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MONETARY RULES FOR COMMODITY TRADERS

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ABSTRACT

We develop a dynamic model of a small open economy that trades commodities whose world prices are subject to realistic random fluctuations, and study the implications of monetary policy alternatives. The model is much more flexible than those of previous studies, especially in allowing to compare perfect risk sharing against financial autarky. In each case we show how to derive analytically optimal Ramsey allocations and flexible price allocations, and hence to examine the crucial role of behavioral elasticities, production structure, and capital mobility in determining the welfare properties of different monetary choices. Applying these insights to a calibrated example, we find that the impulse responses associated with PPI targeting track flexible price allocations closely, but can diverge greatly from the Ramsey allocations, especially when risk sharing is perfect and the elasticity of demand for exports of a home aggregate is high. In those cases, policies that stabilize the real exchange rate more than PPI targeting, such as targeting expected inflation, deliver higher welfare. But PPI targeting is the clear winner under portfolio autarky.

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1 Introduction

In recent years, many central banks around the world have embraced inflation targeting (IT), thus tying monetary policy to the attainment of an explicit and preannounced quantitative target for a measure of inflation. That measure has frequently been the one most directly associated with the welfare of households, such as the consumer price index (CPI). But such a choice has been questioned on at least two grounds. First, the currently dominant academic literature on monetary economics, based on the New Keynesian paradigm summarized by Woodford (2003) and Gali (2008), justifies IT but finds that it is often superior to target not the CPI but a producer price index (PPI), the intuition being that that indicator is more closely tied than the CPI to the underlying distortions, such as price dispersion, associated with nominal rigidities. While Woodford, Gali, and others developed the argument in closed economy settings, the intuition is strong enough that Gali and Monacelli (2005) showed that PPI targeting is indeed optimal in open economies under some special conditions on fundamental parameters, while Di Paoli (2009), Faia and Monacelli (2007), and others found that PPI targeting is still nearly optimal even if those conditions fail, as long as parameters are calibrated realistically.

A second motivation for reconsidering monetary choices has been the increased volatility of commodity prices over the past few years, which has complicated monetary management in several ways. For countries that import basic commodities such as oil and food, the large price swings for those commodities can affect the CPI directly as well as costs of domestic production, to the extent that those commodities represent a large share of consumption baskets and/or production inputs. For countries that export commodities, such as metals, volatile export prices has led to volatile exchange rates, prompting calls for the monetary authority to try to stabilize the exchange rate or export prices.

In order to shed light on these issues, this paper analyzes monetary policy choices in a dynamic open economy framework of the New Keynesian type. We extend basic open economy models, such as those of Gali and Monacelli (2005) and Di Paoli (2009), in several directions intended to capture the complex and diverse reality of emerging economies and, in particular, their exposure to commodity price shocks. Accordingly, we allow our model economy to both export and import commodities with variable world relative prices; we allow for imports to be used as an input in domestic production, which makes our framework applicable to study the implications of oil price fluctuation; and we include an "enclave" export sector, which may approximate the reality of countries whose exports are dominated by metals. Finally, the model is studied under two polar assumptions on international capital mobility: perfect risk sharing and portfolio autarky. This extension is, in fact, a significant departure from much of the existing literature, which assumes perfect risk sharing.[1]

The many departures of our model relative to others not only help accommodate salient features of commodity traders but also raise the question of whether the main policy prescriptions of the existing literature, especially the desirability of PPI targeting, survive in our context. If they do not, one would also like to know what features of the economy account for the difference. While one might have feared that the relative complexity of our model might make its solution intractable, we present and discuss a very intuitive closed form characterization of optimal (or Ramsey) policy and of flexible price (natural) equilibria, which is quite useful if only because PPI targeting often replicates the latter. Our discussion emphasizes that optimal policy in must balance the correction of distortions associated with domestic nominal rigidities against allocational gains that emerge because monetary policy can affect the world relative price of domestic output (this is sometimes called the *terms of trade externality*). This point has, of course, been made previously by others, most prominently by Corsetti and Pesenti (2001), Benigno and Benigno (2003), Gali and Monacelli (2005), Faia and Monacelli (2007), and recently Monacelli (2012). Our treatment here is, however, simpler and more direct, which adds intuition and allows for the analysis of more complicated cases, including financial autarky. Thus our discussion identifies how changes in behavioral parameters, production structure, and financial market structure affect the discrepancy between optimal allocations and flexible price allocations, and hence the relative merits of policies that emphasize stabilizing the PPI vis a

[1] A notable excepion is Blanchard and Gali (2007).

vis the exchange rate.

