The simple geometry of transmission and stabilization in closed and open economies[1]

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Abstract

This paper provides a graphical introduction to the recent literature on macroeconomic stabilization in closed and open economies. Among the issues we discuss: international transmission of real and monetary shocks and the role of exchange rate pass-through; optimal monetary policy and the welfare gains from macroeconomic stabilization; monetary coordination among interdependent economies.

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1 Introduction

How do shocks in a country transmit to the rest of the world? What is the appropriate response of monetary policy? Do optimal policy strategies change when an economy becomes more globalized? Do they require coordination among central banks?

In the attempt to answer these and similar queries, the past decade has witnessed rapid and substantial developments in the literature on macroeconomic stabilization in closed and open economies. Despite important differences in emphasis and style, a number of tightly related research agendas — from the 'new neo-classical' synthesis to the 'neo-Wicksellian' monetary economics to the 'new open-economy macroeconomics' (NOEM), and so on — have shed light on the mechanism of transmission and propagation of supply and demand shocks in the presence of imperfectly competitive markets and price/wage rigidities. Building on these premises, a new generation of multi-country 'Dynamic Stochastic General-Equilibrium' (in short, DSGE) models for scenario analysis and policy evaluation have recently found fertile grounds among central banks and policy institutions.

The objective of this paper is to introduce an intuitive graphical apparatus to help understand and communicate some of the key results of these research strands. We make no attempt to provide an exhaustive overview of the literature (a task well beyond the scope of a 'simple geometry'). Rather, based on our direct experience in classroom, conferences and policy presentations over the years, we are confident that a broad audience of scholars and policy analysts would welcome a graphical toolset to 'inspect the mechanism' and convey important results from more complex models in a direct, transparent and immediate fashion.

This may be especially relevant for the study of international spillovers and cross-country interdependencies, a research field in which analytical complexities can reach formidable peaks and hinder access to — and communication of — its basic results beyond a restricted niche of acolytes. Not surprisingly, graphical tools have underlaid the popularity of more traditional teaching and research material in open-economy macroeconomics for decades. While the textbook treatment of the augmented IS-LM approach to visualize the Mundell-Fleming-Dornbusch model is unlikely to be superseded soon, alternative approaches that bridge frontier research and pedagogical objectives are definitely viable. This is a first pass in that direction.

Transparency and immediacy are achieved in what follows by focusing on a highly stylized model with very specific properties. In fact, we choose to parameterize households' preferences and firms' technology in such a way to maintain analytical tractability and concentrate on the substance of the argument without sacrificing theoretical coherence. Also, in characterizing macroeconomic uncertainties, we restrict our attention to a very limited set of shocks. Needless to say, restrictions on the model's specification may well hamper the degree of realism of our framework. But to a very large extent the general principles conveyed by our analysis are quite robust, and go through — *mutatis mutandis* — in more articulated models.

By the same token, intertemporal considerations are kept at a very minimum in our analysis: whenever possible, we choose to make our points in terms of static concepts (say, prices and output) rather than dynamic ones (inflation and growth), confident that our analytical results will be easily reinterpreted in terms of deviations from nominal and real trends. Very few equations — and only extremely intuitive ones — appear in the main text. Readers interested in analytical details are referred to the appendices of the paper (available online or in Corsetti and Pesenti 2005b), where full-fledged versions of the models described in the main text are available.

This paper is organized as follows. Section 2 describes the basic macroeconomic model in closed economy, with flexible prices and nominal rigidities. Section 3 extends the model to interdependent open economies, discussing cross-border market segmentation and nominal rigidities in export markets. Section 4 analyzes the macroeconomic transmission mechanism, revisiting the traditional view of the role played by exchange rate movements. Section 5 considers optimal monetary policy under discretion and its implications for the relationship between openness and inflation. Section 6 characterizes optimal monetary policy under commitment and discusses the desirability of international policy coordination. Section 7 concludes.

2 A basic model of output and prices

2.1 Preferences, technology and market structure

We start by developing a stylized macroeconomic model for a closed economy without external trade in goods or assets. The population size is normalized to one, so that we can use the same notation for aggregate and per-capita variables. The economy consists of households, firms, and the government.

Households have identical preferences. They derive utility from consuming the products supplied by the firms, and disutility from supplying labor to the firms in exchange for wage incomes. At any point in time, utility U is equal to:

$$U = \ln C - \kappa\ell \tag{1}$$

where C is consumption and ℓ is hours worked. The consumption good C is a basket of many product varieties (or 'brands'), and households consume all available varieties supplied by the firms. The parameter κ measures the discomfort associated with labor effort, so that the marginal rate of substitution between consumption and leisure is:

$$\left.\frac{\partial C}{\partial \ell}\right|_{dU=0} = \kappa C. \tag{2}$$

Firms have identical technologies. They produce their goods by using labor supplied by the households as the only input in production. Households own the firms, and receive their profits as dividend income. Productivity (output per unit labor) is subject to economy-wide shocks. The labor market is assumed to be perfectly competitive: real wages are equal to productivity.

Each firm produces a single variety of the consumption good, and no other firm produces the same variety: each firm has therefore some monopoly power over its product. However, each firm competes with all the remaining firms, since consumers consider each firm's brand as a substitute — however imperfect — to all other available brands.

As firms have market power over the supply of their products, they set prices to maximize their profits, keeping into account the elasticity of demand for their varieties. We consider two cases, one in which prices are fully flexible (a meaningful assumption over a long-term horizon), and another in which we allow for nominal price rigidities (a realistic assumption in the short run, say over the time horizon of a business cycle). In the latter case, for simplicity we assume that firms preset the price of their own products before the shocks are observed, and stand ready to meet current demand at this price for any realization of the shocks.

The government includes both the central bank in charge of monetary policy and the fiscal authorities. Throughout our analysis we abstract from public consumption, so that fiscal policymakers only redistribute revenue across agents.

2.2 Consumption and employment

Our model can be synthesized by means of three schedules, as illustrated in Figure 1: Aggregate Demand [AD], Aggregate Supply [AS], and the Natural Rate [NR].[1] Figure 1 plots labor effort ℓ on the horizontal axis and consumption C on the vertical axis.

Let P denote the consumer price index associated with the consumption basket C, that is, an average of the prices of all consumption varieties. Without investment or government spending, C coincides with aggregate demand in real terms, while PC is aggregate nominal spending.

Let μ denote a variable that synthesizes the effect of current and expected future monetary policy (whatever the specific policy instruments used) on aggregate nominal spending PC. We can refer to μ as the aggregate monetary stance of the country.[2] The Aggregate Demand 'AD' equation can then be written as:

$$C = \mu/P \tag{3}$$

In terms of Figure 1, the 'AD' schedule is a horizontal line. A monetary ease (higher μ) provides nominal stimulus to the economy. Given the price level P, a higher monetary stance μ translates into higher real consumption C. By the same token, given the monetary stance μ, consumption is high when agents' purchasing power is strong, that is, when the price level is low.

Next, let Z denote labor productivity. The Aggregate Supply 'AS' equation relates output (that in closed economy is equal to real domestic expenditure) to total employment measured in terms of hours worked:

$$C = Z\ell \tag{4}$$

Holding employment ℓ constant, shocks to productivity Z lead to fluctuations in aggregate output C. In Figure 1, the 'AS' schedule is a ray from the origin with slope determined by the productivity parameter Z: higher productivity translates into a steeper line.

At any point in time, the intersection between 'AD' and 'AS' determines the equilibrium allocation of consumption C and labor ℓ for given values of the exogenous variables μ and Z, as well as for a given price level P. Of course, the price level is an endogenous variable in our system. We therefore need to analyze how firms optimally set their prices. Note that all firms are symmetric and face similar technologies, so that in equilibrium they all charge the same price for their products.

2.3 Flexible prices

Consider first the case in which prices are perfectly flexible and adjust in response to supply and demand interactions in the product market (as indexed by the subscript $flex$). Imper-

[1] Throughout the paper we maintain the Aggregate Demand / Aggregate Supply conceptual apparatus of most macro textbooks, although our graphical approach is closer in spirit to the microeconomic treatment of input/output relations. Thus, readers used to thinking about 'Aggregate Supply' in reference to the relation between the price level and output, or inflation and the output gap, may prefer to consider our AS schedule as the consumption-employment relation implied by the technology of production.

[2] In Corsetti and Pesenti 2005b, Appendix 1, we consider some examples of policy instruments corresponding to a given stance μ.

fectly competitive firms set prices by charging an optimal markup over their marginal costs. Labor is the only input in production, so that marginal costs are labor costs per unit of product, i.e. the wage rate (here denoted by W) divided by labor productivity Z.

The markup charged by a firm is a function of its monopoly power in the product market. Let θ denote the elasticity of substitution between different varieties of the consumption good. It is assumed that θ is sufficiently large — to capture the idea that consumption varieties are good substitutes for each other — but not 'too' large (otherwise all varieties would substantially be similar in the eye of the consumers, and a firm would have no monopoly power at all in setting the price of its product). Specifically, we assume $1 < \theta < \infty$.

The optimal price charged by the representative firm will then be:

$$P^{flex} = \overbrace{\frac{\theta}{\theta - 1}}^{\text{markup}} \quad \overbrace{\frac{W}{Z}}^{\text{marg. costs}} \tag{5}$$

Interpreting the expression above, if the elasticity of substitution θ were very high, prices would be equal to marginal costs W/Z. But if θ were relatively small (close to one), firms would face very inelastic demand curves for their products, and would be able to exploit their significant market power by charging extremely high prices relative to the production costs.

Moreover, with a perfectly competitive labor market, the equilibrium wage rate in units of consumption (W/P) must be equal to the marginal rate of substitution between consumption and leisure of the representative agent according to (2):[3]

$$\frac{W}{P} = \kappa C \tag{6}$$

Combining (5) and (6), in equilibrium the profit-maximizing product price P^{flex} is determined as follows:

$$P^{flex} = \frac{\theta}{\theta - 1} \frac{\kappa P^{flex} C}{Z} \tag{7}$$

Now, replacing C with $Z\ell$ according to (4) in the previous expression and rearranging, we obtain:

$$\ell = \frac{\theta - 1}{\theta \kappa} \equiv \bar{\ell} \tag{8}$$

Equation (8) defines the 'natural' or 'potential' rate of employment, $\bar{\ell}$, as the level of employment that would prevail in an economy without nominal rigidities. The natural rate depends on agents' preferences about leisure, as captured by the parameter κ: the lower is κ, the higher is households' supply of labor inputs to firms in equilibrium. It also depends on the monopolistic distortions in the economy: the higher is θ, the lower is the equilibrium markup, and the higher is the equilibrium level of employment.[4] Observe that, while the natural rate of employment is constant, the natural rate of output $Z\bar{\ell}$ (defined as output in

[3] If the labor market were imperfectly competitive, there would be a wedge (labor market markup) between real wage and marginal rate of substitution, reflecting workers' market power.

[4] This result can be easily extended to the case of non-linear disutility of labor effort. Suppose for instance that $U = \ln C - \kappa \ell^{1+\nu}/(1+\nu)$. In this case the natural rate of employment is a constant equal to $[(\theta - 1)/\theta\kappa]^{1/1+\nu}$. For more general model specifications, the natural rate need not be constant, and consequently the graphical representation of the equilibrium allocation turns out to be less straightforward. For a generalization of our graphical apparatus to the case in which the natural rate depends on consumption see Corsetti and Pesenti (1997).

an economy without nominal rigidities) will fluctuate as a function of productivity shocks Z.

In Figure 1, we plot equation (8) as the third schedule 'NR' or 'Natural Rate': a vertical line above the constant $\bar{\ell}$. In the flex-price equilibrium, the 'AD' and 'AS' schedules cross each other corresponding to the natural rate of employment. Once C and ℓ are determined at the intersection of 'AS' and 'NR', the price level P adjusts for any level of the current monetary stance μ to make sure that 'AD' intersects the other two schedules at the equilibrium point.

2.4 Nominal rigidities

Macroeconomic adjustment is quite different with nominal price rigidities. Consider the case in which firms preset their prices and are unable to modify them once they observe the actual realizations of W and Z. Under these conditions, the optimally chosen price level[5] depends on *expected* marginal costs:[6]

$$P = \frac{\theta}{\theta - 1} E\left(\frac{W}{Z}\right) \tag{9}$$

Of course, when prices are preset, unanticipated changes in marginal costs can reduce or raise the *ex-post* profits of the firm.[7]

We now show that, in a sticky-price environment, employment is equal to the natural rate only in *expected* terms. To see this, recall that $W = \kappa PC$ and $PC = \mu$ from (6) and (3). Combine these expressions with (9) to rewrite the optimal product price as follows:

$$P = \frac{\theta\kappa}{\theta - 1} E\left(\frac{\mu}{Z}\right) \tag{10}$$

Next, multiply both sides by C and use (4) and (3) to write:

$$\mu = \frac{\theta\kappa}{\theta - 1} E\left(\frac{\mu}{Z}\right) Z\ell \tag{11}$$

Rearranging and taking expectations, we obtain:

$$E(\ell) = E\left(\frac{\theta - 1}{\theta\kappa} \frac{\mu/Z}{E(\mu/Z)}\right) = \frac{\theta - 1}{\theta\kappa} = \bar{\ell} \tag{12}$$

An intuitive interpretation of (12) is that firms choose prices so as to insure that, on average, they will operate on their flex-price supply curve. If P is set at a level below (10), market demand for the firms' goods turns out to be excessively high, and they need to hire labor above $\bar{\ell}$ to meet demand at unchanged prices, sacrificing their profits. If P is set at an excessively high level, firms' sales revenue turns out to be too low and ℓ falls below $\bar{\ell}$. In

[5] Product prices are optimally preset to maximize the discounted value of the firm's profits. While in general this problem is quite complex, it greatly simplifies in our setting.

[6] In what follows, $E(X)$ will refer to the expected value of the variable X based on information available at the time expectations are taken. With one-period nominal rigidities, the expression $E(X)$ is shorthand for $E_{t-1}(X_t)$.

[7] The ex-post gross markup is $P/(W/Z)$, or $\theta/(\theta - 1) * E(W/Z)/(W/Z)$. As long as $\theta > 1$ and the shocks are not too large, firms' ex-post markups will remain above one. Note that in a model without monopolistic distortions any increase in marginal cost would lower the ex-post markup below one, prompting firms to adjust their prices in response to the shock: in that framework, nominal rigidities would be inconsistent with the rational behavior of firms.

equilibrium, expected employment is equal to its natural rate. We will return to this point later in Figure 11.[8]

To sum up: the 'Aggregate Demand' equation (3) relates nominal spending to the monetary policy stance. The 'Aggregate Supply' equation (4) relates aggregate supply to employment. Prices in the short run are set such that, in expectation, the economy operates along the 'Natural Rate' equation (12). In the long run, when prices are flexible, the 'NR' equation determines labor ℓ, the 'AS' equation determines consumption C given ℓ and Z, and the 'AD' equation (3) determines the price level P given C and μ.

2.5 Welfare considerations

With the help of our graphical apparatus, we can analyze the welfare implications of macroeconomic shocks and changes in structural parameters that shift the three schedules in Figure 1. Having specified the utility function as in (1), the indifference curves in the space (ℓ, C) are convex and upward sloping, with slope proportional to consumption according to (2). In Figure 1 the dashed curve is the indifference curve associated with the equilibrium O. Utility is increasing as we move upwards or westwards, corresponding to higher consumption levels for any given labor effort, or lower labor effort for any given consumption level.

In the presence of monopolistic distortions in the product market, an economy operating at the natural rate $\bar{\ell}$ will not be Pareto efficient:[9] the equilibrium level of employment and output will be suboptimally low, as firms contract their supply of goods to exploit their monopoly power and maximize their profits.

