoe, and Finn E. Kydland "Dynamics of the Trade Balance and the Terms of Trade: The J Curve?" *American Economic Review 82* 84(1): 864-88 (1994).

[7] Ball, Laurence, "Has Globalization Changed Inflation?" NBER working paper no.12687 November 2006.

[8] Baxter, Marianne,. and Mario J. Crucini, "Business cycles and the asset structure of foreign trade," *International Economic Review* 36(4): 821-854 (1995).

[9] Bean, Charles, "Globalisation and Inflation," *World Economics* 8(1): 57-73 (2007).

[10] Beaudry, Paul, and Franck Portier, "Stock Prices, News, and Economic Fluctuations," *American Economic Review* 96(4): 1293-1307.(2006).

[11] Benigno, Pierpaolo, "Optimal Monetary Policy in a Currency Area," *Journal of International Economics* 63 (2): 293-320 (2004).

[12] Benigno, Pierpaolo, "Price Stability with Imperfect Financial Integration," *Journal of Money, Credit and Banking* 41: 121-149.(2009).

[13] Benigno, Pierpaolo, "Price Stability with Imperfect Financial Integration," CEPR discussion paper no. 2854, May 2001.

[14] Benigno, Gianluca, and Pierpaolo Benigno, "Price Stability in Open Economies," *Review of Economic Studies* 70: 743-764 (2003).

[15] Benigno, Gianluca, and Pierpaolo Benigno, "Designing Targeting Rules for International Monetary Policy Cooperation," *Journal of Monetary Economics* 53 (4): 473-506 (2006).

[16] Benigno, Pierpaolo, and Michael Woodford, "Linear-Quadratic Approximation of Optimal Policy Problems," NBER working paper no. 12672, November 2006 (revised 2008).

[17] Bergin, Paul R., and Robert C. Feenstra, "Staggered price setting, translog preferences, and endogenous persistence," *Journal of Monetary Economics* 45(3): 657-680 (2000).

[18] Betts, Caroline, and Michael B. Devereux, "Exchange Rate Dynamics in a Model of Pricing-to-Market," *Journal of International Economics* 50 (1): 215-244 (2000).

[19] Bilbiie, Florin, Fabio Ghironi, and Marc J. Melitz, "Monetary Policy and Business Cycles with Endogenous Entry and Product Variety," *NBER Macroeconomics Annual* 2007.

[20] Blanchard, Olivier, and Jordi Galí, "Real Wage Rigidities and the New Keynesian Model," *Journal of Money, Credit and Banking* 39(1): 35-65 (2007).

[21] Broda, Christian, "Exchange Rate Regimes and National Price Levels," *Journal of International Economics* 70(1): 52-81 (2006).

[22] Burstein, Ariel, Martin S. Eichenbaum, and Sergio Rebelo, "Modeling Exchange Rate Pass Through After Large Devaluations," *Journal of Monetary Economics* 54(2): 346-368 (2007).

[23] Burstein, Ariel, Martin S. Eichenbaum, and Sergio Rebelo, "Large Devaluations and the Real Exchange Rate," *Journal of Political Economy* 113(4): 742-784 (2005).

[24] Campa, José Manuel, and Linda Goldberg, "Exchange Rate Pass Through into Import Prices", *Review of Economics and Statistics* 87(4): 679-690 (2005)

[25] Canzoneri, Matthew B., and Dale W. Henderson, *Monetary Policy in Interdependent Economies*, MIT press, 1991.

[26] Canzoneri, Matthew B., Robert Cumby, and Behzad Diba, "The Need for International Policy Coordination: What's Old, What's New, What's Yet to Come?", *Journal of International Economics* 66: 363-384 (2005).

[27] Chang, Roberto, and Andrés Velasco, "Monetary Policy and the Currency Denomination of Debt: A Tale of Two Equilibria," *Journal of International Economics* 69: 150-175 (2006).

[28] Chari, V.V., Patrick J. Kehoe, and Ellen McGrattan, "Can Sticky Prices Generate Volatile and Persistent Real Exchange Rates?," *Review of Economic Studies* 69: 633-63 (2002).

[29] Chinn, Menzie D., *Empirical Exchange Rate Economics: Estimation and Implications*, Cambridge University Press, forthcoming 2010.

[30] Clarida, Richard, "Reflections on Monetary Policy in the Open Economy," in J. Frankel and C. Pissarides, eds., *NBER International Seminar on Macroeconomics 2008*, NBER Books, National Bureau of Economic Research, 2009.

[31] Clarida, Richard, Jordi Galí, and Mark Gertler, "A simple framework for international policy analysis," *Journal of Monetary Economics* 49: 879–904 (2002).

[32] Coenen, Gunter, Giovanni Lombardo, Frank Smets, and Roland Straub, "International Transmission and Monetary Policy Cooperation," in J. Galí and M. Gertler, eds., *International Dimensions of Monetary Policy,* University of Chicago Press, 2009.

[33] Cole, Harold L., and Maurice Obstfeld, "Commodity Trade and International Risk Sharing: How Much Do Financial Markets Matter?" *Journal of Monetary Economics* 28: 3-24 (1991).

[34] Cooley, Thomas F., and Vincenzo Quadrini, "Common Currencies vs. Monetary Independence," *Review of Economic Studies* 70(4): 785-806 (2003).

[35] Corsetti, Giancarlo, "Openness and the case for flexible exchange rates," *Research in Economics* 60: 1-21 (2006).