To translate our theoretical results into concrete and also hopefully realistic policy implications, we calibrate the parameters of the model in the usual way and study the dynamic and welfare implications of a set of monetary rules selected because of their prominence in the literature. Our set of rules naturally includes PPI and CPI inflation targeting but, in another novelty of our contribution, it also includes a CPI forecast targeting rule as well as the targeting of the commodity export price index (EPT) advocated by Frankel (2010), neither of which has been previously considered in the small open economy policy literature. Given each rule, we compute impulse responses and compare them against optimal Ramsey responses and natural responses. In addition, we compute a second order approximation to the resulting welfare, which allows us to compare each rule against each other and identify which one is best in any given case of our model.

The calibrated exercise yields several novel findings. The relative desirability of the different rules depends on both behavioral parameters, especially elasticities of substitution in demand, the structure of production, and on the degree of international risk sharing. If risk sharing across countries is perfect, then PPI is welfare superior to the other rules when elasticities of substitution are not too different from one, a case often emphasized in the literature. But if those elasticities are large, which is plausible for the world demand for manufacturing exports from emerging economies, PPI is dominated by expected CPI targeting or EPT. The reason, as our discussion emphasizes, is that optimal allocations prescribe more exchange rate stabilization and thus heavier reliance on the terms of trade externality than flexible price allocations; PPI targeting tends to implement the latter, while expected CPI targeting and EPT are closer approximations to the former. Perfect capital mobility turns out to be crucial for the comparison: PPI targeting emerges as a clear winner under portfolio autarky.

This paper follows previous contributions that extend the basic New Keynesian model to small open economies, including Gali and Monacelli (2005), Gali (2008), Di Paoli (2009), and Faia and Monacelli (2007). As mentioned, those papers study optimal monetary policy under more restrictive assumptions on parameters and production structure than we allow for here, and in addition assume only perfect international sharing. Our discussion of optimal monetary policy is inspired by and has some overlap with Gali and Monacelli (2005) and Faia and Monacelli (2007). But our approach is simpler and more intuitive, which allows us to extend the analysis to our much more complicated settings, and to the case of financial autarky.

In spite of the recent prominence of the issue, studies of open economies subject to relative price shocks are relatively scarce. The notable exception is a large and influential literature concerned with the macroeconomic effects of oil price shocks, which includes Blanchard and Gali (2007), Bodenstein, Erceg and Guerrieri (2008), and Kilian (2009).[2] By and large, PPI stabilization emerges as the clear policy prescription of studies in this group. In contrast, we show when and why that prescription needs qualification in our framework.

Finally, Catao and Chang (2010) and Hevia and Nicolini (2012) have recently studied optimal monetary policy in open economies that, like the ones in this paper, trade commodities whose world relative prices are subject to exogenous shocks. The present paper extends our previous one in several directions, such as including a competitive exports sector, assuming imports can be used as productive inputs and, more significantly, deriving optimal allocations for all cases under consideration. Hevia and Nicolini (2012) characterize optimal allocations and argue that complete PPI stabilization is always optimal. Their result, however, hinges on the assumption that monetary policy is complemented by the active management of a very wide set of taxes and transfers. We instead stick to the usual assumption that fiscal policy is fixed when studying monetary policy. Nevertheless, our theoretical discussion clarifies what can happen when fiscal instruments are as flexible as Hevia and Nicolini assume, and hence identifies the source of the differences between our results and theirs. It must also be remarked that Hevia and Nicolini characterized Ramsey allocations only under perfect risk sharing, while we can describe and interpret them also under portfolio autarky.

The paper proceeds as follows: section 2 describes the model under consideration. Section

[2]See also IMF (2011) and the various references therein.

3 discusses the general problem of optimal monetary policy in small open economies of the type studied here, and provides analytical characterizations of Ramsey allocations and flexible price allocations under both perfect risk sharing and financial autarky. Section 4 describes the calibration of the model and the set of monetary rules to be evaluated, and then presents and discusses implications for the dynamics of the model under different scenarios and policies. Section 5 describes the implications of the different rules for welfare. Concluding remarks are gathered in section 6. For ease of exposition, some technical material is delayed to an Appendix.