We can provide a simple graphical representation of this point. In Figure 1, the indifference curve that goes through the equilibrium point crosses the 'AS' locus from above. That is, at the equilibrium $C = Z\bar{\ell}$, the marginal rate of substitution (measured by the slope of the indifference curve of the representative household) is smaller than the marginal rate of transformation (the slope of the aggregate supply schedule):

$$\left.\frac{dC}{d\ell}\right|_{dU=0,\ell=\bar{\ell}} = \kappa C|_{\ell=\bar{\ell}} = \kappa Z \frac{\theta-1}{\theta\kappa} = Z\frac{\theta-1}{\theta} < Z \tag{13}$$

Intuitively, in equilibrium agents work and consume 'too little', so that the additional disutility from a small increase in labor effort is lower than the additional utility from higher revenue. This illustrates a general and crucial feature of economies with monopolistic power in production.

In the absence of monopolistic distortions, the equilibrium in the model would correspond to a point in which the indifference curve is tangent to the 'AS' locus. To see this, assume that product varieties are highly substitutable, i.e. let θ become infinitely large, so that the monopoly power of firms is arbitrarily small and the economy approaches perfect competition. Expression (13) shows that in equilibrium the slope of the indifference curve will be identical to the slope of the 'AS' locus, and equal to Z. Indeed, the competitive (and Pareto-efficient) level of employment is $1/\kappa > \bar{\ell}$. In Section 5 we reconsider the difference between 'natural' (point O in Figure 10) and 'competitive' (point X in Figure 10) output, and its implications for the choice of monetary policy under discretion.

[8] In more complex models, expected employment need not be at the natural rate in any period. Nevertheless, optimal price setting is such that employment converges to the natural rate asymptotically.

[9] An allocation is Pareto efficient if there is no other allocation in which some other individual is better off and no individual is worse off.

2.6 The effects of nominal and real shocks under flexible prices

We can now use our apparatus to analyze the macroeconomic effects of monetary and productivity shocks (Christiano, Eichenbaum and Evans 1999, 2005, Clarida, Gali and Gertler 2000, Gali 2003, Goodfriend and King 2001, Walsh 2003, Woodford 2003). Throughout the analysis, we focus on *positive* shocks, defined as unexpected increases in μ and Z (with the understanding that the analysis of negative shocks would be perfectly symmetric).

When prices are fully flexible, as in (7), the effects of monetary shocks (exogenous changes in μ) are straightforward: nothing changes in terms of real equilibrium allocation. In fact, to the extent that μ and P move instantaneously in the same proportion, consumption remains unchanged.

Consider now a productivity boom under flexible prices. In this case, an increase in Z does not affect the equilibrium level of employment, which remains constant at $\bar{\ell}$. Instead, a shock to Z raises proportionally the equilibrium level of output for a given $\bar{\ell}$, generating excess supply in the economy. If nominal spending μ (and the wage rate W) does not change, marginal costs fall reflecting higher productivity. The price level P then falls enough to boost consumption demand to the new level of output.

Figure 2 illustrates graphically the effect of the positive productivity shock just described. Let O be the initial equilibrium allocation. An increase in Z tilts the 'AS' locus upwards: higher productivity raises the level of consumption that is sustainable for any given employment level. With employment at $\bar{\ell}$ and no change in the monetary stance μ, prices fall in response to the excess supply, shifting the 'AD' locus upward. The new equilibrium, A in the Figure, corresponds to an increase in consumption (measured by the segment OA) and lower prices, while employment remains unchanged at its natural rate $\bar{\ell}$.

2.7 Sticky prices and the effectiveness of monetary policy

What do the data say about the equilibrium response to productivity shocks? While the issue has not been controversy-free from a methodological viewpoint, the empirical consensus is that technology improvements are to some extent contractionary on impact. This evidence can hardly be reconciled with the adjustment process implied by flex-price models and synthesized in the previous paragraph (Basu, Fernald and Kimball 2006). Instead, models in which prices are sticky in the short run provide a simple analytical framework consistent with the stylized facts.

If P cannot adjust, aggregate demand is pinned down by monetary policy μ; without a change in nominal spending, consumption is constant in real terms in the short term. Hence, fluctuations in productivity that are not matched by changes in aggregate demand necessarily translate into changes in short-run employment and output. Relative to the natural rate of employment and output, a positive productivity shock opens both an employment gap and an output gap.

Figure 2 illustrates these points. Without price flexibility, a productivity shock that rotates the 'AS' locus upwards does not translate into a fall in prices, and therefore is not matched by a proportional upward movement of the 'AD' locus. Unless μ is raised by the monetary authorities, the new short-run equilibrium will correspond to the point B in which the new 'AS' locus crosses the (unchanged) 'AD' locus. Comparing the short-run equilibrium B with the initial equilibrium O, employment falls below $\bar{\ell}$ while output and spending remain unchanged, both in nominal and in real terms. Agents are able to maintain the same level of consumption in spite of a loss of wage incomes, thanks to higher dividend incomes accruing from the firms they own.

As shown in Figure 3, a productivity shock opens an employment gap OB, which in our economy is proportional to the output gap OA.[10] Note that the appropriate measure of output gap in our context is the difference between the amount of resources that *could* be produced and consumed under flexible prices (at point A), and the *actual* amount produced in the presence of nominal rigidities (at point B).

Monetary policy can be effective in this framework. Provided monetary authorities are able to observe or predict Z with accuracy, and can use appropriate policy instruments to control nominal spending, they can engineer a monetary expansion to raise μ and bring the economy to operate *as if* prices were flexible. Figure 3 shows what happens when policymakers use monetary instruments to raise μ in proportion with Z: the 'AD' curve shifts up by the amount OA and closes the employment and the output gaps. As a result, the short-run inflexibility of prices does not prevent the economy from operating at the natural rate.

Note that the monetary stance that brings employment and output to their natural rates is expansionary when the economy experiences a productivity shock that opens negative employment and output gaps (by symmetry, it will be contractionary when an adverse productivity shock leads to overheating of the economy at unchanged demand conditions). Intuitively, thanks to the productivity boom firms are potentially able to supply an increased amount of consumption goods. But if prices do not fall, consumers whose nominal incomes are unchanged are unable to purchase these additional products. Hence the need for a monetary stimulus, which generates additional aggregate demand and brings the economy back to potential. By moving in tandem with productivity shocks, monetary policy stabilizes the markups of domestic firms.

Needless to say, once we move beyond the boundaries of our stylized framework and account for additional realistic elements, there are other possible policy trade-offs that make monetary policy less effective than suggested by the above analysis. Namely, monetary policy will not target 'exactly' the flex-price allocation in the presence of cost-push and sectoral shocks, dual wage and price rigidities, investment dynamics etc. Yet, the main principles established in this section remain largely valid: for instance, in response to positive supply shocks that generate deflationary pressure, it is generally meaningful for the policy authorities to provide nominal stimulus to the economy by easing the monetary stance. We return to this points in Section 6.

3 Exchange rates and prices in open economies

We now extend our analysis to the study of interdependent, open economies. Relative to the closed-economy model analyzed above, there are at least two new important features to consider.

First, firms sell now in two markets, both domestically and abroad. As the NOEM literature has emphasized, modelling nominal rigidities thus raises important issues about firms' pricing behavior. Are product prices preset in the domestic currency only? Or, rather, do firms fix two sets of prices, one for the domestic market and the other for the export

[10] With P fixed during the period, there is no short-run inflation (deflation) in response to positive (negative) output gaps. However, one could obtain some responsiveness of the 'AD' schedule to productivity shocks by allowing for an imperfect degree of short-run price flexibility — without changing the message from our results above. For instance, if prices could partially respond to excess supply, a fall in the price level would somewhat raise the 'AD' schedule, moving the equilibrium allocation closer to the natural rate.

market (provided that product markets are sufficiently segmented so that agents cannot arbitrage price differentials)?

A second difference is that, in addition to the macroeconomic distortions associated with nominal rigidities and monopoly power in production, there is now a new distortion related to a country's monopoly power on its terms of trade, that is, the relative price of foreign (traded) goods in terms of domestic (traded) goods. In fact, firms ignore the impact of their pricing and production decisions on the country's overall terms of trade. A decentralized equilibrium reflects this inefficiency, adding a further dimension to the policy problem.

In what follows we build a two-country general-equilibrium theoretical framework. This is the analytical skeleton of the medium- and large-scale multi-country DSGE models for policy evaluation currently under development at policy institutions worldwide, such as GEM at the International Monetary Fund, SIGMA at the Fed Board of Governors, and NAWM at the European Central Bank, among others. Our graphical apparatus in the two-country case is to a large extent similar to the one developed for closed-economy analysis. However, because of a number of features specific to open economies, the derivation and interpretation of the equilibrium schedules need to be modified appropriately.

3.1 Extending the basic model to the world economy

The world economy consists of two countries of equal size, Home and Foreign, each producing a country-specific type of good that is traded worldwide. Countries and types of goods are denoted by the letters H and F, respectively. Similar to the closed-economy case, in each country monopolistic competitors produce imperfectly substitutable varieties of the same national good, employing a linear technology with labor as the only input in production.

Households consume both national and foreign goods. In both countries the elasticity of substitution between different varieties of the same type of goods (θ) is higher than the elasticity of substitution between the two types of goods H and F, that we posit equal to one.[11]

In terms of notation, we adopt the convention that prices denominated in Foreign currency, as well as quantities chosen by Foreign firms and households, are denoted with a star. So, the Home and Foreign consumer price indexes are denoted by P and P^* respectively, employment levels by ℓ and ℓ^*, aggregate consumption levels by C and C^*. Home consumption C is a symmetric basket of the two country-specific goods: C_H is Home consumption of the Home good, and C_F is Home consumption of the Foreign good. By the same token, C_F^* is Foreign consumption of local varieties and C_H^* denotes Foreign imports from the Home country. Similarly, P is an index of the prices of the two goods P_H and P_F in the Home countries, and P^* is an index of the prices P_H^* and P_F^* in the Foreign country.

There are three international prices. First, the *nominal* exchange rate is denoted $\mathcal{E}$, defined as Home currency per unit of Foreign currency. Second, the *real* exchange rate is defined as the relative price of the Foreign consumption basket in terms of Home consumption baskets, and is therefore $\mathcal{E}P^*/P$. Third, the *terms of trade* are defined as the relative price of Home imports in terms of Home exports, or $P_F/\mathcal{E}P_H^*$. Each international price is defined in such a way that its increase represents a depreciation or deterioration from the viewpoint of the Home country.

[11] See Tille 2001 for a theoretical extension of this setup and Bergin 2003 for an empirical assessment of similar models.

We denote the country-specific monetary stances with μ and μ^* respectively. In each country output is subject to a country-specific productivity shock, denoted by Z and Z^*.

Our stylized model has no room for capital accumulation and international investment, thus has intrinsically little to say about the main driving forces of current account adjustment. Also, given our emphasis on the mechanism of price adjustment in response to world shocks, it is meaningful to opt for simplicity and to minimize analytical differences with respect to the closed-economy case. For these reasons we proceed by positing from the start that there is balanced trade, so that aggregate net exports are zero in each country:

$$P_F C_F = \mathcal{E} P_H^* C_H^* \tag{14}$$

A synthesis of the model (except the equations determining prices) is given in Table 1. It is also illustrated in Figure 4, with the Home country on the left and the Foreign country on the right. As for the closed-economy case, the monetary stance in each country synthesizes the effect of monetary policy on nominal spending. Hence the 'AD' schedule (first row of Table 1) is formally identical to the 'AD' in the previous sections. However, private spending on consumption now falls on both Home and Foreign goods. As shown by the second and third rows in Table 1, nominal spending on consumption is equally divided between domestically produced goods and imports, consistent with the assumption of symmetric consumption baskets. Hence, relative to the closed economy case, the domestic price level is an equally-weighted index of domestic and import prices (fourth row of Table 1).[12]

The 'AS' schedule (fifth row of Table 1) is also different from the closed-economy case, since it now translates the supply of domestic goods into the consumption of *both* domestic and imported goods. The Home (Foreign) 'AS' schedule includes the new term τ (τ^*), defined in the sixth row of Table 1. To understand this term, observe that at current prices it takes $1/\tau$ units of Home output to buy one unit of the Home consumption basket C (a symmetric definition applies to the Foreign economy).

Intuitively, τ must then be a function of the degree of openness of the Home economy. In fact, in a symmetric equilibrium τ is equal to $1/2$, the size of imports in the Home consumption basket. Graphically, the important implication is that the 'AS' locus is flatter relative to the closed-economy case (or $\tau = 1$). Recall (from Figure 1) that in the closed-economy equilibrium there is a wedge between the (low) slope of the indifference curve and the (high) slope of the 'AS' locus, as monopolistic competition creates a distortion between marginal rate of transformation and marginal rate of substitution. Now, in an open economy (Figure 4) the slope of the 'AS' locus is lower, and consequently the difference between the two slopes at the equilibrium point O is smaller. This is because in equilibrium there are now *two* distortions — the monopolistic distortion *and* the terms of trade distortion — that to some extent offset each other. This point has important implications for the relation between openness and inflationary bias. We return on this issue in Section 5.

As we discuss below in detail, the price of consumption in terms of output is also a function of the terms of trade between the two countries, defined above as the price of imports in terms of the price of exports, or $P_F/(\mathcal{E}P_H^*)$. For instance, a lower international price for

[12] For this reason, nominal price rigidities do not necessarily rule out endogenous fluctuations in the consumer price indexes P and P^*, which may reflect movements in import prices in response to appreciation or depreciation of the currency. For instance, given μ, an increase in $\mathcal{E}$ may raise the Foreign good price in domestic currency, thus reducing Home aggregate demand. However, such 'imported inflation' would affect not only the level, but also the composition of consumer demand. In fact, Home consumption would switch in favor of the now cheaper domestic good.

Table 1: The open-economy model

	Home country	Foreign country
The AD block	$C = \mu/P$	$C^* = \mu^*/P^*$
	$P_H C_H = \frac{1}{2} PC$	$P_F C_F = \frac{1}{2} PC$
	$P_H^* C_H^* = \frac{1}{2} P^* C^*$	$P_F^* C_F^* = \frac{1}{2} P^* C^*$
	$P = 2 P_H^{1/2} P_F^{1/2}$	$P^* = 2 P_H^{*1/2} P_F^{*1/2}$
The AS block	$C = Z \ell \tau$	$C^* = Z^* \ell^* \tau^*$
	$\tau \equiv \left[\frac{P}{2} \left(\frac{1}{P_H} + \frac{1}{\mathcal{E} P_H^*} \right) \right]^{-1}$	$\tau^* \equiv \left[\frac{P^*}{2} \left(\frac{1}{P_F^*} + \frac{\mathcal{E}}{P_F} \right) \right]^{-1}$
Exchange rate	$\mathcal{E} = \frac{\mu}{\mu^*}$	
Natural Rate	$\bar{\ell} = \frac{\theta - 1}{\theta \kappa}$	$\bar{\ell}^* = \frac{\theta - 1}{\theta \kappa}$

the Home good worsens the Home terms of trade and reduces τ, causing a downward rotation of the 'AS' schedule. For any level of Home consumption, Home output and employment must now rise. So, in an open-economy context the 'AS' can tilt downward either because of negative productivity shocks (which are exogenous), or because of relative price movements worsening the terms of trade (which are endogenous).

Finally, in our economy the nominal exchange rate $\mathcal{E}$ depends on current and expected future monetary developments in the Home country relative to the rest of the world (last row of Table 1). This result is a direct consequence of the balanced trade assumption (14) which, in light of the spending equations above, can be rewritten as:

$$PC = \mathcal{E} P^* C^* \tag{15}$$

Accounting for the 'AD' equations, we obtain $\mathcal{E} = \mu/\mu^*$ in Table 1.[13] A Home monetary expansion and/or a Foreign monetary tightening depreciate the Home nominal exchange rate. Similarly, $\mathcal{E}$ appreciates when the monetary stance of the Home country is contractionary

[13] What would happen if we relaxed the balanced trade assumption? In principle, national residents in the two countries would benefit from having access to international financial markets, trading securities whose payoffs move in tandem with the domestic shocks, and reducing the exposure of their wealth and consumption to national sources of risk. Consider the opposite extreme case of complete international asset markets. In this case, the ratio of the marginal utilities of Home and Foreign consumption in any state of

relative to the Foreign stance.