[36] Corsetti, Giancarlo, and Luca Dedola, "Macroeconomics of International Price Discrimination," *Journal of International Economics* 67: 129-156 (2005).

[37] Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, "International Risk-Sharing and the Transmission of Productivity Shocks," *Review of Economic Studies* 75: 443-473 (2008a).

[38] Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, "High exchange rate volatility and low pass-through," *Journal of Monetary Economics* 55: 1113–1128 (2008b).

[39] Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, "Optimal Monetary Policy and Sources of Local Currency Price Stability," in J. Galí and M. Gertler, eds., *International Dimensions of Monetary Policy*, University of Chicago Press, 2009a.

[40] Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, "Demand imbalances, real exchange rate misalignments and monetary policy," unpublished draft, European University Institute, 2009b.

[41] Corsetti, Giancarlo, and Paolo Pesenti, "Welfare and Macroeconomic Interdependence," *Quarterly Journal of Economics* 116 (2): 421-446 (2001).

[42] Corsetti, Giancarlo, and Paolo Pesenti, "International Dimensions of Optimal Monetary Policy," *Journal of Monetary Economics* 52: 281-305 (2005).

[43] Corsetti, Giancarlo, and Paolo Pesenti, "The simple geometry of transmission and stabilization in closed and open economy," *NBER International Seminar on Macroeconomics 2007*, NBER Books, National Bureau of Economic Research, 2008.

[44] Curdia, Vasco and Michael Woodford, "Credit frictions and optimal monetary policy," unpublished draft, Federal Reserve Bank of New York (2009).

[45] De Paoli, Bianca, "Monetary Policy under Alternative Asset Market Structures: The Case of a Small Open Economy," *Journal of Money, Credit and Banking* 41(7): 1301-1330 (2009a).

[46] De Paoli, Bianca, "Monetary Policy and Welfare in a Small Open Economy," *Journal of International Economics* 77: 11-22 (2009b).

[47] Dellas, Harris, "The Implications of International Asset Trade for Monetary Policy," *Journal of International Economics* 25(3-4): 365-372 (1988).

[48] Devereux, Michael B., "Should the exchange rate be a shock absorber?" *Journal of International Economics* 62: 359-377 (2004).

[49] Devereux, Michael B., and Charles Engel, "Monetary policy in the open economy revisited: Price setting and exchange rate flexibility," *Review of Economic Studies* 70: 765-783 (2003).

[50] Devereux, Michael B., and Charles Engel, "Expectations, Monetary Policy, and the Misalignment of Traded Goods Prices," *NBER International Seminar on Macroeconomics 2006*, 2007.

[51] Devereux Michael B., Charles Engel and Peter E. Storgaard, "Endogenous Exchange Rate Pass-through when Nominal Prices are Set in Advance," *Journal of International Economics* 63: 263-291 2004

[52] Devereux, Michael B., Kang Shi, and Juanyi Xu J., "Global Monetary Policy under a Dollar Standard," *Journal of International Economics* 71(1): 113-132 (2005).

[53] Devereux, Michael B., and Alan Sutherland, "Financial Globalization and Monetary Policy," *Journal of Monetary Economics* 55: 1363-1375 (2008).

[54] Dornbusch, Rudiger, "Exchange Rates and Prices," *American Economic Review* 77: 93-106 (1987)

[55] Duarte, Margarita, and Maurice Obstfeld, "Monetary Policy in the Open Economy Revisited: The Case for exchange rate Flexibility Restored," *Journal of International Money and Finance* 27: 949-957 (2008).

[56] Engel, Charles, "Expenditure Switching and exchange rate Policy," in B. Bernanke and K. Rogoff, eds., *NBER Macroeconomics Annual 2002*, Cambridge, MA: MIT Press, 2002.

[57] Engel, Charles, "Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing," *Journal of the European Economic Association* 4(6): 1249-60 (2006).

[58] Engel, Charles, "Currency Misalignments and Optimal Monetary Policy: A Reexamination," NBER working paper no.14829, April 2009.

[59] Engel, Charles, Nelson C. Mark, and Kenneth D. West, "Exchange Rate Models Are Not as Bad as You Think," in D. Acemoglu, K. Rogoff and M. Woodford, eds., *NBER Macroeconomics Annual 2007*, Cambridge, MA: MIT Press, 2007.

[60] Erceg Christopher, Dale W. Henderson, and Andrew T. Levin, "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics* 46(2): 281-313 (2000).

[61] Faia, Ester, and Tommaso Monacelli 2008, "Optimal Monetary Policy in A Small Open Economy with Home Bias," *Journal of Money, Credit and Banking* 40: 721-750, (2008).

[62] Friberg, Richard, "In which currency should exporters set their prices?," *Journal of International Economics* 45, 59-76 (1998).

[63] Friedman, Milton, "The Case for Flexible Exchange Rates," in *Essays in Positive Economics*, Chicago, IL: University of Chicago Press, 1953.

[64] Galí, Jordi, *Monetary Policy, Inflation and the Business Cycle*, Princeton University Press, 2008.

[65] Galí, Jordi, and Mark Gertler, eds., *International Dimensions of Monetary Policy*, University of Chicago Press, 2007.

[66] Galí, Jordi, and Tommaso Monacelli, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies* 72:.707–734 (2005).

[67] Giannoni, Marc P., and Michael Woodford, "Optimal Target Criteria for Stabilization Policy," unpublished draft, Columbia University, August 2009.

[68] Goldberg, Linda, and Cedric Tille, "Vehicle currency use in international trade," *Journal of International Economics* 76(2): 177-192 (2008).