2 The Model

Catao and Chang (2010, henceforth CC) developed a small open economy whose residents consumed two kinds of commodities: an imported commodity, whose world price was subject to exogenous shocks; and an aggregate of monopolistically competitive differentiated goods produced at home. Here we extend CC to allow for the imported commodity to be used as an input to home production. We also add an export good produced and sold competitively. This framework is sufficiently flexible to accommodate several cases of practical interest. On the other hand, since many of the basic features of the model are borrowed from the current New Keynesian literature on small open economies, the description below is brief.

2.1 Households

The economy has a representative household with preferences:

$$E\sum_{t=0}^{\infty}\beta^t[u(C_t)-v(N_t)]$$

where $0<\beta<1$, C_t denotes consumption, N_t labor effort, $E(.)$ is the expectations operator,

$$u(C)=\frac{C^{1-\sigma}}{(1-\sigma)},v(N)=\frac{\varsigma N^{1+\varphi}}{1+\varphi}$$

and σ, φ, and ς are parameters.

Consumption is a C.E.S. aggregate of a home good C_{ht} and imports C_{mt} :

$$C_t = \left[(1-\alpha)^{1/\eta} C_{ht}^{(\eta-1)/\eta} + \alpha^{1/\eta} C_{mt}^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)}$$

where η is the elasticity of substitution between home and foreign goods, and α measures the degree of openness.[3]

We will see later that C_h is an aggregate of varieties of a differentiated good produced at home. Our formulation of preferences is the same as in CC but, departing from that paper, here we assume that imports can be used as inputs to home production as well as consumed. This extension allows us to interpret imports as (possibly an aggregate of) oil or food.

For the representative agent, however, the above details are irrelevant: he just assumes he can purchase any quantities of C_h and C_m at their prevailing market prices. The minimum cost of a unit of consumption, or *CPI*, expressed in domestic currency, is then

$$P_t = \left[(1-\alpha) P_{ht}^{1-\eta} + \alpha P_{mt}^{1-\eta} \right]^{1/(1-\eta)} \tag{1}$$

where P_{ht} and P_{mt} denote the domestic currency prices of the home consumption aggregate and imports (P_{ht} will also be called the *PPI*). Also, optimal demands for imports and home goods are given by $C_{ft} = \alpha \left(P_{mt}/P_t \right)^{-\eta} C_t$ and

$$C_{ht} = (1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{-\eta} C_t \tag{2}$$

Note that, if $P_{ht} = P_{mt} = P_t$, α equals the fraction of all consumption that is imported. In this sense, α is a measure of openness. The case $\alpha < 1/2$ is often associated with "home bias".

The representative agent chooses consumption and labor effort taking prices and wages as given. The agent owns all domestic firms and receives their profits (dividends) as well as any

[3] We have assumed $\eta \neq 1$. If $\eta = 1$, C_t (and P_t below) are Cobb Douglas.

transfer from the government.

The resulting maximization problem is well known. If W_t is the nominal wage, optimal labor supply is given as usual by:

$$\frac{v'(N_t)}{u'(C_t)} = \varsigma C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{3}$$

In order to study the role of financial imperfections in this economy, we allow for two polar scenarios with respect to the menu of foreign assets available to domestic residents. The first scenario is one of complete markets and frictionless international risk sharing which, as well known, implies that the growth rates of marginal rates of substitution in consumption at home and abroad are equal up to a real exchange rate correction. With CRRA utility[4] this implies, in turn, that for some constant κ,

$$C_t = \kappa X_t^{1/\sigma} C_t^* \tag{4}$$

where C_t^* is an index of world consumption and X_t is the *real exchange rate* (the ratio of the price of world consumption to the domestic CPI, both measured in a common currency).

The second scenario assumes that home agents are excluded from international financial markets, so that the trade balance must be zero at all times: $P_t C_t = V_t$, where V_t denotes domestic *value added* in nominal terms, to be defined shortly.

We assume, however, that domestic agents can trade a full set of contingent securities among themselves. Then any domestic security can be priced observing that the *stochastic discount factor* at t for domestic currency payoffs at $t + k$ is given by

$$\Xi_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+k}} \right)$$

[4] That is, assuming that the marginal utility of consumption in the rest of the world is proportional to $C_t^{*-\sigma}$.

In particular, the domestic safe interest rate is given by

$$\frac{1}{1+i_t} = E_t \Xi_{t,t+1} = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] \tag{5}$$

2.2 Prices

For simplicity, we assume that the world price of imports is given exogenously in terms of a world currency. Using asterisks to denote prices denominated in the world currency, the domestic currency price of imports is then $P_{mt} = S_t P^*_{mt}$, where S_t is the nominal exchange rate (domestic currency per foreign currency). So, there is full pass through from world prices to the price of domestic imports.