As in the closed-economy model, in the absence of nominal rigidities firms charge an optimal fixed markup over marginal costs. With linear technologies and constant-elasticity demand functions, there is no incentive for a firm to price-discriminate across markets: this implies that prices are equalized across countries when expressed in terms of the same currency, i.e. the 'law of one price' holds. Thus, the four equations determining the four (flexible) prices P_H^{flex}, P_F^{flex}, P_H^{*flex}, P_F^{*flex} are:

$$P_H^{flex} = \mathcal{E} P_H^{*flex} = \frac{\theta\kappa}{\theta - 1}\frac{\mu}{Z} \tag{16}$$

$$P_F^{*flex} = \frac{P_F^{flex}}{\mathcal{E}} = \frac{\theta\kappa}{\theta - 1}\frac{\mu^*}{Z^*} \tag{17}$$

Once again, the natural employment rates 'NR' in both countries can be easily calculated using these expressions together with the 'AD' and 'AS' equations.

To sum up: the 'AS' is a line through the origin. Its slope includes a term reflecting openness and the level of the terms of trade. The natural rate locus 'NR' remains identical in both the closed- and open-economy versions of our model — a property that will be very useful in carrying out comparative analysis of our results. The 'AD' is similar to the closed-economy case: it draws a horizontal line in the (ℓ, C) or (ℓ^*, C^*) spaces depicted in Figure 4. However, in a closed economy P_H and P coincide, so that nominal rigidities affecting the producer price P_H imply that the consumer price index P is also fixed in the short run. This need not be the case in an economy open to international trade: in the Home country, the consumer price level P may now adjust in the short run — despite nominal rigidities affecting the producer price P_H — per effect of fluctuations in import prices P_F driven by the exchange rate $\mathcal{E}$.

3.2 Nominal rigidities and the pricing of exports

The recent literature has revived an important debate about the empirical evidence on the response of prices to exchange rate movements, providing different possible approaches to model nominal rigidities in an open economy. Empirical evidence on the elasticity of exchange rate pass-through onto import (export) prices supports few certainties: this elasticity is smaller over the short term than in the long run, it varies across sectors and countries, and is different for consumer goods and wholesale prices (Goldberg and Knetter 1997, Campa and Goldberg 2005).

Considered as a decision variable of the exporter, the determinants of exchange rate pass-through may clearly include some of the variables considered in our model such as the volatility of monetary and real shocks (Taylor 2000, Corsetti and Pesenti 2002, Devereux, Engel and Storgaard 2004). But it may reasonably depend on many other factors outside the scope of our contribution — such as the exporter-importer working relationship stressed

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nature must be proportional to the relative price of consumption (i.e. the real exchange rate):

$$\frac{\partial U^*/\partial C^*}{\partial U/\partial C} = \frac{P^*\mathcal{E}}{P}$$

Now, given the specification of utility in (1) and its Foreign analog, the risk-sharing expression above can be written exactly as (15)! Cole and Obstfeld 1991 show that under condition isomorphic to our parameterization, movements in the terms of trade are sufficient to guarantee full consumption risk-sharing across countries exactly as if agents had access to a system of transfers contingent to the realization of the shocks.

in the relationship-marketing literature, the presence of distribution costs (Corsetti and Dedola 2005, Laxton and Pesenti 2003), the market share of exporters in the local market (Bacchetta and Van Wincoop 2005), or the availability of financial strategies to limit exposure of exporters' profits to exchange rate fluctuations (Friberg 1998).

Given the scope of our contribution, we take the degree of pass-through as an exogenous factor linked to the invoice currency in the presence of nominal rigidities. In what follows we discuss three possible specifications of export prices consistent with such an approach.

'Producer Currency Pricing' (PCP) In a first class of models, firms preset prices in their own currency and let prices abroad move one-to-one with the exchange rate (Obstfeld and Rogoff 1995, 1996 ch.10, 2000, Corsetti and Pesenti 2001). In other words, P_H and P_F^* are sticky but P_F and P_H^* are not. Since export prices are set in the producer's currency, the literature often refers to this case as 'Producer Currency Pricing', or PCP. With PCP, firms optimally set:

$$P_H = \mathcal{E}P_H^* = \frac{\theta\kappa}{\theta - 1}E\left(\frac{\mu}{Z}\right) \tag{18}$$

$$P_F^* = \frac{P_F}{\mathcal{E}} = \frac{\theta\kappa}{\theta - 1}E\left(\frac{\mu^*}{Z^*}\right) \tag{19}$$

Observe that in this case there is one-to-one pass-through of exchange rate movements onto the price of imports, at both the border and the consumer-price level. As demand elasticities are identical in the two countries, the 'law of one price' holds: once measured in the same currency, goods prices are the same in all markets.

Under PCP, the terms of trade $P_F/\mathcal{E}P_H^*$ are equal to $P_F^*\mathcal{E}/P_H$. Since P_H and P_F^* in (18) and (19) are preset, the Home terms of trade worsen with a nominal depreciation of the Home currency (i.e. a higher $\mathcal{E}$). The same nominal depreciation of the Home currency will instead appreciate the Foreign terms of trade. Thus, when the Home currency weakens, Home goods are cheaper relative to Foreign goods in both the Home and the Foreign country. As demand shifts in favor of the goods with the lowest relative price, world consumption of Home goods increases relative to consumption of Foreign goods. These are referred to as 'expenditure switching' effects of exchange rate movements.

'Local Currency Pricing' (LCP) According to a second class of models, firms preset a price in domestic currency for the domestic market, and a price in foreign currency for the export markets (Bacchetta and van Wincoop 2000, Betts and Devereux 2000, Chari, Kehoe and McGrattan 2002, Duarte and Stockman 2005). Since export prices are preset in the consumers' currency, the literature often dubs this case as 'Local Currency Pricing', or LCP. With LCP firms optimally set:

$$P_H = \frac{\theta\kappa}{\theta - 1}E\left(\frac{\mu}{Z}\right) \qquad P_H^* = \frac{\theta\kappa}{\theta - 1}E\left(\frac{\mu}{\mathcal{E}Z}\right) \tag{20}$$

$$P_F^* = \frac{\theta\kappa}{\theta - 1}E\left(\frac{\mu^*}{Z^*}\right) \qquad P_F = \frac{\theta\kappa}{\theta - 1}E\left(\frac{\mu^*\mathcal{E}}{Z^*}\right) \tag{21}$$

Exchange rate pass-through onto import prices is zero both at the border- and the consumer-price level. The law of one price is violated with any unanticipated fluctuation of the exchange rate: unless the exchange rate is fixed or perfectly forecastable, the consumer price of the Home good in domestic currency P_H will be different from its export price in Home currency $\mathcal{E}P_H^*$. Analogously, the consumer price of the Foreign good in Foreign currency P_F^* will be different from its export price in Foreign currency $P_F/\mathcal{E}$.[14]

Observe that, with P_H^* and P_F predetermined in the short run, a nominal depreciation of the Home currency improves the Home terms of trade $P_F/\mathcal{E}P_H^*$. Correspondingly, the Foreign terms of trade worsen. The effects of currency movements on the terms of trade go in the opposite direction relative to the PCP case. Since prices are preset in local currency, exchange rate fluctuations do not affect the relative price faced by importers and consumers. There is no 'expenditure switching' effect of exchange rate movements.

'Dollar Pricing' (DP) While the literature has mainly focused on the previous two polar cases, there is also a third possibility (probably the most relevant one from an empirical viewpoint): the world export prices are set in one 'vehicle' currency only, say, in the Home country's currency. Home firms preset all prices in their own currency; Foreign firms preset export prices in the Home currency (Corsetti and Pesenti 2005a, Devereux, Engel and Tille 2003, Devereux, Shi and Xu 2007). In this case — that we dub 'dollar pricing' or DP — we have:

$$P_H = \mathcal{E}P_H^* = \frac{\theta\kappa}{\theta - 1} E\left(\frac{\mu}{Z}\right) \tag{22}$$

$$P_F^* = \frac{\theta\kappa}{\theta - 1} E\left(\frac{\mu^*}{Z^*}\right) \qquad P_F = \frac{\theta\kappa}{\theta - 1} E\left(\frac{\mu^*\mathcal{E}}{Z^*}\right) \tag{23}$$

In the DP case the law of one price only holds for the Home country products. Exchange rate pass-through is asymmetric: it is zero in the Home country, but complete in the Foreign country. Thus, a Home depreciation does not affect the price of imports in the Home country, but lowers the price of imports in the Foreign country. Interestingly, however, the benefits of lower prices and higher purchasing power for the Foreign country consumers are offset by the profit losses of Foreign firms and shareholders. In fact, Foreign firms that export to the Home country sell their products at the price P_F — which is fixed in the short run — but repatriate their export sales revenue at the rate $1/\mathcal{E}$ — which falls with the Home currency depreciation.

Export pricing and the natural rate We conclude this section by noting an important property of the model. Independent of which pricing specification is selected among the three possibilities described above, expected employment is always equal to its natural rate — exactly as in the closed economy. As a straightforward implication of the equations presented above, we have in fact:

$$E(\ell) = E(\ell^*) = \frac{\theta - 1}{\theta\kappa} \tag{24}$$

for *any* characterization of the nominal rigidities in the export markets.

4 International macroeconomic transmission

In this section we study the international transmission of country-specific productivity shocks. Similar to the closed-economy case, we start by considering the allocation with

[14] It is worth restating that, for these differences to be a feature of a market equilibrium, one needs to assume that no agent in the economy can take advantage of arbitrage opportunities in the goods markets.

flexible prices, which provides a benchmark to guide our policy analysis below. Next, we study the equilibrium allocation and international spillovers when policymakers react to shocks by pursuing policies that stabilize output and employment at their natural rate — the policy conduct that, as we saw above, is able to replicate the flex-price allocation in a closed economy.

4.1 Domestic and foreign effects of productivity shocks under flexible prices

Figure 5 illustrates the macroeconomic response to a positive productivity shock in the Home country, assuming that prices are perfectly flexible. On impact, a positive shock to Z rotates the 'AS' schedule upward. We have seen that the natural rate of employment is independent of productivity shocks. Hence, in an equilibrium without price rigidities higher productivity raises consumption along the 'NR' locus. Different from the closed economy case, however, the higher supply of Home goods lowers their international price: the terms of trade move against the Home country.[15]

The fall in τ, that reflects worsening terms of trade, tilts the 'AS' schedule downward, partially offsetting the upward rotation of the 'AS' due to a positive Z shock. In other words, relative to the closed-economy case, a shock to Z makes the 'AS' rotate by less. For any given Home monetary stance μ the domestic marginal cost and the price of Home goods P_H both fall one-to-one with the productivity increase. The Home CPI P also falls, although by less than P_H as part of Home consumption falls on imported Foreign goods. Hence the 'AD' shifts upwards, but not as far as it would in a closed economy. The equilibrium moves from point O to point H.

Part of the gains from higher productivity in the Home country accrue to consumers abroad. The fall in the international price of Home goods raises Foreign incomes in real terms. Because of lower import prices, the Foreign terms of trade are stronger, raising τ^*: the 'AS*' rotates upward. Lower import prices also lower the Foreign CPI P^*, raising consumption demand along with the 'AD*' schedule. The equilibrium in the Foreign country moves from point O^* to point H^*. Overall, Foreign consumption increases while employment remains at its natural level. This is an unambiguous welfare gain for the Foreign economy. The international transmission of productivity shocks is clearly positive.

4.2 Productivity shocks in open economies with nominal rigidities

In the presence of nominal rigidities, the macroeconomic impact of country-specific productivity shocks is sharply different. An unexpected increase in Home productivity does not move the nominal exchange rate, which only responds to monetary factors. Hence the shock has no impact on import prices, which are either sticky (as in LCP case) or move with the exchange rate (as in the PCP case). With no changes in prices and the CPI, aggregate demand is constant in real terms in both countries. Higher domestic productivity at Home therefore translates into a lower level of domestic employment — precisely as in the closed-economy case. Without changes in the exchange rate, there are no consequences for the Foreign economy.

[15] A new generation of models are revisiting the implications of productivity shocks on the terms of trade when accounting for creation and trade of new product varieties. The analysis of this section only focuses on the 'intensive' margin of trade, that is the international performance of sectors producing a given set of varieties, without studying the 'extensive' margin associated with new traded products. See Bergin and Glick 2003, Ghironi and Melitz 2005, and Corsetti, Martin and Pesenti 2007.

The previous point can be restated in graphical terms, as in Figure 6: other things equal, a positive shock to Home productivity rotates the 'AS' upward and opens an employment/output gap. The equilibrium moves from point O to point B. Consumption is not affected, economic activity is too low — exactly as in the sticky-price equilibrium of Figure 2. The Foreign economy remains completely unchanged at point O^*.

Note that this result holds regardless of the specification of nominal rigidities in the export markets (i.e. PCP or LCP or DP). In all cases, productivity shocks have no direct effects on prices and exchange rates. But as for the closed economy, shocks that translate into undesirable employment fluctuations, and open employment and output gaps, invite a monetary policy response. Thus, productivity shocks may have an indirect effects on prices, via changes in the monetary stance aimed at stabilizing the macroeconomy.

4.3 Stabilization properties of the exchange rate (the PCP model)

In our analysis of the closed economy we have seen that, when monetary authorities react to productivity shocks by closing the output gap completely, the market equilibrium coincides with the flex-price allocation. Is monetary policy equally effective in our open-economy setting? To answer this question we need to focus on the role of exchange rate movements in the international transmission mechanism.

The conventional wisdom exemplified by the enduring contributions of Friedman 1953 and Mundell 1963 suggests that, in a world with nominal price rigidities, exchange rate movements facilitate the efficient adjustment of international relative prices. With flexible prices, the relative price of Home goods falls in response to a positive productivity shock. With sticky prices, adjustment can be achieved via an exchange rate depreciation (corresponding to Home monetary expansion relative to Foreign), that lowers the international price of the Home goods relative to Foreign goods.

To revisit the theoretical foundations of the conventional wisdom, we can reconsider our open-economy model under PCP (the first of the three export-pricing specifications discussed above). We focus on the following scenario. There is an unexpected, positive increase in productivity in the Home country. Home monetary policymakers are assumed to adopt an 'inward-looking' policy rule, and set the monetary stance to close the domestic output gap opened by productivity fluctuations. Foreign monetary policymakers maintain a constant monetary stance. This scenario provides a useful baseline for our analysis of the international transmission mechanism. Note that we have said nothing about the optimality of the policy responses described above: we take these monetary conducts as given and analyze their macroeconomic properties. Later, we discuss whether or not these policies can be rationalized as welfare-maximizing.

The experiment is illustrated in Figure 7. The positive productivity shock at Home rotates the 'AS' upward, but when the monetary authorities respond to the shock by loosening the monetary stance, the exchange rate depreciates and the terms of trade fall, lowering τ: a drop in τ offsets in part the rotation of the 'AS' due to Z. At the same time, looser monetary conditions (a higher μ) shift the 'AD' upward, but less than one-to-one. This is because, to the extent that import prices rise with exchange rate depreciation, the country experiences some CPI inflation. The Home economy moves from O to H along the 'NR' schedule.

The exchange rate depreciation in the Home country improves the terms of trade abroad: a higher τ^* tilts the 'AS*' upward. Note that the 'AS*' rotation does not reflect any improvement in Foreign productivity (Z^* remains constant). Lower import prices translate into a fall of the Foreign CPI. For a given Foreign monetary stance μ^*, a fall in the price level raises demand, shifting the 'AD*' curve upwards. The Foreign economy moves from point O^* to point H^* along the 'NR*' schedule, mirroring the adjustment of the Home economy. In the new equilibrium, Foreign households enjoy a higher level of consumption for an unchanged level of labor effort. The international transmission of Home shocks is unambiguously positive.