[69] Goldberg, Pinelopi K., and Michael M. Knetter, "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature* 35: 1243-1272 (1997).

[70] Goldberg, Pinelopi K., and Rebecca Hellerstein, "A Framework for Identifying the Sources of Local-Currency Price Stability With an Empirical Application," NBER working paper no. 13183, June 2007.

[71] Goldberg, Pinelopi K., and Frank Verboven, "The evolution of price dispersion in the european car market," *Review of Economic Studies* 68: 811-48 (2001).

[72] Goodfriend, Marvin, and Robert King, "The New Neoclassical Synthesis and the Role of Monetary Policy," NBER Chapters, in: *NBER Macroeconomics Annual 1997*, National Bureau of Economic Research, Inc., 1997.

[73] Gopinath, Gita, and Roberto Rigobon, "Sticky Borders," *Quarterly Journal of Economics* 123(2): 531-575 (2008).

[74] Gourinchas, Pierre O., and Helene Rey, "International Financial Adjustment," *Journal of Political Economy* 115(4): 665-703 (2007).

[75] Helpman, Elhanan, and Assaf Razin, *A theory of international trade under uncertainty*, San Francisco: Academic Press, 1978.

[76] Jeanne, Olivier, and Andrew Rose, "Noise Trading and Exchange Rate Regimes," *Quarterly Journal of Economics* 117(2): 537-569 (2002).

[77] Kollmann, Robert, "Monetary Policy Rules in the Open Economy: Effects on Welfare and Business Cycles," *Journal of Monetary Economics* 49: 989-1015 (2002).

[78] Krugman, Paul, "Pricing to Market When the Exchange Rate Changes," in S. W. Arndt and J. D. Richardson, eds., *Real-financial linkages among open economies*, Cambridge, MA: MIT Press, 1987.

[79] Lane, Philip R., and Gian Maria Milesi-Ferretti, "The Transfer Problem Revisited: Net Foreign Assets and Real Exchange Rates," *The Review of Economics and Statistics* 86(4): 841-857 (2004).

[80] Lahiri, Amartya, Rajesh Singh, and Carlos Vegh, "Segmented asset markets and optimal exchange rate regimes," *Journal of International Economics* 72(1): 1-21 (2007).

[81] Lombardo, Giovanni, "Targeting Rules and Welfare in an Asymmetric Currency Area," *Journal of International Economics* 68(2): 424-442 (2006).

[82] Mendoza, Enrique, "The Terms of Trade, The Real Exchange Rate and Economic Fluctuations," *International Economic Review* 36: 101-137 (1995).

[83] Monacelli, Tommaso, "Monetary Policy in a Low Pass-Through Environment," *Journal of Money Credit and Banking* 37(6): 1047-1066 (2005).

[84] Nakamura, Emi, and Dawit Zerom, "Accounting for Incomplete Pass-Through," *Review of Economic Studies*, forthcoming (2009).

[85] Obstfeld, Maurice, "Inflation-targeting, exchange rate pass-through, and volatility," *American Economic Review* 92: 102–7 (2002).

[86] Obstfeld, Maurice, and Kenneth Rogoff, "Exchange Rate Dynamics Redux," *Journal of Political Economy* 103: 624-660 (1995).

[87] Obstfeld, Maurice, and Kenneth Rogoff, "New Directions fro Stochastic Open Economy Models," *Journal of International Economics* 50(1): 117-153 (2000).

[88] Obstfeld, Maurice, and Kenneth Rogoff, "Global Implications of Self-Oriented National Monetary Rules," *Quarterly Journal of Economics* 117: 503-36 (2002).

[89] Pappa, Evi, "Do the ECB and the Fed really need to cooperate? Optimal monetary policy in a two-country world," *Journal of Monetary Economics* 51: 753-779 (2004).

[90] Persson, Torsten, and Guido Tabellini, "Double-Edged Incentives: Institutions and Policy Coordination," in G. Grossman and K. Rogoff, eds., *Handbook of Development Economics* vol. III, Elsevier, 1995.

[91] Ravenna, Federico, and Carl Walsh, "Optimal Monetary Policy with the Cost Channel," *Journal of Monetary Economics* 53(2): 199-216 (2006).

[92] Ravn, Morten, Stephanie Schmitt-Grohe, and Martin Uribe, "Pricing to Habits and the Law of One Price", *American Economic Review* 97(2): 232-38 (2007).

[93] Rogoff, Kenneth, "Globalization and global disinflation," *Economic Review Federal Reserve Bank of Kansas*, Fourth Quarter: 45-78 (2003).

[94] Romer, David, "Openness and Inflation: Theory and Evidence," *Quarterly Journal of Economics* 108: 869-903 (1993).

[95] Rotemberg, Julio, and Michael Woodford, "An optimization-based econometric model for the evaluation of monetary policy," *NBER Macroeconomics Annual*, 1997.

[96] Sbordone, Argia, "Globalization and Inflation Dynamics: the Impact of Increasing Competition," in J. Galí J and M. Gertler, eds., *International Dimensions of Monetary Policy,* University of Chicago Press, 2009.

[97] Sims, Christopher, "Comments on Coenen G. et al. International Transmission and Monetary Policy Cooperation," in J. Galí and M. Gertler, eds., *International Dimensions of Monetary Policy,* University of Chicago Press, 192-195, 2009.