Likewise, we assume that the world currency price of the world consumption aggregate is exogenous. Denoting it by P^*_t, the real exchange rate is then:

$$X_t = S_t P^*_t / P_t$$

It is useful also to define the domestic price of imports relative to the price of the home consumption aggregate, or *consumption terms of trade,* by

$$Q_t = \frac{P_{mt}}{P_{ht}} = \frac{S_t P^*_{mt}}{P_{ht}} \tag{6}$$

Several recent models (e.g. Gali and Monacelli 2005) imply that there is a one to one relation between the real exchange rate and the consumption terms of trade. In fact, those models imply that X_t and Q_t always move in the same direction. In this model, however, fluctuations in the relative world price of imports weakens that link, with potentially important consequences for welfare and optimal policy, as discussed later.

To see this more precisely, use the definitions of Q_t and X_t to rewrite 1 as:

$$1 = (1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{1-\eta} + \alpha X_t^{1-\eta} Z_t^{*1-\eta} \tag{7}$$

where $Z_t^* = P_{mt}^*/P_t^*$ is the world's relative price of imports, which we take as exogenous.

From (1), an improvement in the terms of trade (a fall in Q_t) requires an increase in the relative price of domestic output (P_{ht}/P_t). Given Z_t^*, 7 then implies that X_t must fall (a real appreciation). Hence X_t and Q_t would always move in the same direction in the absence of shocks to Z_t^*, as in other models. But it is clear that here X_t and Q_t can move in opposite directions when Z_t^* moves.

2.3 Domestic Production

As mentioned, the economy produces two kinds of goods: varieties of a differentiated good, which can be assembled to obtain an aggregate that can be consumed or exported; and a perfectly competitive, homogenous export, which is sold only to the world market at exogenous world prices. We describe each production sector in turn.

2.3.1 The imperfectly competitive sector

The first consumption-export good, which we will refer to as the *domestic aggregate*, is just a conventional Dixit-Stiglitz aggregate of differentiated goods. The total quantity of the domestic aggregate, denoted by Y_{ht}, the PPI P_{ht}, and the demand for each variety $j, Y_t(j)$, can then be defined in the usual fashion.

Each variety j, in turn, is produced by a single firm using labor $L_t(j)$ and imports $M_t(j)$ according to

$$Y_t(j) = \iota A_t L_t(j)^{1-\varkappa} M_t(j)^{\varkappa} \tag{8}$$

where A_t is a common (country-wide) productivity shock, $\varkappa$ is the commodity share in production, and $\iota = [\varkappa^{\varkappa}(1-\varkappa)^{1-\varkappa}]^{-1}$ is an irrelevant constant.

Variety producers take input prices and wages as given. We allow for the existence of a subsidy to employment in this sector at constant rate υ. Cost minimization requires each variety producer to choose inputs such that

$$\frac{M_t(j)}{L_t(j)} = \frac{M_t}{L_t} = \frac{\varkappa}{1-\varkappa}\frac{W_t(1-\upsilon)}{P_{mt}} \tag{9}$$

where the first equality emphasizes that all variety firms choose the same relative input mix, and we have defined $L_t = \int_0^1 L_t(j)dj$ and $M_t = \int_0^1 M_t(j)dj$.

Nominal marginal cost is therefore the same for all variety firms and given by

$$\Psi_t = P_{mt}^{\varkappa}((1-\upsilon)W_t)^{1-\varkappa}/A_t \tag{10}$$

Variety producers are monopolistic competitors and set prices in domestic currency as in Calvo (1983): each individual producer is allowed change nominal prices with probability $(1-\theta)$. As is now well known, all variety producers with the opportunity to reset prices in period t will choose the same price, say $\bar{P}_t$, which satisfies:

$$\sum_{k=0}^{\infty}\theta^k E_t\left[\Xi_{t,t+k}Y_{t+k|t}(\bar{P}_t - \frac{\varepsilon}{\varepsilon-1}\Psi_{t+k})\right] = 0 \tag{11}$$

where ε denotes the elasticity of substitution between domestic intermediate varieties and $Y_{t+k|t}$ is the demand in period $t+k$ for a producer that last set her price in period t. Also, the price of the home aggregate is given by:

$$P_{ht} = \left[(1-\theta)\bar{P}_t^{1-\varepsilon} + \theta P_{h,t-1}^{1-\varepsilon}\right]^{1/(1-\varepsilon)} \tag{12}$$

2.3.2 The Competitive Exports Sector

As mentioned, we extend CC by allowing for a competitive export sector, modeled after "enclaves" often found in developing countries. Firms in that sector use labor to produce a good sold in the world market at exogenous prices.