Three points are worth emphasizing. First, in a PCP world it is possible to undo the effects of nominal rigidities and replicate the flex-price allocation by following exactly the same policy prescription considered in the closed-economy case (μ moves one-to-one with Z). A policy that targets domestic price stability, and closes the Home employment gap, raises consumption at Home and abroad in proportion to productivity. Given that employment remains constant in equilibrium, higher Home productivity Z means a higher world supply of Home goods. In an efficient allocation, their world prices must drop.

Second, observe that with nominal prices sticky in domestic currency, it is the exchange rate that induces the efficient adjustment in relative prices, re-directing world demand towards the more abundant product. Thus, under PCP exchange rate movements are stabilizing and exchange rate flexibility is desirable.[16]

Third, we should note however that, since the exchange rate is equal to the relative monetary stance, the 'right' price adjustment through the exchange rate depends on the 'right' conduct of monetary policy.[17] While the equilibrium of Figure 5 is exactly similar to the equilibrium of Figure 7 (points H and H^* are the same in the two Figures), the adjustment mechanisms are different. In the flex-price case of Figure 5 adjustment is automatic. Under price stickiness as in Figure 7 efficient adjustment requires a specific and deliberate course of action by the monetary policymakers.

4.4 Market segmentation and imperfect pass-through (the LCP model)

According to the conventional view, exchange rate movements modify the relative price of domestic and imported goods. However, empirical studies and casual observation suggest that, in practice, the prices of most imported goods at the consumer level are rather inelastic to exchange rate movements (Engel 1999, Engel and Rogers 1996, Goldberg and Knetter 1997, Parsley and Wei 2001, Rogoff 1996). Then, exchange rate movements may not induce the expenditure switching-effects that the conventional view places at the heart of the transmission mechanism (Engel 2002).

Consider our model under the assumption that firms preset prices in domestic currency for the national market, and in foreign currency for the export market (the LCP case discussed above). With nominal rigidities, all prices in the world economy are now fixed in the short run regardless of currency fluctuations. In contrast to the PCP case, exchange rate movements neither affect the price of the Home goods abroad, nor re-direct world demand towards them. The crucial effect of exchange rate movements in this economy is on

[16] This general principle is subject to a number of caveats, as 'optimal' exchange rate regimes depend in practice on the circumstances of the particular country and time (Frankel 1999).

[17] From a global perspective, the effect of the Home monetary expansion can be broken down into two components. The first component is symmetric and affects the level of world demand: a looser monetary stance at Home translates into a looser monetary stance for the world economy as a whole, raising consumption worldwide. The second component is instead asymmetric and affects the composition of world demand. The monetary stance is relatively more expansionary at Home, depreciating the exchange rate, and redirecting world demand towards Home goods.

firms' markups and profits. Since the Foreign-currency price of the Home goods is preset, a depreciation of the Home exchange rate raises the revenue in domestic currency of each unit of product sold abroad: hence the markup over marginal costs increases with depreciation. But this means that nominal depreciation improves — instead of worsening — the Home terms of trade $P_F/\mathcal{E}P_H^*$.

Let's reconsider the equilibrium effects of a productivity shock when Home monetary authorities stabilize the output gap in the new framework (Figure 8). As in the PCP case above, a positive productivity shock rotates the 'AS' upward, and a Home monetary expansion raises Home nominal spending. However, its macroeconomic effects differ from the PCP case in two important respects. First, raising μ now has a much stronger impact on the aggregate demand, since all consumer prices are sticky in the short run. Even if the exchange rate depreciates, there is no 'imported inflation'. The 'AD' shifts one-to-one with μ (as in the closed economy case). Second, the Home depreciation improves the terms of trade: τ rises with the exchange rate and the 'AS' rotates upwards even further, reinforcing the initial impact of the productivity shock.

The Home economy moves from point O to point L. In the new equilibrium, employment is at its natural rate (this is by construction, given our assumption about Home monetary policy), but stronger terms of trade allow domestic households to increase their consumption much more than in the PCP case. For any given shock to Z, the segment OL in Figure 8 is larger than the segment OH in Figure 7. The economy operates away from its flex-price benchmark allocation, delivering higher utility to domestic households.

The extra gains for the Home economy come at the expense of the Foreign country. Home expansions have no effect on Foreign consumption. Foreign consumer prices are preset in Foreign currency and are therefore inelastic to exchange rate movements in the short run: the Foreign 'AD*' schedule does not move. Conversely, the Foreign terms of trade now worsen with the Home currency depreciation. The 'AS*' rotates downward and hours worked increase: Foreign country residents need to work more to sustain the same level of consumption. A higher level of effort at an unchanged level of consumption unambiguously worsens Foreign households' welfare. The international transmission of policy shock is clearly negative, that is 'beggar-thy-neighbor'.

To sum up, the main predictions of the LCP model are quite distant from the PCP case. The sign of policy transmission is different: positive in the PCP case, negative in the LCP case. Also far apart are the responses of international prices: in a world with PCP, monetary expansions worsen the terms of trade; they improve it in the LCP case. In the PCP case, exchange rate movements affect relative prices for a given consumption level, switching demand across different categories of goods. In the LCP case, there is no expenditure-switching effect from exchange rate movements. If anything, what is switched is the labor burden to sustain world consumption.

4.5 A case of asymmetric transmission (the DP model)

Transmission in an economy where all export prices are set in one currency (the DP case) somewhat combines the two cases discussed above. The crucial feature of such an economy is that different mechanisms mute the responses of τ and τ^* to shocks. In the Home country, consumer prices do not respond to the exchange rate, while dollar pricing insulate exporters' markups from exchange rate movements. In the Foreign country, the positive effects of lower import prices are offset by a fall in profits from exports: the local-currency value of export sales fall with the Home depreciation.

We can visualize these effects in Figure 9. Once again, the shock to Z tilts the 'AS' upward and prompts an increase in μ to close the output gap. In the Home country, where all prices are preset in Home currency, the monetary expansion raises domestic demand one-to-one. The ensuing Home depreciation has no implications for the profits of domestic firms, since pass-through of exchange rate movements onto Home export prices is complete. Consumption rises above the natural rate, while employment remains at the natural rate. The Home economy moves from O to D, where the length of the segment OD lies somewhere between OH in Figure 7 and OL in Figure 8.

In the Foreign country, Home depreciation translates into lower import prices, hence into a lower CPI. For a given domestic monetary stance, the 'AD*' shifts upward. But since there is no effect on the relative price of consumption in terms of output, τ^*, the 'AS*' does not rotate. The Foreign economy moves from point O^* to point D^* along the unchanged 'AS*' schedule. Thus, in the new equilibrium Foreign households enjoy higher consumption (actually, as high as in the PCP case: the gain in Foreign consumption O^*H^* in Figure 9 is equal to the segment O^*H^* in Figure 7), but also work more. In other words, the international transmission is positive as regards consumption, negative as regards labor effort. However, to the extent that monopolistic distortions in production are more relevant than the terms of trade distortion, the first component dominates and the international transmission is overall positive. In this case, in fact, the indifference curve in the pre-shock equilibrium cuts the 'AS*' from above. Hence a small movement along the 'AS*' raises welfare.

Note that, from the point of view of Foreign consumers, the exchange rate plays a stabilizing role in the product market: Home currency depreciations lower the price of Home goods. The sign of the adjustment is consistent with the flex-price benchmark. But the negative implications of exchange rate movements on Foreign firms' profits are clearly 'destabilizing'. *Vis-a-vis* the received wisdom on international transmission (corresponding to the PCP case) and its strongest critique (the LCP case), the case of 'dollar pricing' stresses the realistic possibility of counteracting effects from exchange rate movements within an economy.

To conclude our analysis of transmission in the DP case, it is worth noticing that the Home economy is fully insulated from external shocks: for any given μ and Z, exchange rate shocks or cyclical developments in the Foreign country have no macroeconomic effects on output, consumption and terms of trade in the Home country. In other words, when Home policymakers respond to local productivity shocks there are repercussions in the rest of the world as illustrated in Figure 9, but when Foreign policymakers react to local shocks there are no spillovers to the Home country economy. This asymmetry stems from the predominant role in global trade of the 'vehicle' currency issued by the Home country.

5 Globalization and inflationary bias

5.1 Monetary discretion in the closed-economy case

In the sections above, monetary policy has been characterized in terms of *ad hoc*, arbitrary rules (such as the Home country targeting full employment and the Foreign country maintaining a passive stance). The remainder of the paper is devoted to an intuitive explanation of 'optimal' policies in closed and open economies.

As a starting point, an important result of our section on monetary policy in a closed economy is that policymakers informed about the state of the economy Z could use monetary instruments to move aggregate demand C toward its flex-price level for a given price level P. Would such a policy conduct be optimal?

To perform such an exercise, we need to specify a welfare metric: in our model, it is natural to assume that the objective function of the policymakers coincides with the utility of the national representative agent, visualized graphically in terms of our map of indifference curves. In Figure 10 we return to the closed-economy model we introduced in Figure 1. The economy is in equilibrium at point O, where actual employment is at its natural rate. The problem with such allocation is that monopoly distortions result in a socially suboptimal level of welfare: in equilibrium the indifference curve cuts the 'AS' curve from above. Once prices are set, *ex-post* utility could be increased through a monetary expansion that moves the equilibrium to the right of $\bar{\ell}$, up to the point X at which the indifference curve is tangent to the 'AS' locus.

To shed light on this point, consider what policymakers would do if they optimized their monetary stance in a discretionary manner once prices have been set. Define as μ_{dis} the monetary stance that maximizes the utility of the representative household, i.e. solves the following problem:

$$\max_{\mu} \ U = \ln C - \kappa\ell = \ln \frac{\mu}{P} - \kappa\ell \tag{25}$$

The monetary authorities take prices as *given*, independent of their decisions. Accounting for (3) and (4), the first order condition of the above problem is:

$$\frac{\mu_{dis}}{PZ} = \frac{1}{\kappa} \tag{26}$$

according to which the optimal monetary policy under discretion pushes labor effort ℓ (the left-hand side of 26) towards its competitive level (the right-hand side of 26) equal to $1/\kappa$.

In our setting there is however a crucial problem in solving for an equilibrium with discretionary monetary policy. Using (26) to solve for P in (10), we obtain:

$$\frac{\mu_{dis}}{Z} = \frac{\theta}{\theta - 1} E\left(\frac{\mu_{dis}}{Z}\right) \tag{27}$$

This condition cannot be part of a rational-expectations equilibrium. In fact, take expectations on both sides of (27): the two sides are equal only when $\theta/(\theta-1) = 1$, i.e. for $\theta \to \infty$. Otherwise, whatever the price level chosen by the firms, there is always an incentive for the policymakers to expand the monetary stance above private expectations and, in terms of Figure 10, manipulate private agents' real incomes to increase employment and consumption at X.

To derive a model where a rational-expectations equilibrium exists, one could modify our specification above by accounting for welfare costs from realized inflation in (25).[18] This approach leads to models in the tradition of the Kydland-Prescott 1977 and Barro-Gordon 1983a,b analysis of inflationary bias. Alternatively, some contributions to the literature analyze monetary policy in economies where distortionary (Pigouvian) tax and subsidies can eliminate the distortions caused by monopoly power, hence making the optimal policy time-consistent.

Suppose in fact that the government can subsidize firms' production at the rate $(1-\zeta)^{-1}$, with $\zeta = 1/\theta$, raising tax revenue in a lump-sum fashion. Then firms' optimality will ensure

[18] For instance, in Albanesi, Chari and Christiano 2003 inflation leads to a costly reduction in consumption purchases because of the operation of the cash in advance constraint.

that prices are equal to expected marginal costs:

$$P = \frac{\theta}{\theta - 1} (1 - \zeta) E \left(\frac{W}{Z} \right) = E \left(\frac{\kappa \mu}{Z} \right) \tag{28}$$

Under these conditions, a monetary stance μ that moves one-to-one with shocks Z is the optimal monetary policy under discretion μ_{dis} as derived in (26). In equilibrium there is no longer any incentive for the policymakers to deviate from the optimal policy:

$$\frac{\mu_{dis}}{Z} = \frac{\theta}{\theta - 1} (1 - \zeta) E \left(\frac{\mu_{dis}}{Z} \right) = E \left(\frac{\mu_{dis}}{Z} \right) \tag{29}$$

The economy operates at an efficient (first-best) natural rate of employment, equal to the competitive level $1/\kappa$, such that the indifference curve in our graph is tangent to the 'AS' curve in equilibrium.

The intuition underlying this result is straightforward. There are two distortions in our closed economy: nominal price rigidities and monopoly power in production. The government needs at least two instruments to achieve efficiency: on the demand side of the economy, monetary policy eliminates the negative consequences of fixed prices; on the supply side of the economy, fiscal policy eliminates distortions due to monopolistic competition. The appropriate monetary *and* fiscal stance allows the policymakers to bring the economy to a first-best allocation.

5.2 Inflationary vs. deflationary bias in open economies

How does economic globalization affect the analysis above? A large literature has focused on the relationship between openness and inflation, providing evidence that more open economies are characterized by lower average inflation rates in a large cross-section of countries (Romer 1993, Lane 1997). We can revisit this point in terms of our apparatus. As for the closed-economy case, the optimal policy in an open economy is not, in general, time-consistent. However, each country faces now the additional distortion related to its monopoly power on the terms of trade. Terms of trade considerations may actually mitigate and possibly offset the inflationary bias described above.

Under discretion Home policymakers maximize agents' current utility with respect to μ after observing the shocks Z and Z^*, taking firms' prices as well as Foreign policy as given. Foreign policymakers solve a similar problem. In the PCP model, the welfare-maximizing monetary stances under discretion are:

$$\frac{\mu_{dis}}{Z} = \frac{1}{2} \frac{\theta}{\theta - 1} E \left(\frac{\mu_{dis}}{Z} \right) \qquad \frac{\mu^*_{dis}}{Z^*} = \frac{1}{2} \frac{\theta}{\theta - 1} E \left(\frac{\mu^*_{dis}}{Z^*} \right) \tag{30}$$

The above conditions cannot be part of a rational expectations equilibrium, except in the special case in which $1/\theta = 2$.[19] We have seen that in a closed economy, monopolistic distortions in production create an incentive for the policymakers to expand demand and

[19] Comparing (29) with (30), an increase in trade openness has effects similar to those of the fiscal subsidy considered before. There is however an important difference. In closed economy the socially optimal level of employment is higher than the natural rate and equal to the competitive level $1/\kappa$; an appropriate subsidy allows the competitive level to be supported in a time-consistent equilibrium. Openness instead reduces the gap between socially optimal employment and natural rate $\bar{\ell}$. This makes it easier — but does not guarantee — for the socially optimal level to be supported in a time-consistent equilibrium. Appropriate fiscal instruments are still required, unless by chance openness and monopolistic distortions happen to *exactly* offset each other.

bring output to its competitive level $1/k$. This need not be true in an open economy. The above expressions make clear that policymakers have an incentive to either expand or contract aggregate demand (given prices) depending on whether the import share in consumption (equal to 1/2 in our specification) is above or below the reciprocal of the markup $(\theta - 1)/\theta$.

In terms of Figure 10, openness reduces (other things equal) the slope of the 'AS' locus. Thus, the slope of the indifference curve at the equilibrium point O can be lower (as in the closed economy case), equal to, or possibly higher than the slope of the equilibrium 'AS'.

Intuitively, recall that in an open economy monopolistic distortions in production coexist with terms of trade distortions, whose magnitude depends — among other things — on the degree of openness of the economy. Under discretion, welfare-maximizing policymakers expand aggregate demand if the former distortions are sufficiently important relative to the latter. When monopoly power in production is sufficiently high ($\theta < 2$ in our specification), policymakers are less concerned with adverse import price movements due to an exchange rate depreciation than with the inefficient level of domestic output. By the same token, in economies that are relatively closed to trade, the exchange rate affects the price of a relatively small share of consumption goods. Also in this case, benevolent policymakers have an incentive to raise output above market equilibrium.