[98] Smets, Frank, and Raf Wouters, "Openness, imperfect exchange rate pass-through and monetary policy", *Journal of Monetary Economics* 49: 947-981 (2002).

[99] Stockman, Alan, and Linda Tesar, "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Co-Movements," *American Economic Review*, 85(1): 168-185 (1995).

[100] Sutherland, Alan, "Incomplete Pass-through, and the Welfare Effects of Exchange Rate Variability," *Journal of International Economics* 65: 375-399 (2005).

[101] Svensson, Lars E. O., "Open-Economy Inflation Targeting," *Journal of International Economics* 50 (1): 155-183 (2000).

[102] Svensson, Lars E. O., and Sweder van Wijnbergen, "Excess Capacity, Monopolistic Competition, and International Transmission of Monetary Disturbances," *Economic Journal,* XCIX: 785-805 (1989).

[103] Taylor, John B., "Low Inflation, Pass-Through, and the Pricing Power of Firms," *European Economic Review* 44(7): 1389-1408 (2000).

[104] Tille, Cedric, "The role of consumption substitutability in the international transmission of shocks," *Journal of International Economics* 53: 421-44 (2001).

[105] Viani, Francesca, "International Financial Flows and Real Exchange Rates," unpublished draft, European University Institute, April 2010.

[106] Woodford, Michael, *Interest and Prices: Foundation of a Theory of Monetary Policy*, Princeton University Press, 2003.

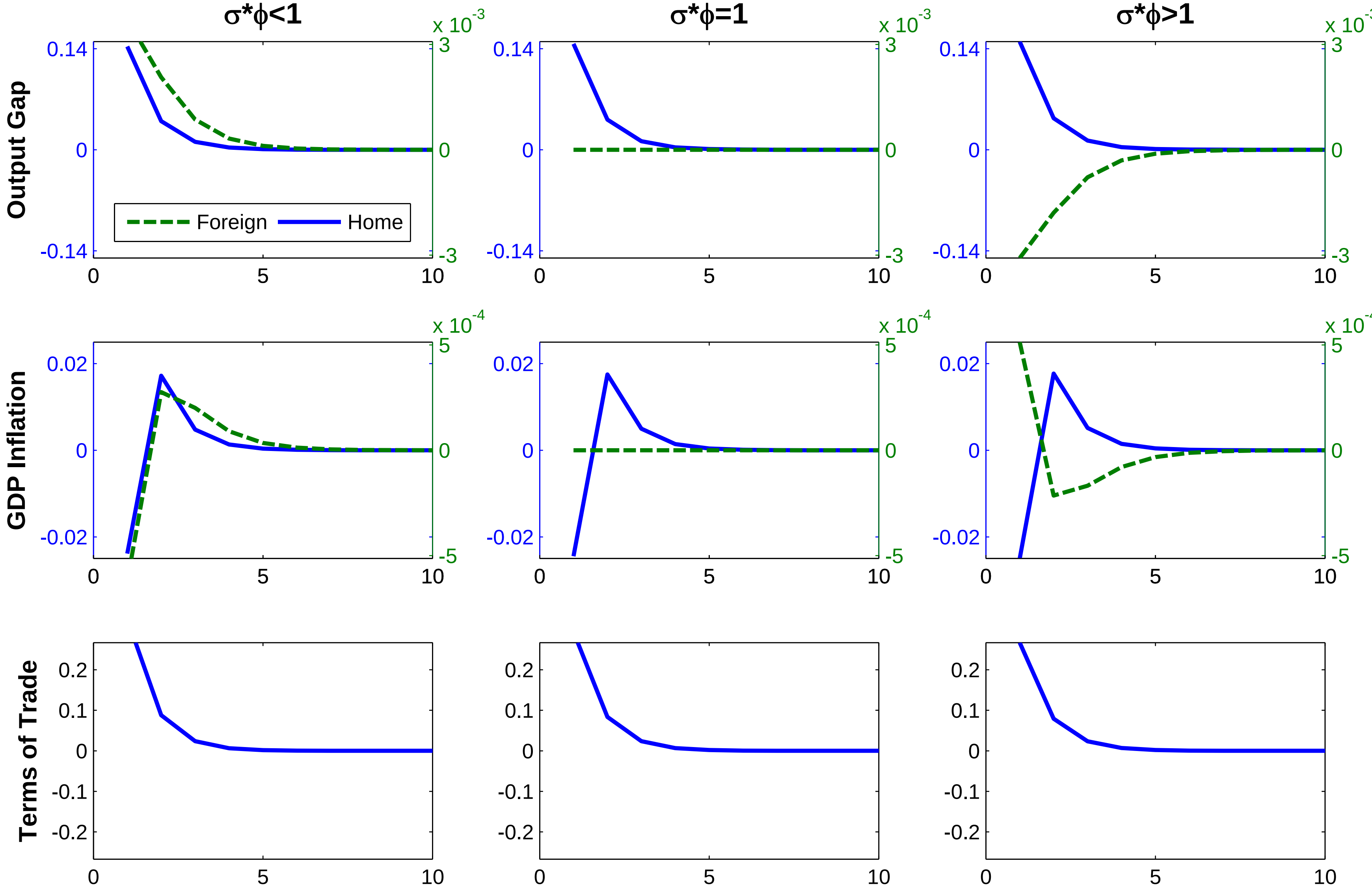
Table I.1. Benchmark parameter values

Benchmark Model	
Preferences and Technology	
Risk aversion	$\sigma = 2$
Probability of resetting prices	$1 - \alpha = 0.25$
Frisch labor supply elasticity (inverse of)	$\eta = 1.5$
Elasticity of substitution between:	
Home and Foreign traded goods	$\phi = 1$
Home traded goods	$\theta = 6$
Share of Home Traded goods	$a_{\mathrm{H}} = 0.90$
Shocks	
Productivity	$\rho_z = 0.95, \ \ \sigma_z = 0.001$
Preference	$\rho_\zeta = 0.95, \ \ \sigma_\zeta = 0.001$
Markup	$\sigma_\zeta = 0.001$