The production function in the competitive export sector is Cobb Douglas:

$$Y_{xt} = A_{xt} L_{xt}^{\varrho}$$

where $0 \leq \varrho \leq 1$, L_{xt} is the amount of labor input in the sector, and A_{xt} a sectoral productivity shock. Note that the case $\varrho = 0$ reduces to the assumption that homogenous exports are given by an exogenous endowment, a case that has received attention in the literature (e.g. Bodenstein and Guerrieri 2011).

Profit maximization then requires:

$$\varrho A_{xt} L_{xt}^{\varrho-1} = \frac{W_t}{S_t P_{xt}^*} = \frac{W_t}{X_t P_t} \frac{1}{Z_{xt}^*} \tag{13}$$

where Z_{xt}^* is the export's world relative price. Note that we have assumed that the wage is not subsidized, in contrast with the differentiated goods sector.

2.4 Equilibrium

We assume that the foreign demand for the domestic aggregate is given by a function of its price relative to P_t^* and the index C_t^* of world consumption. Hence market clearing for the home good requires:

$$Y_{ht} = C_{ht} + \phi \left(\frac{P_{ht}}{S_t P_t^*} \right)^{-\gamma} C_t^* = (1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{-\eta} C_t + \phi \left(\frac{P_{ht}}{S_t P_t^*} \right)^{-\gamma} C_t^* \tag{14}$$

where the second equality follows from 2, ϕ is a constant and γ is the price elasticity of the foreign demand for the domestic aggregate. Note that we allow the home and foreign elasticities of demand for home goods, γ and η, to differ.[5]

Equilibrium also requires that the supply of labor equal the demand for labor:

[5] In the case $\phi = 0$, the home aggregate is a nontraded good. We do not explore that case here, however.

$$N_t = L_t + L_{xt} \tag{15}$$

Finally in equilibrium, value added in home production must be:

$$V_t = P_{ht}Y_{ht} + S_t P^*_{xt} Y_{xt} - P_{mt}M_t = P_{ht}Y_{ht} + Z^*_{xt} X_t P_t A_{xt} L^{\varrho}_{xt} - Z^*_t X_t P_t M_t \tag{16}$$

The description of the model is complete once a monetary policy rule is specified. Before stating the class of rules we will be concerned with, however, the next section motivates and justifies our choice with a discussion of analytical aspects of monetary policy.

3 Monetary Policy Choices: Conceptual Issues

Dominant New Keynesian models of closed economies often imply that optimal policy must completely stabilize the PPI. In those models, as discussed by Woodford (2003), Gali (2008), and others, this suffices to correct the distortions associated with nominal rigidities. While this prescription has been qualified in various ways [6], its practical implication has been that studies of closed economies usually focus on monetary rules that target the PPI.

In extensions of New Keynesian models to the small open economy, the ability of the monetary authorities to affect international relative prices introduces a second consideration, sometimes called *terms of trade externality.* This is well known to imply that PPI stabilization does not generally deliver optimal allocations (Corsetti and Pesenti 2001, Benigno and Benigno 2003). But Gali and Monacelli (2005) identified a special case where it does, while Faia and Monacelli (2007) and De Paoli (2009) found that, for many other plausible parametrizations of the models, PPI targeting is almost optimal. Likewise, Hevia and Nicolini (2012) argue that PPI stabilization is in fact optimal if complemented appropriately by tax policy.

All of these results suggest that one should restrict attention to PPI targeting even in a

[6] For instance, if there are cost push shocks or real rigidities.

model like ours. However, our model has many features that distinguish it from others, such as a variable world price of imports, as well as alternative assumptions about international risk sharing.[7] To understand why and how these model features affect the monetary policy problem, this section lays out that problem in some detail.[8]

3.1 The Social Planner's Tradeoffs

Suppose that the economy has a social planner that maximizes the welfare of the representative agent. Our first task is to identify the planner's tradeoffs.