The reverse is true when monopolistic distortions in production are relatively low ($\theta > 2$), or the economy is sufficiently open. In the latter case, while raising output and employment, a monetary expansion would also increase the price of a substantial proportion of consumption goods. When terms of trade movements become the dominant concern in discretionary policy making, monetary authorities actually prefer to engineer surprise re-valuations, as a way to improve the relative prices of their country's output.[20]

We close this section with an important caveat: openness *in itself* need not guarantee a lower inflationary bias. Exchange rate pass-through considerations also matter. In fact, moving away from the PCP model and reducing the degree of pass-through would clearly blunt the terms of trade effects of monetary policy. To show this, consider the LCP case introduced above. When pass-through is low worldwide, the solutions to the policy problems under discretion are:

$$\frac{\mu_{dis}}{Z} = \frac{2\theta}{\theta - 1} E\left(\frac{\mu_{dis}}{Z}\right); \qquad \frac{\mu^*_{dis}}{Z^*} = \frac{2\theta}{\theta - 1} E\left(\frac{\mu^*_{dis}}{Z^*}\right) \tag{31}$$

In this case, discretionary policy is unambiguously biased towards surprise monetary expansions, even *more* so than in the closed-economy case!

6 Optimal monetary policy under commitment

6.1 The closed-economy case revisited

In Section 5 policymakers were unable to commit to a credible monetary policy. In this section we are interested instead in the optimal design of monetary rules, accounting for the fact that forward-looking firms set the prices of their products on the basis of their expectations about both economic fundamentals and policy variables. Is it still true that

[20] It is worth mentioning another dimension of the relationship between globalization and inflation. If globalization increases the degree of competition in the economy and lowers average markups (i.e. moves θ upward), then it also reduces the gap between competitive and natural output. As the distance between O and X shrinks in Figure 10, so does the underlying inflationary bias (Rogoff 2007).

the optimal policy stance does stabilize producers' markups? And what happens when both domestic and foreign firms supply products to local consumers?

To address these questions, we start by re-specifying the appropriate welfare metric. In our model, it is natural to assume that the objective function of the policymakers, here denoted by $\mathcal{W}$, coincides with the *expected* utility of the national representative agent:

$$\mathcal{W} = E(U) = E(\ln C - \kappa \ell) \tag{32}$$

As before, the welfare-maximizing stance is contingent to the realization of the shocks. Different from before, it is determined taking into account that private expectations (and prices) are affected by the specific features of the policy rule itself.

Let's reconsider the closed-economy case, and recall that in a market equilibrium expected employment is constant and equal to its natural rate, according to (12). Thus, using the equilibrium expression for optimal preset prices (10), the welfare criterion simplifies to:

$$\begin{aligned} \mathcal{W} &= E\left(\ln \frac{\mu}{P}\right) - \kappa \bar{\ell} = \\ &= E(\ln \mu) - \ln E\left(\frac{\mu}{Z}\right) + constant \end{aligned} \tag{33}$$

Maximizing the above expression with respect to μ yields:

$$\frac{1}{\mu} - \frac{1/Z}{E(\mu/Z)} = 0 \tag{34}$$

solved by a policy μ that moves one-to-one with productivity shocks Z, say:

$$\mu = \alpha Z \tag{35}$$

where α is an arbitrary positive parameter that firms know when they set their prices.[21]

The previous condition characterizes the optimal monetary policy stance up to the scale of nominal variables in the economy. The optimal policy consists of a commitment to provide a nominal anchor for the economy, α, and to deviate from such stance only when productivity shocks in the economy threaten to destabilize marginal costs and move employment and output away from their potential levels. In our framework, by responding fully and systematically to Z, such policy completely eliminates uncertainty in marginal costs, and thus in profits. Prices are stabilized at the level $P = \alpha\kappa\theta/(\theta - 1)$.[22]

If monetary authorities deliver the optimal monetary stance (35), nominal rigidities are inconsequential, in the sense that policymakers can stimulate aggregate demand to close the output gap and push the economy toward potential regardless of stickiness in price

[21] In expression (35), α need not be constant over time: it can represent any deterministic process that firms are able to predict at the time they take their expectations. Adao, Correia and Teles 2005 provide conditions that rule out indeterminacy, so that the equilibrium is unique. In our framework, this follows from perfect commitment by the central bank, implying that α provides a credible nominal anchor to private sector expectations.

[22] It would be straightforward to restate the results above in terms of inflation rates, rather than price levels. Suppose that the monetary authorities set the nominal anchor according to $\alpha = P_{-1}(1 + \widetilde{\pi})$, where P_{-1} is the lagged price level observed at the time expectations are taken, and $\widetilde{\pi}$ is the 'desired' rate of inflation — i.e. the (implicit or explicit) inflation target of the policymakers, which may be equal to zero. Given the above nominal anchor, in the absence of shocks ($Z = 1$) firms would optimally set their prices equal to α in each period and the economy would exhibit a constant inflation rate equal to $\widetilde{\pi}$,that is: $P/P_{-1} = (1 + \widetilde{\pi})$. But this is precisely the outcome that would prevail in the presence of shocks to Z, provided that the monetary authorities implement (35).

adjustment. In terms of Figure 3, any stochastic rotation of the ‘AS’ locus is perfectly matched by a corresponding shift in the ‘AD’ locus, so that in the short run the equilibrium always lies along the ‘NR’ vertical line above the natural rate. Note that, under optimal monetary policy, consumption will not be constant but rather fluctuate with productivity, perfectly matching the flexible-price allocation.

6.2 High markups and low purchasing power as the outcomes of insufficient stabilization

Having established what optimal policy means in the framework of our model, we can now turn our attention to a different issue: what are the consequences of adopting a sub-optimal monetary policy not aimed at full stabilization? We will show that insufficient stabilization translates into suboptimally high markups and price levels — making a case for ‘price stability’ in the design of optimal stabilization policies.

To provide a graphical treatment, without loss of generality consider an economy where Z is a random variable that can rise or fall by the same amount with equal probability 1/2, with $E(Z) = 1$. Figure 11 depicts the two possible ‘AS’ lines, corresponding to a high and a low level of Z. They intersect the ‘NR’ locus at points A and A', respectively. Observe that, were the optimal policy (35) in place, employment would be constant at its natural level $\bar{\ell}$, and consumption would be high or low depending on the realization of the productivity shock. For convenience, we draw the ‘AS’ line corresponding to the average productivity level, $E(Z) = 1$, which intersects the ‘NR’ locus at point O, with $AO = O'A$. The BOB' ‘AD’ line that goes through O corresponds to the average consumption level in the flex-price allocation. In the graph, we also draw a second ‘AD’ locus below the first one, the FQF' line whose interpretation will be made clear shortly.

We are interested in studying the equilibrium allocation when policymaking deviates from the optimal monetary stance. For instance, suppose that monetary authorities set the current stance according to a passive rule:

$$\mu = \alpha \tag{36}$$

In other words, μ does not respond at all to the output gap. With sticky prices, consumption will then be constant but employment will be fluctuating with Z: it will be below the natural rate when the shock is positive, above the natural rate when the shock is negative.

These points are illustrated in Figure 11. Consider the upper ‘AD’ line, drawn for the price level P_B at a level of consumption equal to average consumption in a flex price equilibrium. If prices are predetermined, and monetary policy is passive, the economy will operate either at B or at B'. The same is true for the lower ‘AD’ locus, corresponding to a higher price level $P_F > P_B$, thus intersecting the ‘NR’ locus at the point Q below the point O: when $P = P_F$ the economy operates either at F or at F'.

Now, it is easy to see that average consumption under a passive monetary policy must be lower than the level that would prevail in a fully stabilized economy. In other words, the preset price P_B cannot be an equilibrium. To see why, recall that firms optimally preset prices to ensure that, *on average*, they operate on their supply schedule. As discussed above, an important implication of such behavior is that expected employment is equal to its natural rate. But Figure 11 clearly suggests that this condition is violated when $P = P_B$.

In fact, consider the two possible equilibria on the upper ‘AD’ line. When the productivity shock is positive, employment falls by the segment BO. But when the shock is negative, employment increases by a larger amount, equal to the segment $OB' > BO$. Taking the average of the two employment levels with equal probability, it follows that at P_B the expected employment gap is be positive, i.e. expected employment is above the natural rate:

$$E(\ell)|_{P=P_B} > \bar{\ell} \tag{37}$$

In other words, at P_B each firm is supplying 'too much' relative to the level of output that maximizes its expected discounted profits. Each firm has therefore an incentive to cut back on its production plans, raising its price: hence P_B cannot be the equilibrium price level.[23]

Given the distribution of Z, equilibrium pricing always equates the average gap between employment and its natural rate to zero. In our example this principle has a simple geometrical interpretation: given the two 'AS' curves corresponding to the two different realizations of the productivity process, and holding μ constant, prices (and the 'AD' schedule) must be set such that the low and high employment allocations are perfectly symmetric around $\bar{\ell}$. In Figure 11, this happens in correspondence to the lower 'AD' curve, based on the higher price index P_F. In this case, when the productivity shock is positive employment falls by the segment FQ, and when the shock is negative employment increases by the segment QF', where $FQ = QF'$.

Figure 11 sheds light on one of the key reasons why insufficient stabilization can reduce national welfare. Facing uncertainty in marginal costs, firms raise their average markups and charge higher prices for their products. As a result, households' purchasing power is suboptimally low: failure to stabilize the economy does not affect expected disutility from labor effort (which is kept constant by firms' optimal pricing), but does reduce utility from consumption.

Observe that, for any given suboptimal monetary policy, the higher the variance of the shock (the further away are the two 'AS' lines from each other in Figure 11), the higher the equilibrium price level (thus, the lower the equilibrium 'AD'). It follows that, for a given monetary stance, changes in the variance of the shocks from one period to another lead to adjustment in prices, creating temporary fluctuations of inflation.[24]

6.3 Optimal policy in open economies and the gains from international coordination

Do optimal stabilization rules in an open economy deviate from their counterparts in closed economy? How do openness and trade affect the design and conduct of monetary policy? In this section we take a first pass at these issues by studying optimal policies for each of the three specifications of export pricing, i.e. PCP, LCP and DP. We discuss both the case in

[23] Our intuitive graphical analysis can be easily checked using the pricing equation directly. Holding $\mu = \alpha$, the equilibrium price level is:

$$P|_{\mu=\alpha} = \frac{\theta\kappa\alpha}{\theta - 1} E\left(\frac{1}{Z}\right) \geq \frac{\theta\kappa\alpha}{\theta - 1}$$

since, with $E(Z) = 1$, $E(1/Z) > 1$. As a straigthforward implications of the Jensen's inequality the optimal price is above our candidate expression on the right hand side: the preset price level is increasing in the variance of the productivity shock.

[24] Similar considerations go through in standard models with price rigidities. For instance, in the absence of policy stabilization lower utility and higher inflation volatility are the results of inefficient dispersion of prices and activities among producers under price staggering. In principle, one cannot rule out that for particular parameterizations of preferences and technology, suboptimal stabilization policies put downward pressure on prices. However, the specifications commonly adopted by the literature yield results consistent with the one discussed in the text.

which national policymakers design their policies independently of each other, and the case in which they do so in a cooperative way (Ball 1999, Benigno 2002, Canzoneri, Cumby and Diba 2005, Clarida, Gali and Gertler 2002, Corsetti and Pesenti 2005a, Gali and Monacelli 2005, Lombardo and Sutherland 2004, Monacelli 2005, Obstfeld 2002, Sutherland 2005, Svensson 2000).

In the absence of international coordination, Home policymakers determine their welfare-optimizing monetary stance by maximizing $\mathcal{W}$ as defined in (32) with respect to μ, while taking the monetary policy in the other country μ^* as given. Similarly, Foreign authorities maximize $\mathcal{W}^*$ with respect to μ^* given μ. We denote the monetary stances independently chosen by the two authorities with μ_{Nash} and μ^*_{Nash}, as shorthand for Nash equilibrium. In a cooperative equilibrium, instead, national authorities jointly maximize a weighted average of Home and Foreign welfare $0.5\mathcal{W} + 0.5\mathcal{W}^*$, whereas the weights coincide with the share of each country in world consumption. The cooperative monetary stances are denoted μ_{Coop} and μ^*_{Coop}.

The PCP model Our model with PCP provides an example in which the optimal policy in open economy is identical to the optimal policy in closed economy: domestic policymakers focus exclusively on the domestic output gap, offsetting any fluctuation in employment and output around their natural level.

In the context of a non-cooperative equilibrium, using the pricing equilibrium expressions with PCP, the policy problem in the Home country can be written as

$$\max_{\mu} \; E[\ln C - \kappa\ell] = \tag{38}$$
$$\max_{\mu} \; [E \ln \mu + \frac{1}{2} E \ln \mu^* - \frac{1}{2} \ln E\left(\frac{\mu}{Z}\right) - \frac{1}{2} \ln E\left(\frac{\mu^*}{Z^*}\right) + constant]$$

The optimal monetary policy satisfies $\mu^{PCP}_{Nash} = \alpha Z$, precisely the same expression as in the closed economy (Clarida, Gali and Gertler 2001). The optimal policy is completely 'inward looking,' in the sense that it is only concerned with stabilizing domestic markups and prices. This is exactly the policy behavior followed by the Home country in Figure 7.

Symmetrically, in the Foreign country the policy problem is:

$$\max_{\mu^*} E[\, \ln C^* - \kappa\ell^*] = \tag{39}$$
$$\max_{\mu^*} \; [\frac{1}{2} E \ln \mu + E \ln \mu^* - \frac{1}{2} \ln E\,(\mu/Z) - \frac{1}{2} \ln E\,(\mu^*/Z^*) + constant]$$

which yields $\mu^{*PCP}_{Nash} = \alpha^* Z^*$. Note that α and α^* may differ, reflecting national preferences over the desired rate of inflation. If the two steady-state inflation rates are different, there will be a trend for the nominal exchange rate equal to the inflation differential, without effects on the steady-state real exchange rate.

Are there gains from international policy cooperation? To answer this question note that, with PCP, the objective function of the Home policymakers in (38) is identical to the Foreign objective function (39): in other words, $\mathcal{W} = \mathcal{W}^*$. Maximizing an average of $\mathcal{W}$ and $\mathcal{W}^*$ yields exactly the the same optimal policy prescriptions $\mu^{PCP}_{Coop} = \alpha Z$ and $\mu^{*PCP}_{Coop} = \alpha^* Z^*$. The non-cooperative rules remain the best policy rules also under cooperation: by 'keeping one's house in order', policymakers are already able to achieve economic efficiency (Obstfeld and Rogoff 2002). This result provides an extreme version of the case for flexible exchange rates made by Friedman 1953: even without price flexibility, monetary authorities can engineer the right adjustment in relative prices through exchange rate movements. In our model with PCP, expenditure-switching effects make exchange rate and price movements perfect substitutes.[25]

The LCP model The optimality of 'inward-looking' policy rules, however, is not a general result. Notably, with LCP, the optimal policy rule still prescribes some degree of output gap stabilization, but complete stabilization is not desirable. Under LCP the Home policy problem in a non-cooperative equilibrium can be written as:

$$\max_{\mu}[E\ln\mu - \frac{1}{2}\ln E\left(\mu/Z\right) - \frac{1}{2}\ln E\left(\mu/Z^{*}\right) + constant] \tag{40}$$

The optimal policy satisfies:

$$\frac{1}{2}\frac{\mu_{Nash}^{LCP}/Z}{E\left(\mu_{Nash}^{LCP}/Z\right)} + \frac{1}{2}\frac{\mu_{Nash}^{LCP}/Z^{*}}{E\left(\mu_{Nash}^{LCP}/Z^{*}\right)} = 1 \tag{41}$$

Home policymakers stabilize a weighted average of Home and Foreign marginal costs, using the CPI weights for the Home and the Foreign goods.

Why? Suppose that the Home monetary authorities followed an 'inward looking' rule, i.e. they completely stabilized Home marginal costs, moving μ to offset productivity shocks as in Figure 8. While such conduct would stabilize domestic producers' markups, Foreign firms selling in the Home country would face exchange rate variability. This would affect the expected discounted profits from the Home market, thus Foreign consumers' dividend incomes (with reference to Figure 8, Foreign residents would suffer large fluctuations of employment away from the natural rate).