Table I.2. Volatilities Under Optimal Policy (Complete Market Economies)

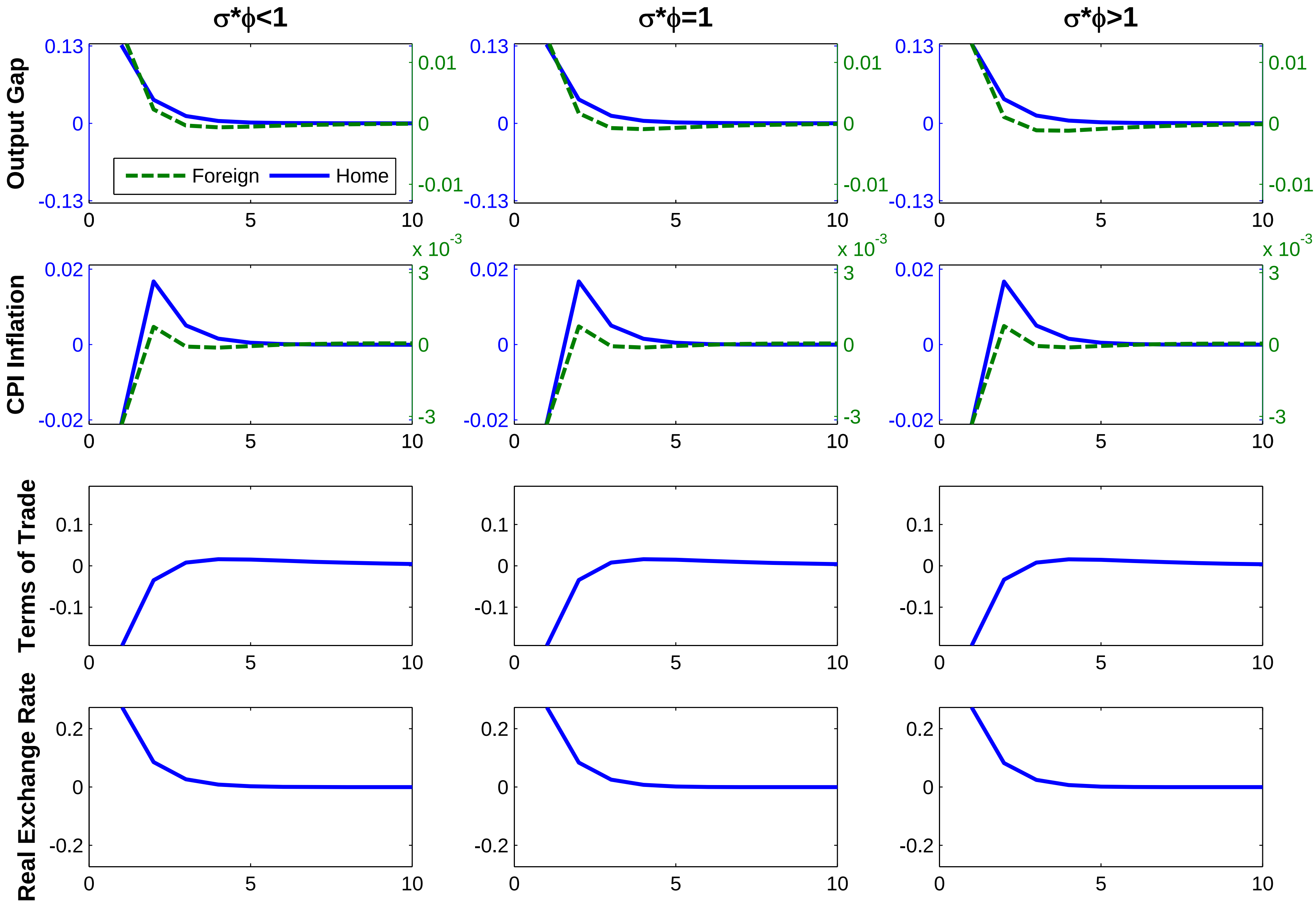
Statistics	With PCP Productivity and Preference Shocks	With PCP With Markup Shocks	With LCP Productivity and Preference Shocks	With LCP With Markup Shocks
Standard deviation (in percent)				
CPI Inflation	0.11	0.12	0.02	0.03
GDP Deflator Inflation	0.00	0.03	0.03	0.04
Output Gap	0.00	0.16	0.14	0.19
Markup	0.00	0.52	0.14	0.53
Standard deviation (Relative to Output)				
Real Exchange Rate	2.71	2.75	2.99	2.59
Terms of Trade	3.39	3.43	2.56	1.60

Figure I.1. International Transmission of an Exogenous Decline in Home Markups Under the Optimal Policy with Producer Currency Pricing and Complete Markets