For simplicity, in this section we assume that there are no competitive exports and that imports do not enter the domestic production function; the general case is delayed to the Appendix. We also normalize here on κ to 1. One implication is that the aggregate production function is linear: $Y_{ht} = A_t L_t = A_t N_t$. Then, using 7, the market clearing condition for home goods, 14, can be written as:

$$A_t N_t = (1-\alpha) g(X_t Z_t)^{\eta} C_t + \phi X_t^{\gamma} g(X_t Z_t)^{\gamma} C_t^{*} \tag{17}$$

where we have expressed P_t/P_{ht} a function of the real exchange rate and the price of imported food:

$$\frac{P_t}{P_{ht}} = g(X_t Z_t) = \left\{ \frac{1-\alpha (X_t Z_t)^{1-\eta}}{1-\alpha} \right\}^{1/(\eta-1)} \tag{18}$$

Equation 17 expresses a crucial aspect of the planner's tradeoff between consumption and leisure, given the real exchange rate. It must hold at all times, i.e. under any scenario and assumption made here.

The description of the relevant planner's tradeoffs is completed with one of our assumptions

[7] All of the studies cited in the previous paragraph assume perfect risk sharing, with the exception of Corsetti and Pesenti (2001). But in the latter international asset markets play no role.

[8] Some of the material in this section overlaps with Faia and Monacelli (2007) and the recent piece by Monacelli (2012). However, we clarify, and simplify the logic in several ways, which helps unifying the discussion and extend it to the many variants of our model. Perhaps most importantly, while Faia and Monaceli (2007) and Monaceli (2012) restricted analysis to the case of perfect risk sharing, we show how to deal with the case of portfolio autarky.

on financial markets, perfect risk sharing versus portfolio autarky. We take up each case in turn.

3.2 Policy With Perfect Risk Sharing

If there is perfect international risk sharing, 4 holds at all times. Together with 17, it summarizes the key restrictions on the planner's choice of C_t, N_t, and X_t.

Since both restrictions are static, the *Ramsey* planner's problem is static too: at any t and given any value of the exogenous shocks, the planner must choose C_t, N_t and X_t to maximize current utility $u(C_t) - v(N_t)$ subject to 4 and 17. To analyze this choice, it is convenient to use 4 to rewrite 17 as:

$$A_t N_t = C_t^* \Theta(X_t, Z_t) \tag{19}$$

where

$$\Theta(X, Z) = (1-\alpha) g(XZ)^\eta X^{1/\sigma} + \phi X^\gamma g(XZ)^\gamma$$

This and 4 summarize the planner's constraints. Consider, specifically, a marginal depreciation of the real exchange rate (an increase in X_t). By the risk sharing condition 4, this raises home consumption with elasticity $1/\sigma$. On the other hand, it increases demand for the home good, and hence labor effort, with elasticity equal to the elasticity of Θ with respect to X_t. Note that the latter depends on the different parameters of the model as well as the shock Z_t.

It is then not too surprising that the first order optimality condition is:

$$u'(C_t) \frac{1}{\sigma} X_t^{1/\sigma - 1} = \frac{v'(N_t)}{A_t} \Theta_1(X_t, Z_t) \tag{20}$$

where Θ_1 denotes the partial derivative of Θ with respect to its first argument X.

The LHS is the utility benefit of a marginal depreciation, while the RHS is the cost of the labor associated with the resulting increase in demand.

The optimal Ramsey allocation is now completely characterized by 4, 19, and 20. Several points are noteworthy. The optimal solution (C_t, N_t, X_t) is generally stochastic and depends on the shocks Z_t and A_t. In particular, the ratio of the marginal rate of substitution between labor effort and consumption, $v'(N_t)/u'(C_t)$, to the marginal product of labor, A_t, is equal to $X_t^{1/\sigma - 1}/\sigma\Theta_1(X_t, Z_t)$, which is constant only in special cases. In other words, optimality does *not* require stabilizing the MRS/MPN ratio.[9]

It is instructive to express the optimality condition in terms of elasticities. Letting $El_X\Theta$ denote the elasticity of Θ with respect to X,[10] and using 4 and 19, 20 can be rewritten as

$$\frac{1}{\sigma}C_t u'(C_t) = v'(N_t)N_t El_X\Theta$$

This just says that the planner equates the marginal benefit of a one percent real depreciation to its cost. By perfect risk sharing, a one percent increase in X_t raises C_t by $1/\sigma$ percent, or C_t/σ units of consumption. So the LHS is the utility benefit of a one percent depreciation. A one percent depreciation raises world demand Θ and, therefore, the demand for labor, by $El_X\Theta$ percent, or $N_t El_X\Theta$ units, so the RHS is the utility cost of the additional demand for labor implied by the depreciation.