Foreign firms would then react to volatility of profits by raising their average markups in their export markets, charging higher prices for their products sold in the Home country. The intuition underlying this result is exactly the same as discussed in the closed-economy case, with reference to Figure 11. In that graph uncertainty stemmed directly from domestic supply shocks Z. In the LCP case the source of uncertainty in the Foreign country is exchange rate fluctuations associated with the response of Home policymakers to domestic shocks. In both cases, the optimal response of the producers is to raise markups and prices (on average), in order to reach (on average) full employment.

Home policymakers thus face a trade-off between stabilizing the markups of domestic producers (translating into lower Home good prices) and stabilizing the markups of Foreign producers' (translating into lower import prices). At an optimum, they will pursue some average between the two, depending on the weight of imports in the consumption basket of Home households. This is precisely the interpretation of (41).

Graphically, the non-cooperative equilibrium under LCP finds the two economies at points S and S^{*} in Figure 8. Heuristically, this point is determined as follows. First, consider the 'AS' locus in the Home country after the realization of the shock Z (but keeping τ unchanged). Take the horizontal distance between the 'NR' locus and the 'AS' locus. This distance is zero at point D (incidentally, this is the same point D as in Figure 9) where the two loci intersect, and increases moving downward from D to O, with Home labor ℓ below the natural rate $\bar{\ell}$. Second, consider the 'AS*' locus in the Foreign country and its horizontal distance from the 'NR*' locus. This distance is zero at point O^{*} and increases

[25] The equivalence between Nash equilibrium and flex-price allocation need not go through under more general conditions, e,g. with less restrictive preference specifications as shown by Benigno and Benigno 2003.

moving upward, with ℓ^* above the natural rate $\overline{\ell^*}$. Starting from O and O^*, and moving upward, there will be a value of consumption $C = C^*$ such that the two employment gaps in the Home and Foreign countries offset each other. This corresponds to the segment SR in the Home country, equal to R^*S^* in the Foreign country. The monetary stances μ and μ^* move in tandem to support consumption gains in both countries by $OR = O^*R^*$. These consumption gains are not as high as in the PCP case (points R and R^* in Figure 8 are below points H and H^* in Figure 7). World employment remains unchanged: the contraction in the Home country is matched by the expansion in the Foreign country. Exchange rates and terms of trade remain unchanged in all countries. Utility gains are larger in the Home country than in the Foreign country.

The magnitude of the optimal deviation from 'inward looking' rules depends on a country's degree of trade openness. In our stylized model, half of the domestic consumption expenditure falls on foreign goods. In the case of small and very open economies, there is a strong incentive to pursue policy rules that are quite 'outward oriented.' In large and less open economies, these considerations may affect policy design only marginally.

In more general terms, the optimal policy prescription could be stated in terms of targeting a weighted average of markups, assigning higher weights (other things equal) to the 'core' sectors in which nominal rigidities are more pronounced. In the PCP case import prices are fully flexible while domestic prices are sticky, so that the optimal monetary policy only stabilizes domestic markups. In the LCP case both domestic and import prices are sticky, and the optimal policy targets the CPI-weighted average of the markups.

Because of the international spillovers of monetary policy on international pricing, one may expect that with LCP there will always be an incentive to cooperate. Surprisingly, however, this is not the case in our model. To see why, note that the objective function of Foreign policymakers is identical to (40), except that $\ln \mu$ is replaced by $\ln \mu^*$. Hence the non-cooperative optimal policy satisfies:

$$\frac{1}{2}\frac{\mu_{Nash}^{*LCP}/Z}{E\left(\mu_{Nash}^{*LCP}/Z\right)} + \frac{1}{2}\frac{\mu_{Nash}^{*LCP}/Z^*}{E\left(\mu_{Nash}^{*LCP}/Z^*\right)} = 1 \tag{42}$$

Comparing (41) with (42) shows that both policymakers stabilize exactly the same weighted average of Home and Foreign marginal costs. Hence they pursue exactly the same monetary policy, $\mu_{Nash}^{LCP} = \mu_{Nash}^{*LCP}$, implying that the nominal exchange rate does not react to shocks. Instead of closing the domestic output gap completely, national policymakers take into account the effects of their policies on exchange rate variability. In equilibrium, an efficient monetary rule limits exchange rate fluctuations (Devereux and Engel 2003).

Solving the cooperative problem does not change this prescription at all. There are no gains from cooperation not because domestic policymaking is already efficient (as in the PCP case, where there are no spillovers in equilibrium), but because what can be achieved by cooperating (the stability or predictability of the exchange rate) is already achieved in the absence of cooperation. As the only spillovers in the world economy stem from exchange rate movements, the world economy cannot gain by pursuing asymmetric policies that imply exchange rate fluctuations. Once again, 'keeping one house in order' is the best rule of conduct.

The DP model An interesting case of asymmetric deviation from inward-looking rules is provided by an economy with Dollar Pricing. In this case, Home welfare is equal to (40), so that Home optimal monetary policy must satisfy (41). Foreign welfare is (38).

Correspondingly, the Foreign optimal policy is completely inward-looking. So, the country that issues the currency used worldwide for export pricing (the Home country) optimally responds to shocks hitting the global economy. The other country only needs to stabilize domestic markups.

The interest in this case mainly concerns its implication for the desirability of international policy cooperation. World welfare indeed increases when monetary policy rules are designed in a cooperative way (by maximizing an equally weighted average of the two national welfare functions). However, the cooperative and noncooperative optimal policy rules coincide for the Foreign country, but not for the Home country. The 'contribution' to cooperation is therefore unilateral: only the Home country is expected to modify its rules. This raises an interesting issue, as to whether there is any incentive for this country to enter any binding cooperative agreement regarding stabilization policy.

7 Conclusion

It is hard to deny that the new paradigm of choice-theoretic models has been contributing many empirical and theoretical elements to our understanding of the international transmission of productivity, monetary and financial shocks, the sign and magnitude of cross-border spillovers, as well as the determinants and cyclical properties of international trade in goods, services and assets. Recent contributions explore the implications of frictions in the asset and credit markets, attempt to integrate financial and real aspects of the international transmission, and address crucial stylized facts of the international economy, from the low degree of international risk-sharing documented by Backus and Smith (1993) to the excess volatility of real exchange rates to the dynamics of comparative advantages in the world economy (Chari, Kehoe and McGrattan 2002, Ghironi and Melitz 2005, Corsetti, Dedola and Leduc 2004). At the same time, pressing policy issues are raising the hurdles for DSGE models, e.g. current account dynamics and the adjustment to global imbalances (Erceg, Gust and Guerrieri 2005, Faruqee et al. 2007).

This paper has presented a stylized but rigorous framework that illustrates fundamental traits of the recent stabilization literature, and sheds light on the architecture of fully-fledged quantitative models in international macroeconomics. As DSGE models are increasingly used as tools for policy evaluation by domestic and international institutions, one of the goals of this paper is to provide an introductory set of analytical instruments to convey the main ideas about international transmission and stabilization policies underlying these models, as well as to provide a smorgasbord of basic questions and intuitions that are developed in quantitative work.

While for the sake of analytical tractability throughout the text we have abstracted from dynamic considerations, it is worth emphasizing that our results would qualitatively go through in richer model specifications, for instance, in models with staggered price setting. The optimal policy for the PCP model derived in section 6.3 would be identical in our economy if firms adjusted prices with constant probability in each period, i.e. according to the Calvo process. Since monetary authorities stabilize domestic marginal costs in nominal terms, there would be no incentive for any firm to change its product price at any time: firms able to re-optimize would post exactly the same price as firms unable to re-set their price. The exchange rate would move with the relative stance of monetary policy, keeping the terms of trade in line with the flex-price allocation (Clarida, Gali and Gertler 2001).

In the LCP case, we have seen in the text that the above strategy (optimal for the PCP case) would translate into inefficient average prices. With staggered price setting, however, it would also produce welfare-reducing price dispersion in the import sector, as only some foreign firms would be able to adjust their prices in response to fluctuations in exchange rates (Smets and Wouters 2002). So, imported goods which are symmetric in production and preferences would be sold, inefficiently, at different prices. Depending on the degree of openness of the economy, monetary authorities could improve welfare by trading off lower prices and less price dispersion in the imports market, against some dispersion in the market for domestically produced goods. The design of optimal stabilization policies would therefore be concerned with minimizing a weighted average of inefficient misalignment of relative prices across categories and within each category of goods, generalizing our results on the international dimensions of optimal monetary policy discussed in the text.

Before drawing strong conclusions from the LCP vs. PCP debate, however, it is worth stressing that models where deviations from the law of one price are an exclusive implication of nominal rigidities (and therefore a short-run phenomenon) may overlook persistent price discrepancies across regions or over time, and overestimate the degree of nominal inertia required to explain the stability in local currency of import prices. A promising way to address these issues appears in recent models that allow for distribution services intensive in local inputs or local assembling of imported intermediate inputs (Erceg and Levin 1995, McCallum and Nelson 1999, MacDonald and Ricci 2001, Burstein, Neves and Rebelo 2003, Corsetti, Dedola and Leduc 2004, Corsetti and Dedola 2005). Assessing the relative importance of optimal price discrimination and monetary frictions in generating incomplete pass-through is clearly a relevant goal for future research.

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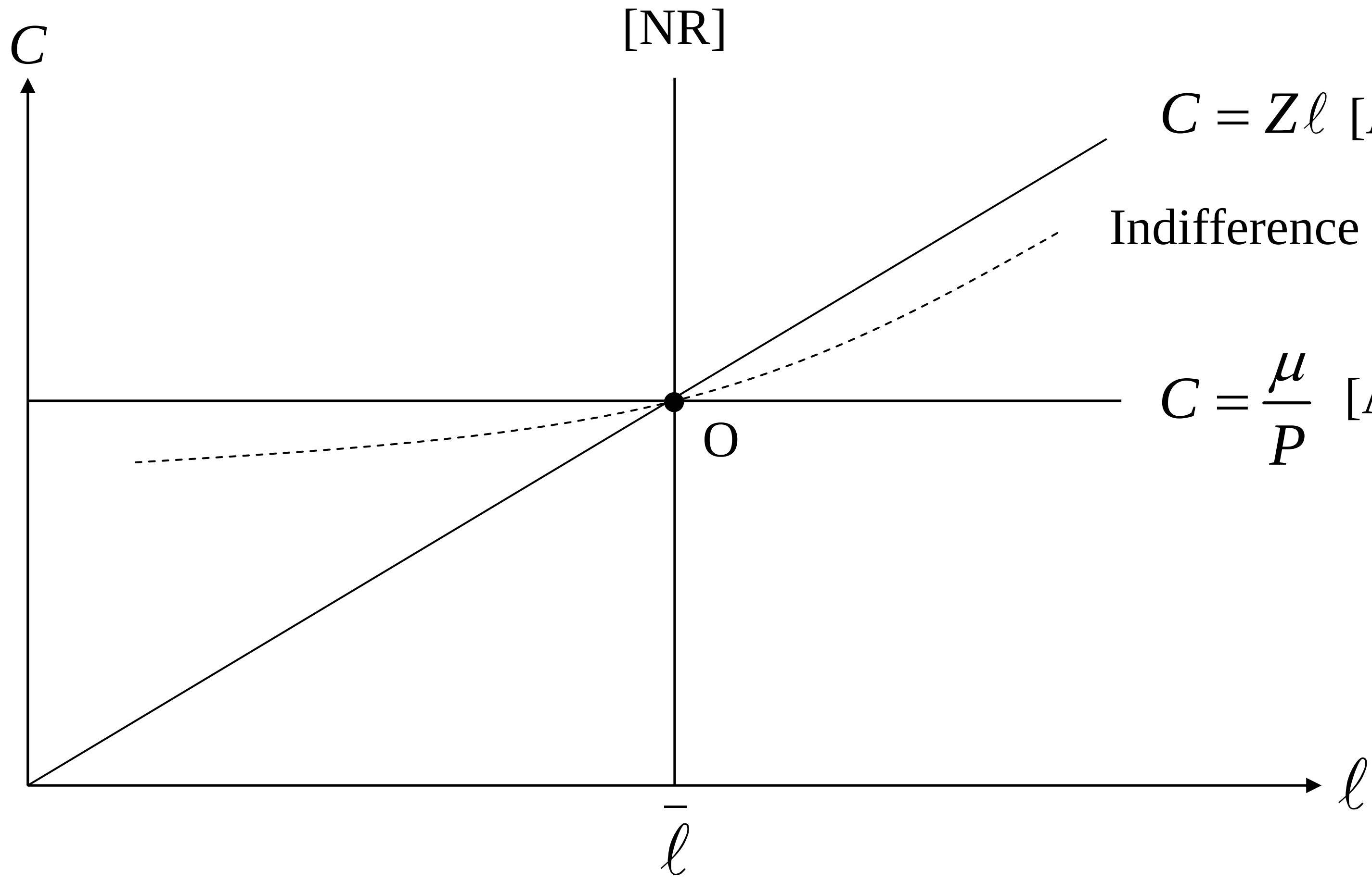
Figure 1