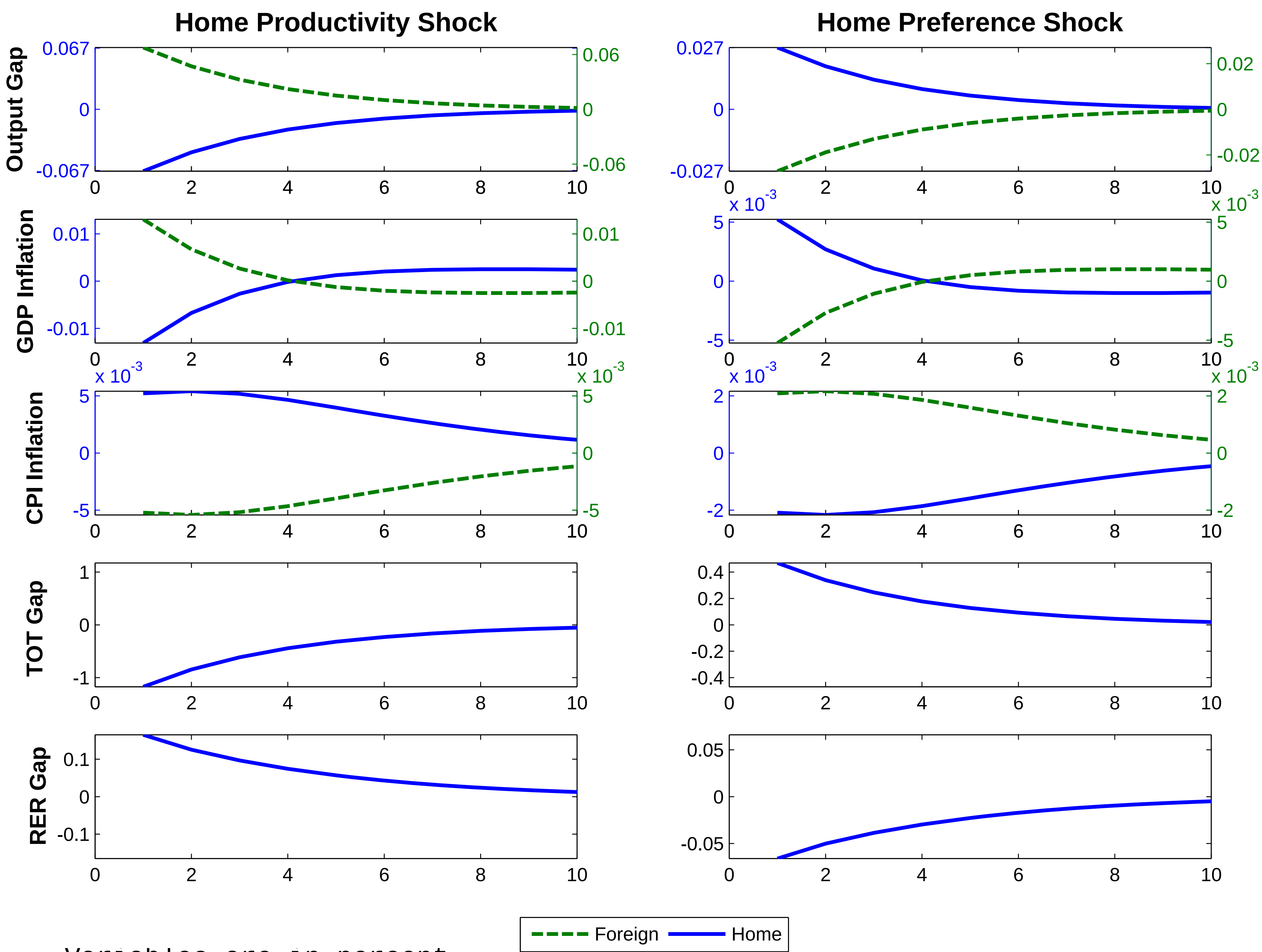
In this figure σ=2, as under the benchmark calibration. In the first column, we set φ=0.3, while in the third one, we set φ=0.7. Variables are in percent.

Figure I.2. International Transmission of an Exogenous Decline in Home Markups Under the Optimal Policy With Local Currency Pricing and Complete Markets