The last expression emphasizes that openness, production and consumption structure, etc. affect the planner's problem to the extent that they influence the equilibrium elasticity of world demand Θ with respect to the real exchange rate, $El_X\Theta$. Intuitively, this is because it is that elasticity which determines the incentives for the planner to exploit the "terms of trade externality".

To see whether the planning allocation can be implemented in a market equilibrium, assume that prices are *flexible.* Then, in any market equilibrium, monopolistic competition implies that

[9] Note that this contrasts with Monacelli (2012, section 2).

[10] It is easiest to define elasticities sequentially. Letting the elasticity of g be denoted by $El_{XZ}g = \alpha(X_tZ_t)^{1-\eta}/(1-\alpha(X_tZ_t)^{1-\eta})$, then

$$El_X\Theta = \frac{(1-\alpha)g(X_tZ_t)^{\eta}X_t^{1/\sigma}}{\Theta}[\eta El_{XZ}g + \frac{1}{\sigma}] + \frac{\phi X_t^{\gamma}g(X_tZ_t)^{\gamma}}{\Theta}[\gamma + \gamma El_{XZ}g]$$

Note that the elasticities are time varying, in general.

prices are a markup over marginal cost, $P_{ht} = \mu MC_t = (1-\upsilon)W_t/A_t = (1-\upsilon)W_t/A_t$. And since $W_t/P_t = v'(N_t)/u'(C_t)$ we get:

$$\frac{v'(N_t)/u'(C_t)}{A_t} = \frac{1}{\mu(1-\upsilon)g(X_t Z_t)} \tag{21}$$

The flexible price market equilibrium (or *natural*) outcome is therefore pinned down by 4, 19, and 21.

Clearly 21 generally differs from 20, so the flex price natural outcome will differ from the Ramsey planner's outcome. This is the case even if $\mu(1-\upsilon) = 1$, that is, even if the wage subsidy is chosen to eliminate the monopolistic competition distortion, as often assumed in the literature. The discrepancy, in fact, is solely due to the terms of trade externality alluded above. [11]

Since complete PPI stabilization results in the flexible price market equilibrium, our analysis identifies why and how PPI targeting may be suboptimal. Conversely, it gives the conditions under which PPI stabilization can be in fact optimal (a case often called *divine coincidence*). Thus, for example, if $\eta = \gamma = 1/\sigma$, it is not hard to show that 20 and 21 coincide exactly provided that

$$\frac{1-\alpha}{(1-\alpha)+\phi} = \frac{1}{\mu(1-\nu)}$$

Under the additional assumption $\alpha = \phi$, this is Gali and Monacelli's (2005) condition for PPI stabilization to be optimal. Our analysis generalizes theirs a little but also indicates that that case is quite special.

Likewise, suppose that the wage subsidy is not constant but time varying instead. Then 20

[11] To see this point more clearly, suppose that, in fact, $\mu(1-\upsilon) = 1$. Then the market flex price outcome would be $u'(C_t) = \frac{v'(N_t)}{A_t} g(X_t Z_t)$, which can be regarded as the optimality condition for a planner that does not exploit the terms of trade margin, that is, a planner that takes world prices as given, and that is also subject to a balanced trade constraint. The LHS would be the utility cost of an additional unit of consumption: for such a "price taking " planner, that unit would require producing $P_t/P_{ht} = g(X_t Z_t)$ units of home output, at labor cost $g(X_t Z_t)/A_t$. The RHS would be the utility cost of the additional output required to pay for the unit of consumption.

and 21 coincide if

$$(1-\upsilon_t) = \frac{\Theta_1(X_t, Z_t)}{\mu g(X_t Z_t)}\sigma X_t^{1-1/\sigma}$$

where the RHS is computed at the optimal allocation, that is, derived from 4, 19, and 20. This says that the flexible price allocation is optimal if the wage subsidy is chosen appropriately.

In effect, the latter explains why Hevia and Nicolini (2012) find that PPI stabilization is optimal in a model quite similar to ours: they assume that fiscal instruments are "sufficiently flexible", which means in our context that the wage subsidy is chosen as given in the previous expression. We proceed, however, under the traditional (and perhaps more realistic) assumption that fiscal instruments are fixed exogenously and separate from the relative evaluation of alternative monetary policies.