Equilibrium in closed economy



μ, Z Exogenous

Figure 2

Productivity shocks with and without price rigidities

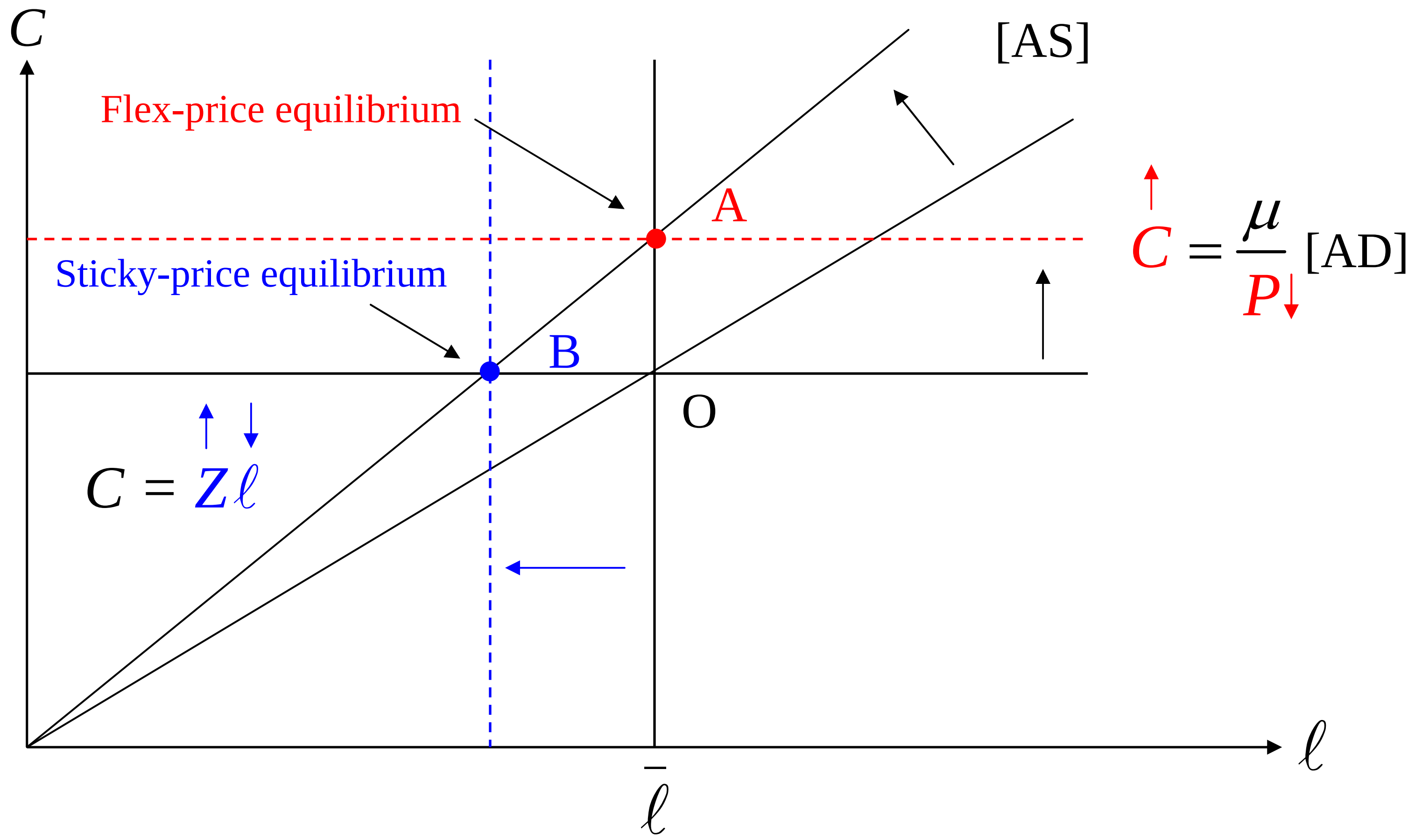


Figure 3

Optimal monetary policy response to shocks under price rigidities

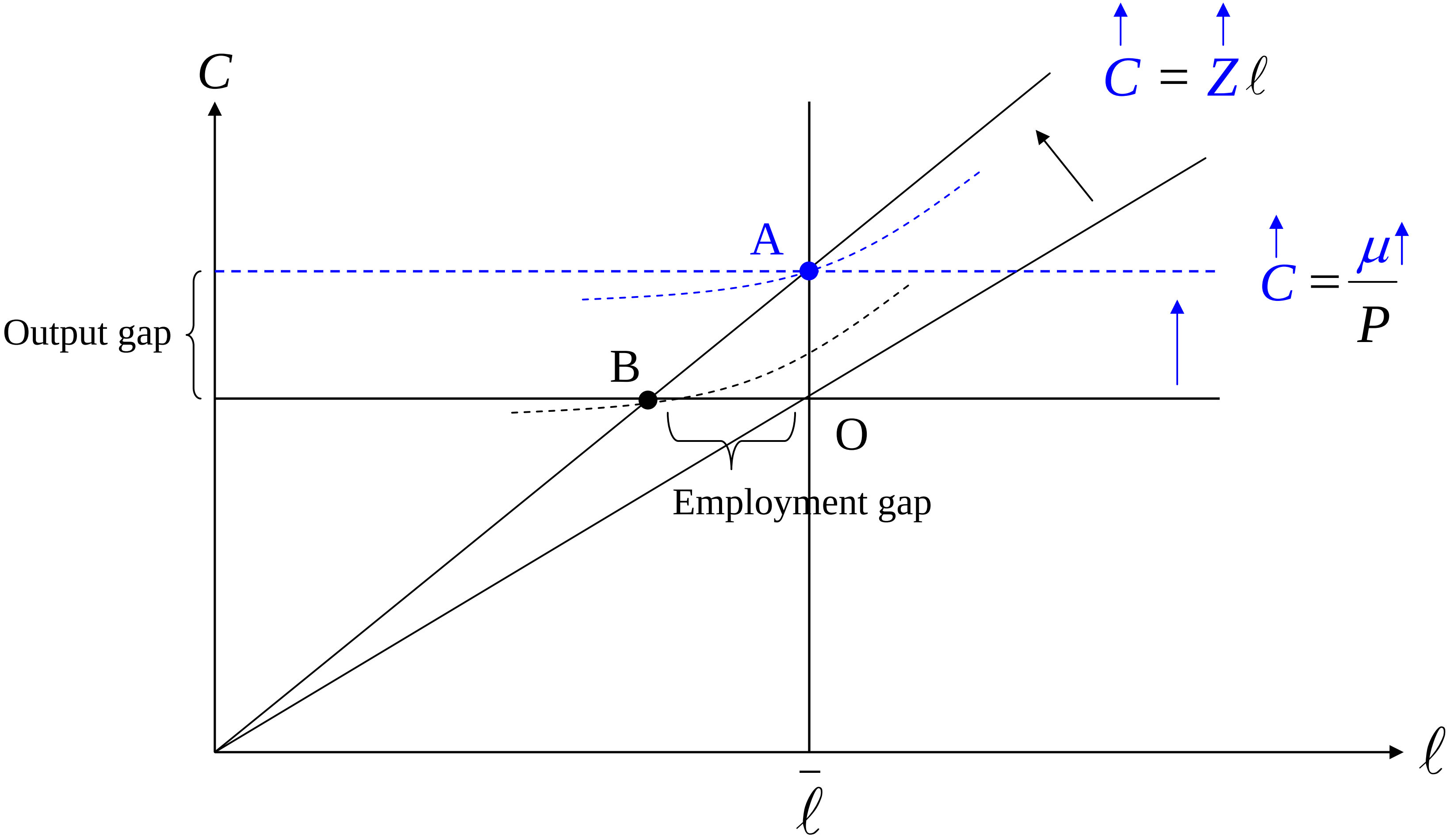


Figure 4

World economy model

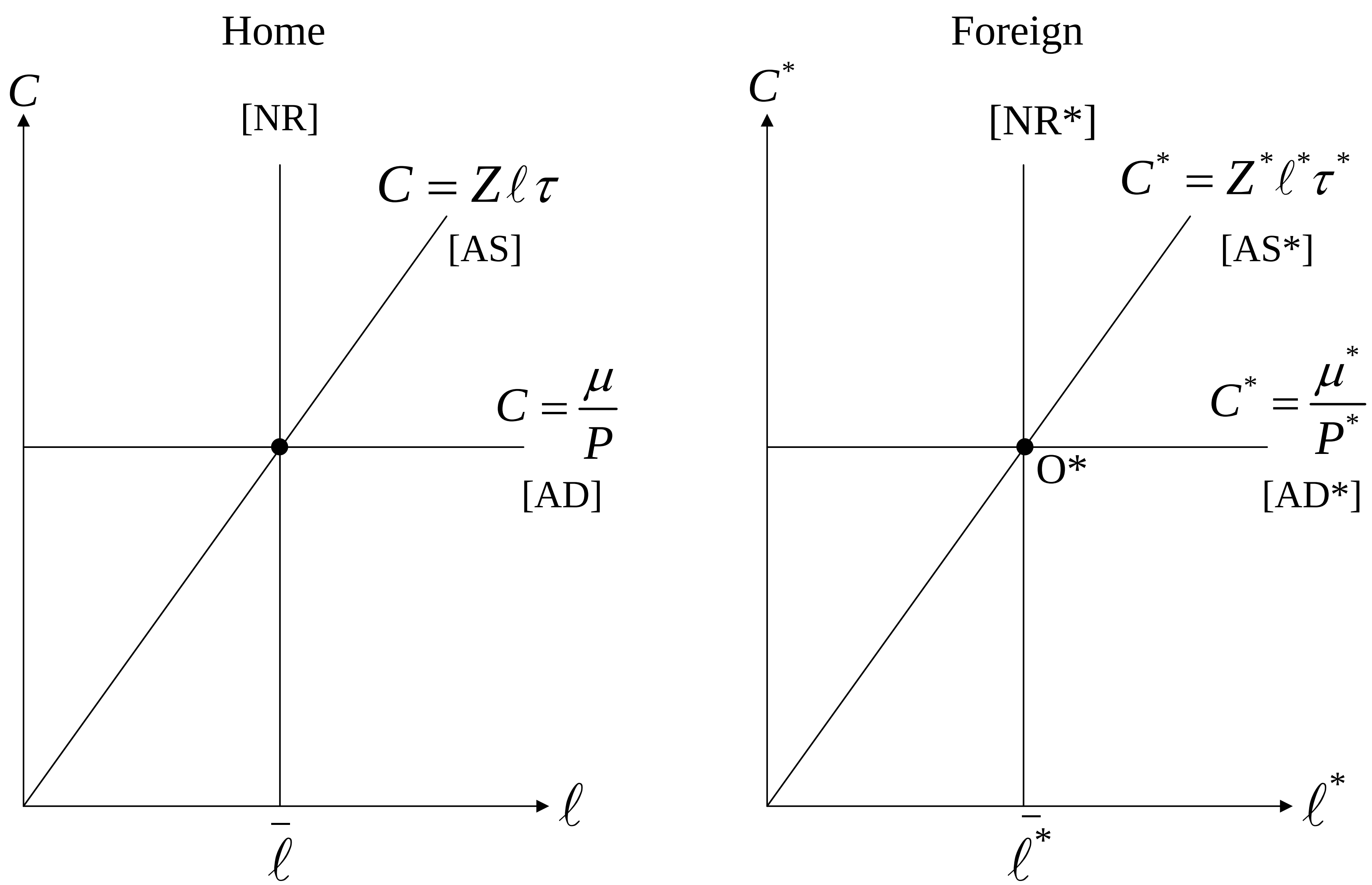


Figure 5

International transmission of productivity shocks under flexible prices

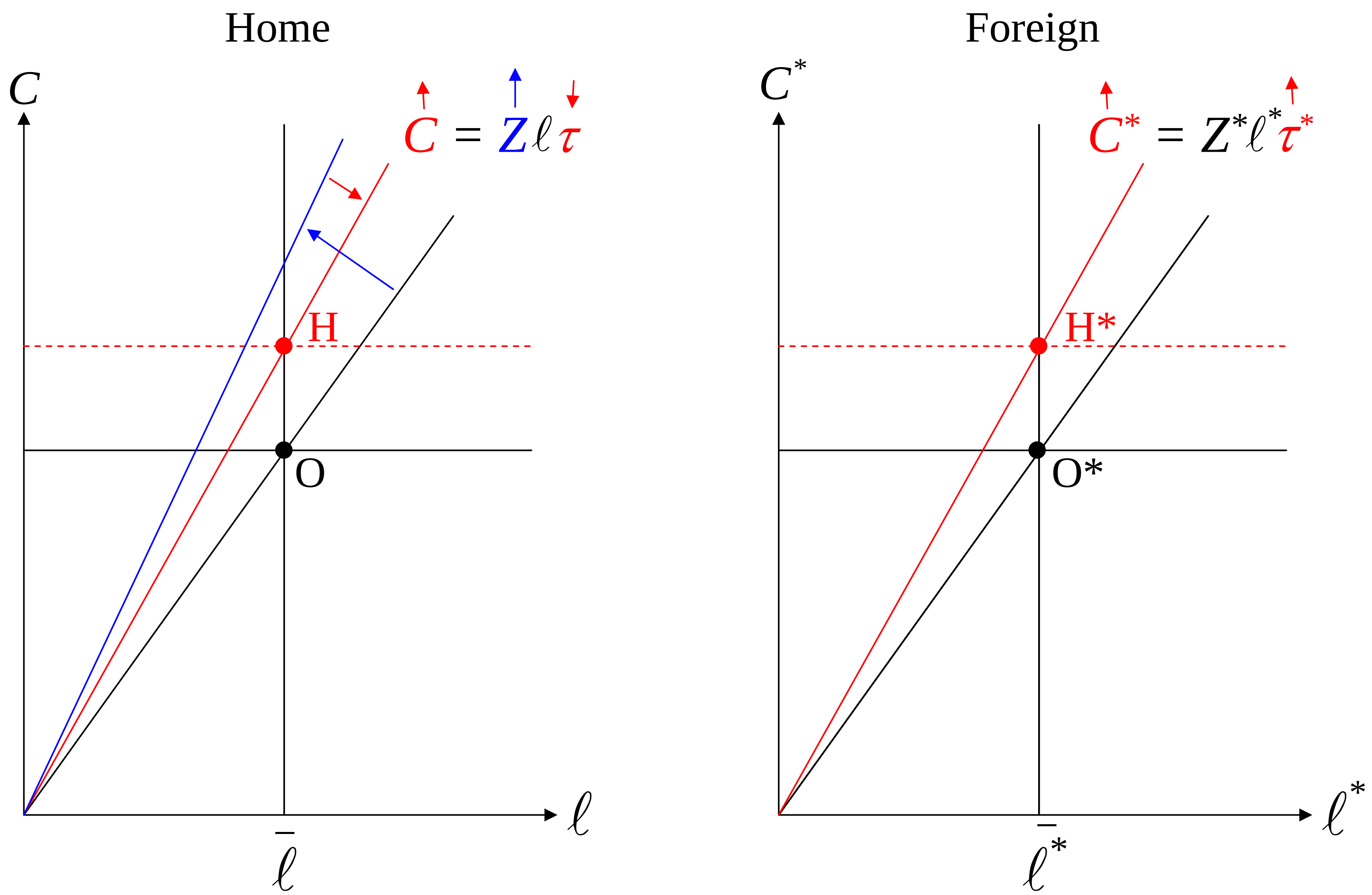


Figure 6

International non-transmission of productivity shocks under price rigidities

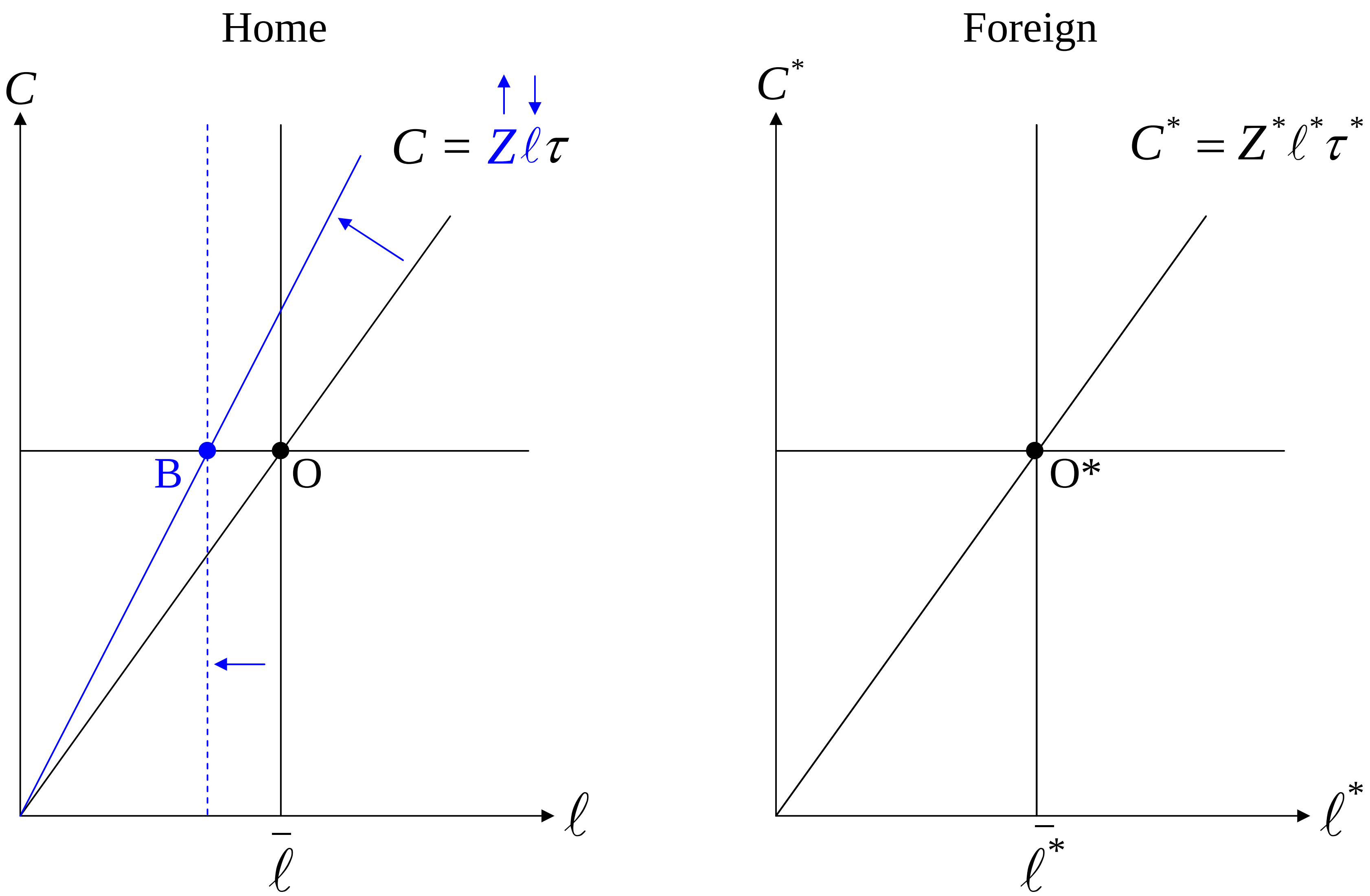


Figure 7

Stabilization policy under high pass-through (PCP)