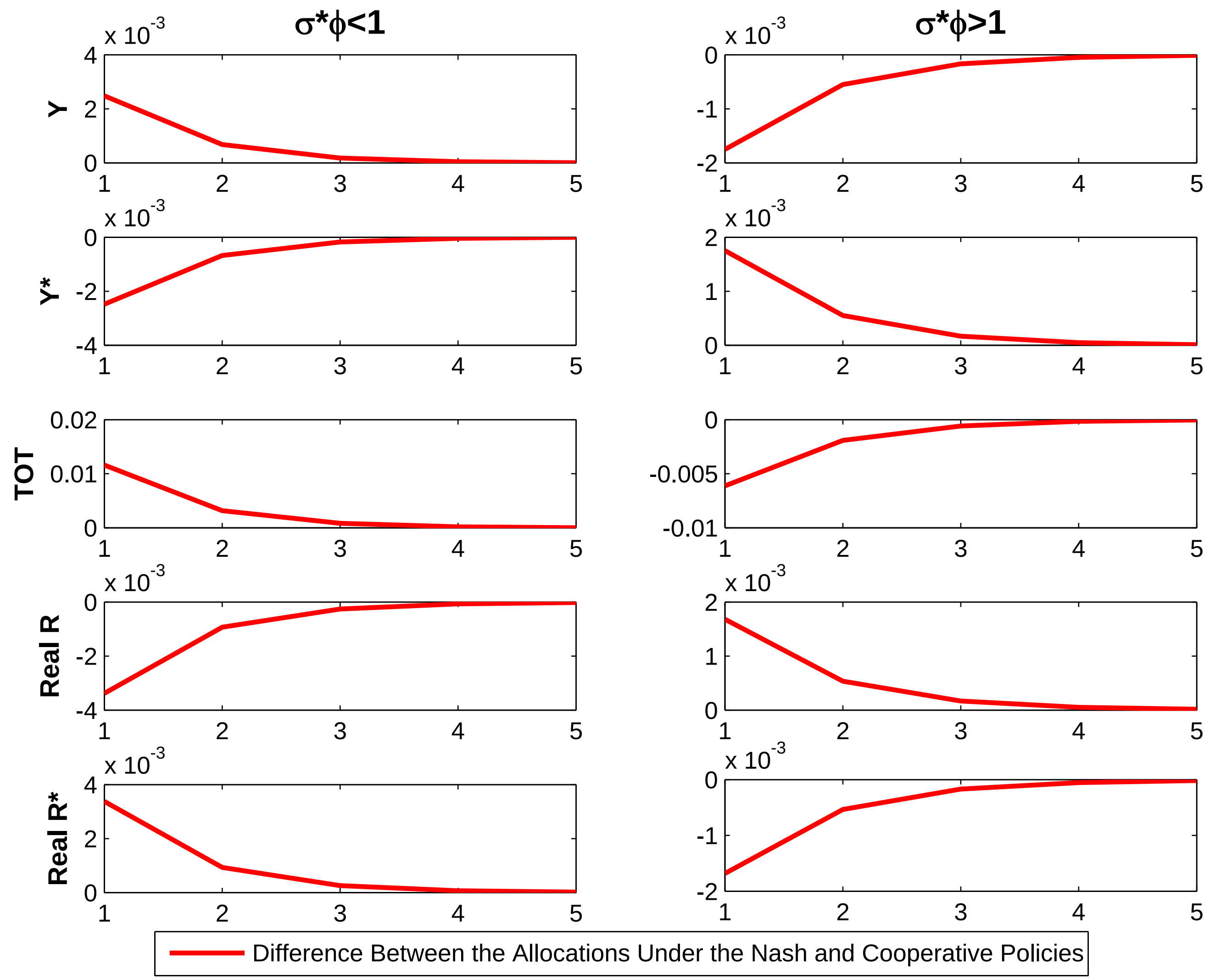
In this figure σ=2. In the first column, we set φ=0.3, while in the third one, we set φ=0.7. Variables are in percent.

Figure I.3. International Transmission of Home Productivity and Preference Shocks Under the Optimal Policy With Local Currency Pricing and Complete Markets



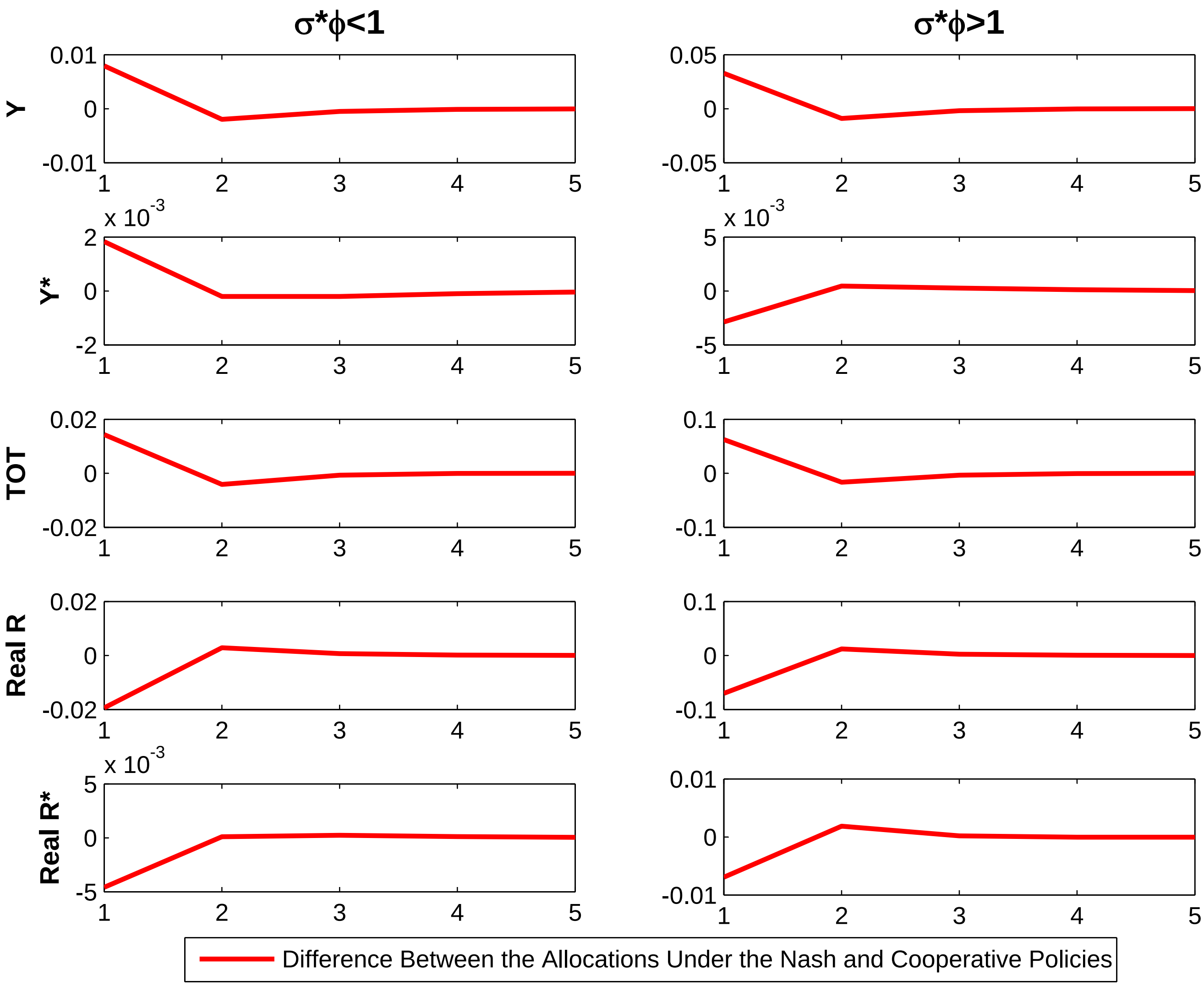
Variables are in percent.

Figure I.4. Nash Gaps Following a Home Productivity Shock



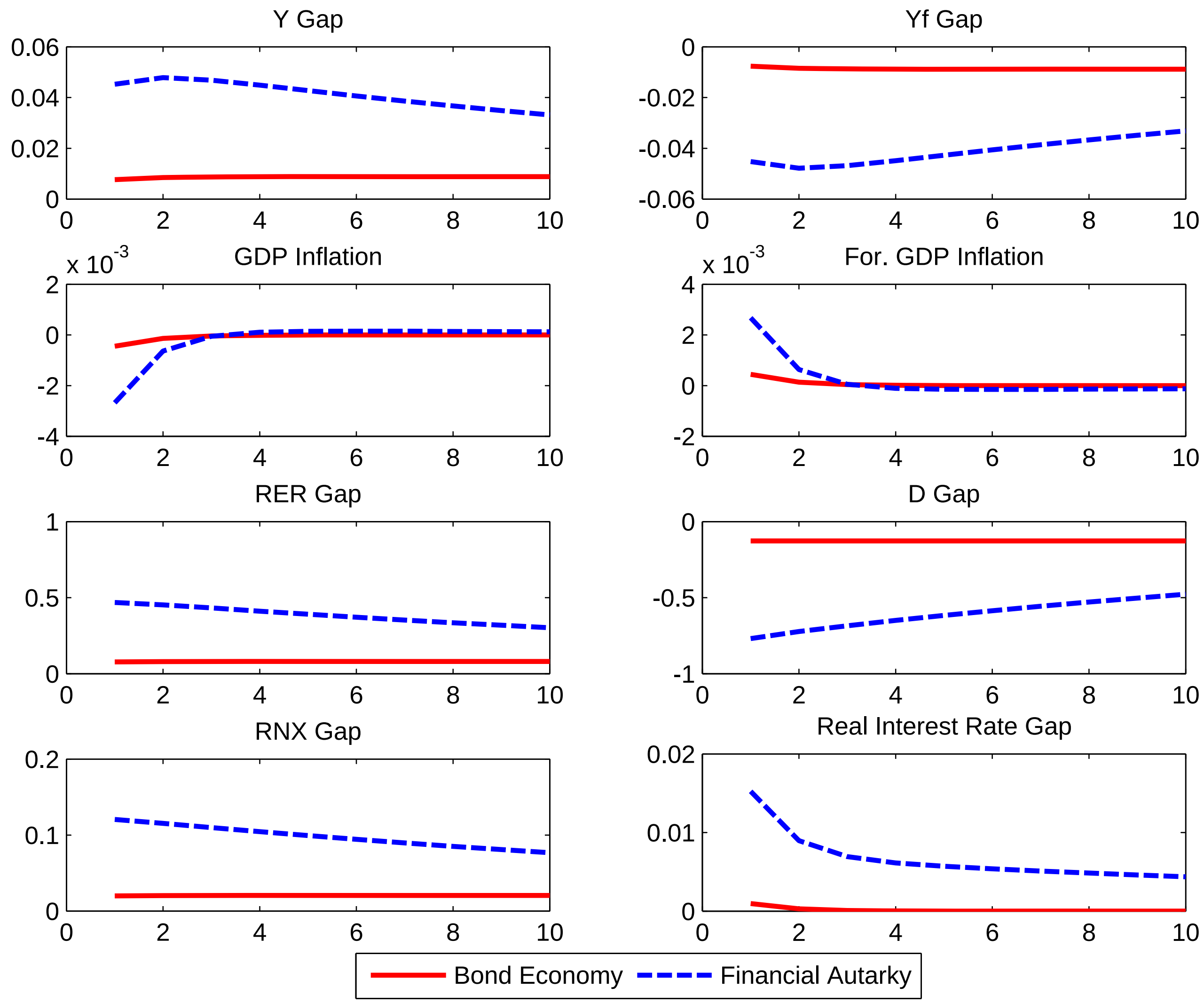
In this figure, σ=2, as under the benchmark calibration. In the first column we set φ=0.3, while in the third one, we set φ=0.7. Variables are in percent.

Figure I.5. Nash Gaps Following an Exogenous Decline in Home Markups



In this figure, σ=2, as under the benchmark calibration. In the first column we set φ=0.3, while in the third one, we set φ=0.7. Variables are in percent.

Figure II.1. Home Preference Shock and Optimal Policy
Under Alternative Financial Structures



Variables are in percent.