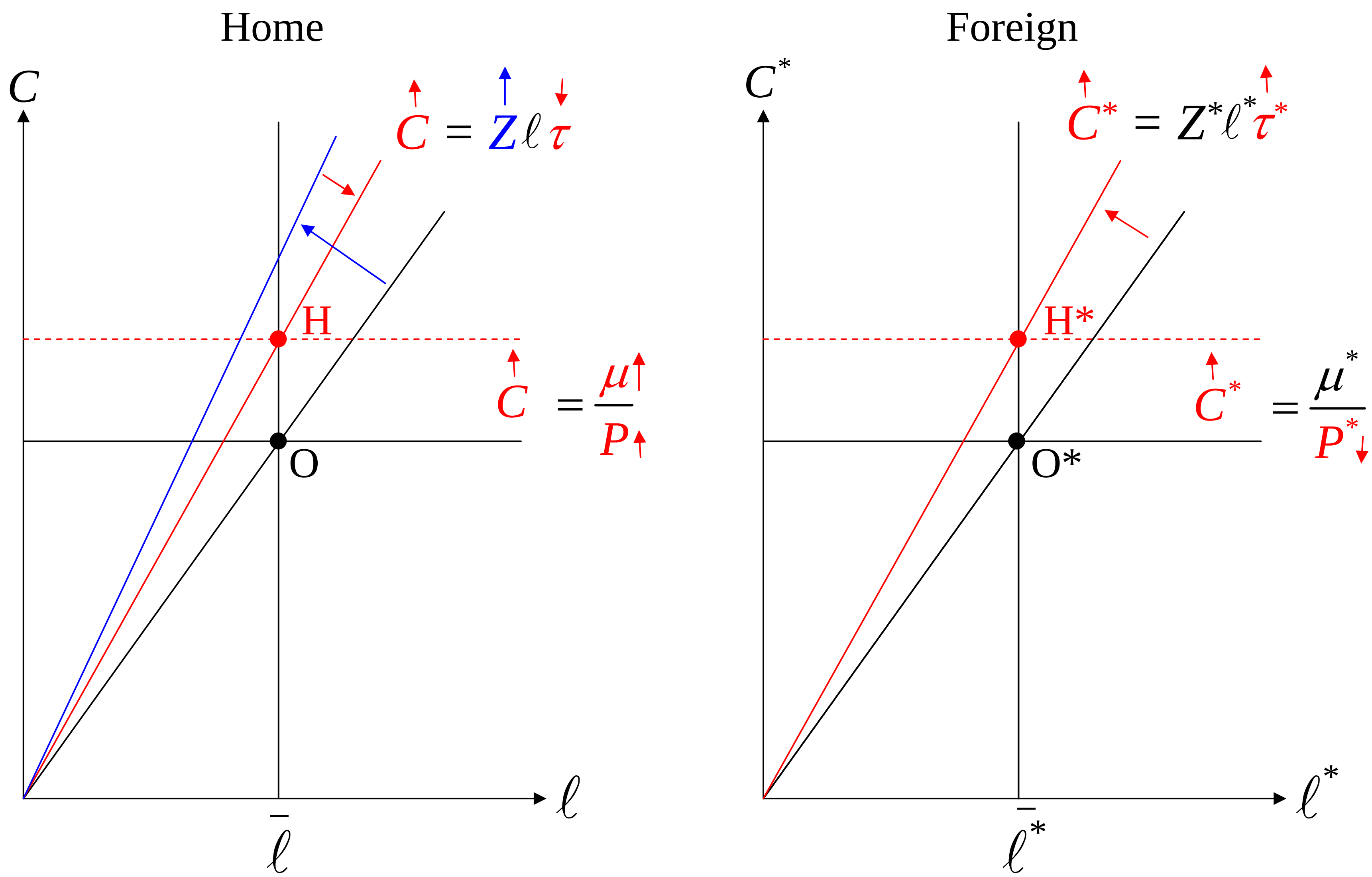


Figure 8

Stabilization policy under low pass-through (LCP)

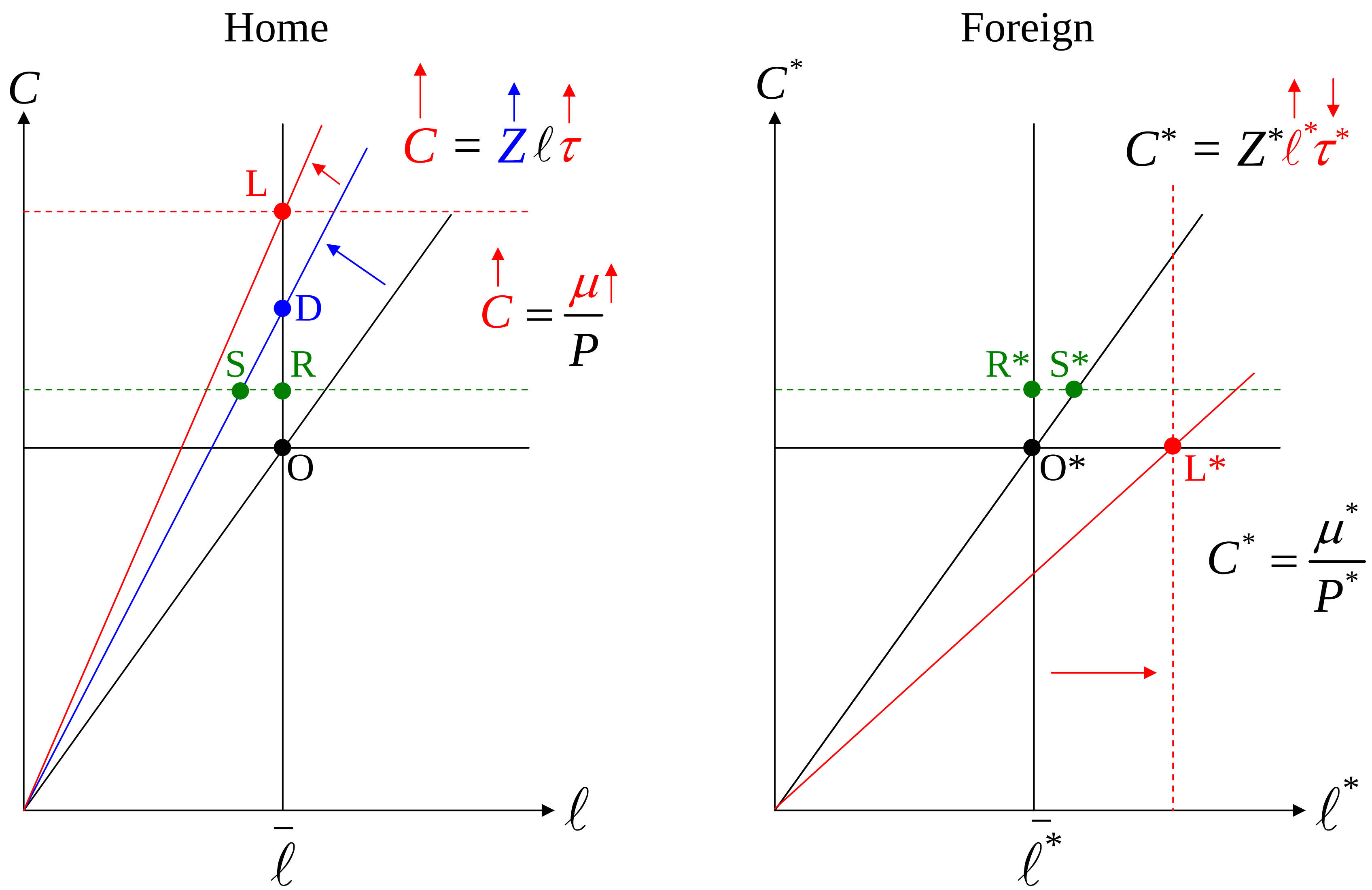


Figure 9

Stabilization policy under asymmetric pass-through (LCP)

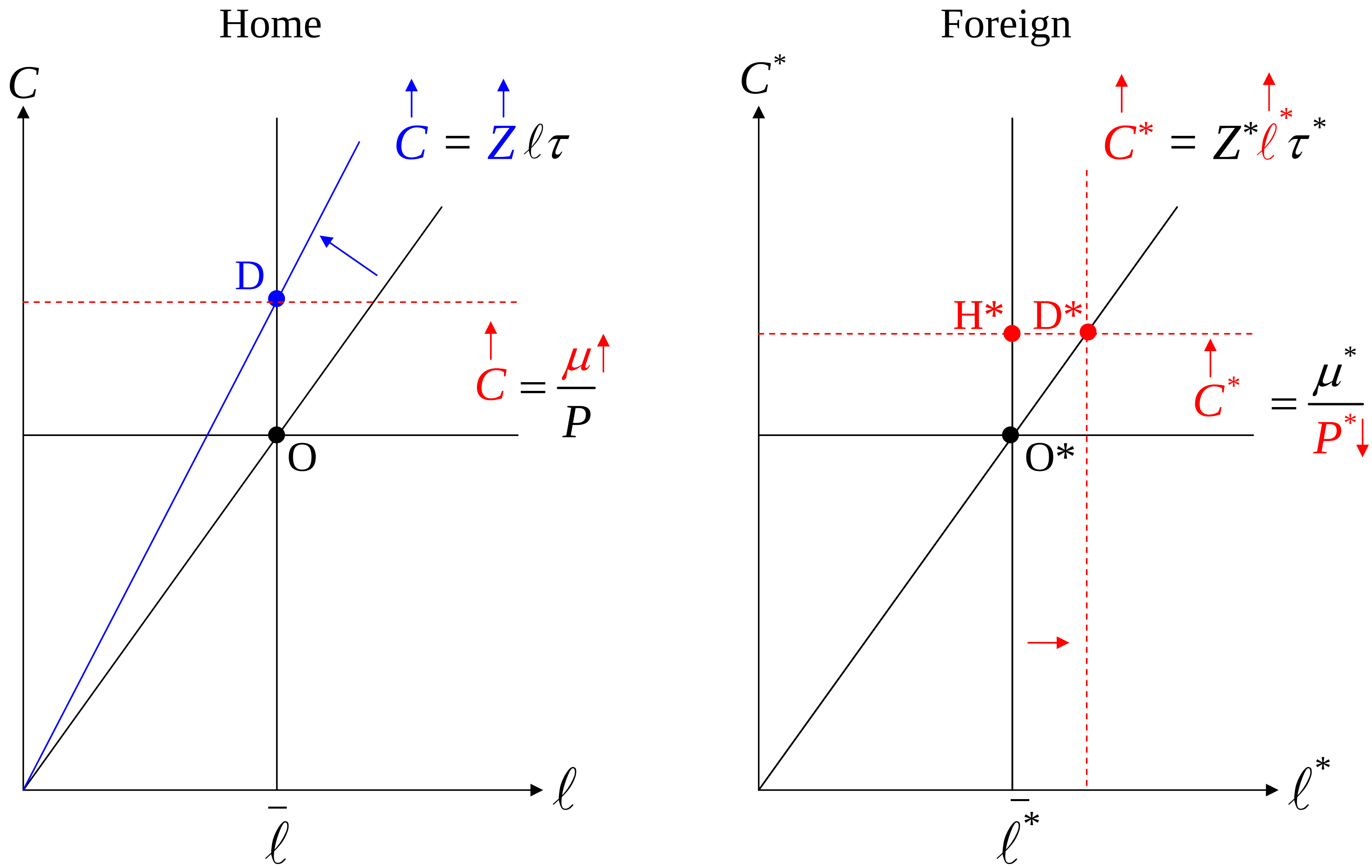


Figure 10

Inflationary bias

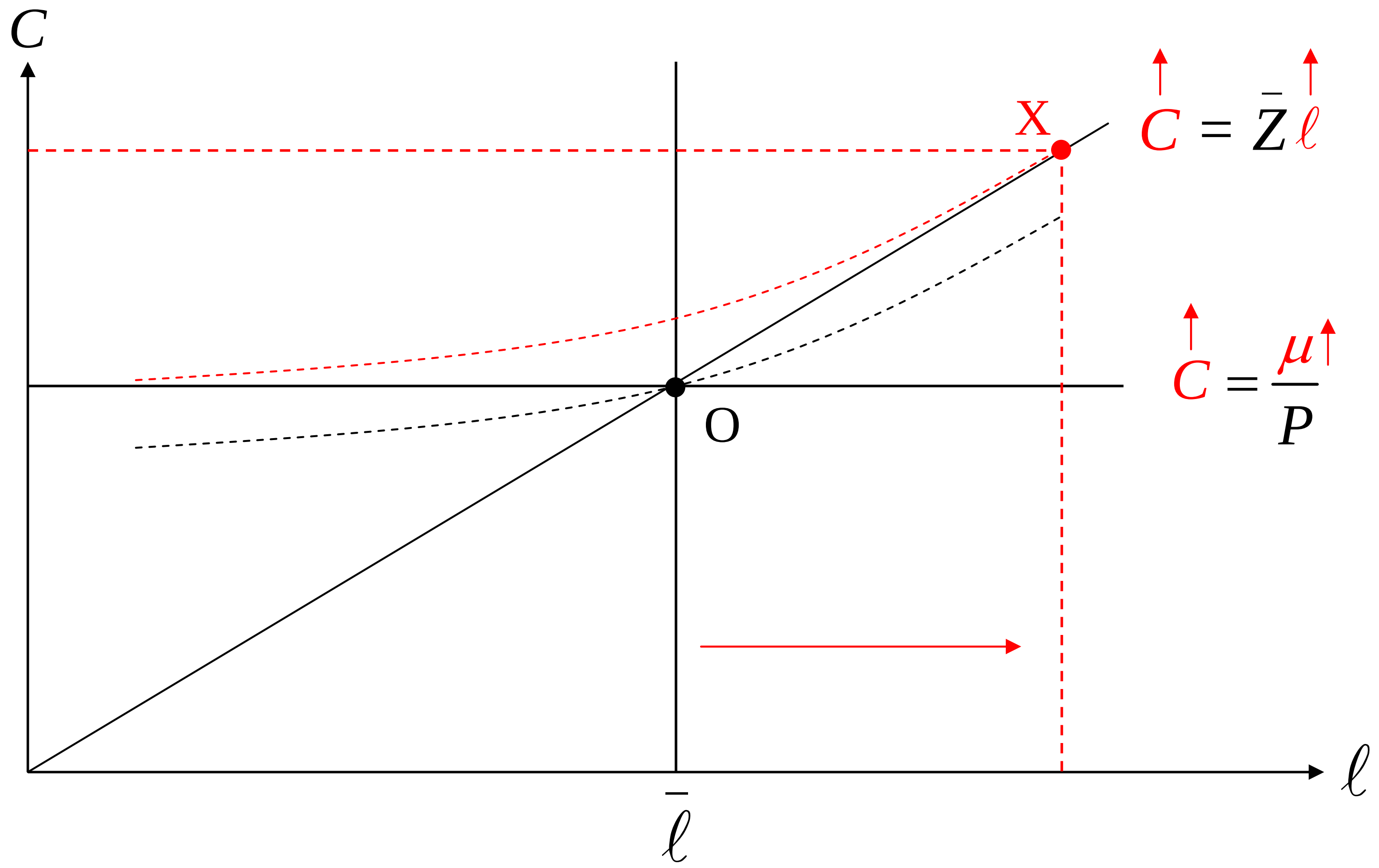


Figure 11

Effects of sub-optimal policy