3.3 Policy Under Financial Autarky

Now assume financial autarky, $P_{ht}Y_{ht} = P_t C_t$, which under the assumptions of this section can be written as:

$$g(X_t Z_t) C_t = A_t N_t \tag{22}$$

To get a sense of the resulting planner's "budget constraint ", use the last expression in 17 to get:

$$A_t N_t = (1-\alpha) g(X_t Z_t)^{\eta} \frac{A_t N_t}{g(X_t Z_t)} + \phi X_t^{\gamma} g(X_t Z_t)^{\gamma} C_t^*$$

This reflects the underlying tradeoff: as before, a real depreciation increases demand via expenditure switching. But it also reduces the purchasing power value of home output, hence leads to lower consumption, which in turn tempers the impact on total demand for output and the demand for labor.

Hence the incompleteness of financial markets changes the terms of the tradeoff for the planner. Optimal policy must then change accordingly.

The Ramsey problem is to choose C_t, N_t, and X_t to maximize $u(C_t) - v(N_t)$ subject to 17 and 22. For a sharp characterization, let D_t denote the RHS of 17, that is, world demand for home goods; note that it is a function of C_t, X_t as well as shocks. Then the first order optimality condition can be written as:

$$\frac{v'(N)}{A} D[El_X D - El_C D El_{XZ} g] = u'(C) C[El_X D - El_{XZ} g] \qquad (23)$$

where $El_X D$ is the elasticity of D wrt X, etc. [12]

The condition is again quite intuitive: the Ramsey planner equates the welfare cost, in terms of labor, of a real exchange depreciation with utility benefit from increased consumption. Consider a one percent real depreciation. The LHS term in brackets is the total percent increase in demand for the home aggregate (the direct effect on demand plus the indirect effect via home consumption). So the LHS product is the utility cost of the additional labor resulting from the increased demand due to the depreciation. In the RHS, the term in brackets is the percentage increase in consumption, equal to the difference between increased production and the fall in the relative price of domestic output. The RHS product is, then, the increase in utility associated with the additional consumption resulting from the one percent depreciation, as claimed.

The preceding condition together with 17 and 22 characterize the Ramsey optimal solution under financial autarky. On the other hand, the flex price market outcome, and *a fortiori* also the result of complete PPI stabilization, is given by 17, 21, and 22. Note that the last equation is the only difference relative to the perfect risk sharing case.

Inspection of these systems of equations reveals that the planner's solution will be, in general, different from the flex price market outcome, as in the perfect risk sharing case. But the equations tell us more precisely the way in which different assumptions about international risk sharing affect the optimal allocations and the way PPI stabilization may not be optimal. In fact, finding cases in which PPI stabilization is optimal (which reduces to the equality of 21 and 22) appears analytically intractable.

[12] Here, $El_C D = (1-\alpha) g(X_t Z_t)^\eta C_t / D_t$ and

$$El_X D = \frac{(1-\alpha) g(X_t Z_t)^\eta C_t}{D_t} \eta El_{XZ} g + \frac{\phi X_t^\gamma g(X_t Z_t)^\gamma C_t^*}{D_t} (\gamma + \gamma El_{XZ} g)$$

3.4 Summary

Our analysis in this section clarifies conditions under which the flexible price allocation and PPI stabilization coincide with the Ramsey planner's allocation. We have stressed that such conditions are quite stringent, which means that there is room for other rules to "beat" PPI stabilization in terms of welfare. We have also seen that some features of the economy, such as openness and production structure, affect the monetary policy problem by changing the relevant elasticities that determine the strength of the terms of trade externality. Assumptions about international risk sharing, in contrast, affect the problem more drastically, by changing the structure of the systems of equations that determine the planning solution and the flex price solution. At this level of generality there is little more than we can say. But we can now make much more progress by looking at parameterized cases. We now turn to those.

4 Parametrization and Dynamics

4.1 Calibration

Table 1 reports on the parameter values we have used for calibrating the model. Many of our choices are standard, including the values for the discount factor, the frequency of price adjustments, and the elasticity of substitution across domestic goods. Since the response of consumption to the real exchange rate is crucial in our model and, under perfect risk sharing, depends on the coefficient of relative risk aversion, we allow for that coefficient to vary between 2 and 6. Regarding the elasticity of labor supply ($1/\varphi$), the range of estimates found in the literature is wide, varying between close to zero to well above one. A unitary labor supply elasticity seems to be a plausible compromise for macro studies (see e.g. Heckman 1993), so we stick to that baseline value.

We set the share of imports in the CPI at 25 percent following Gali and Monacelli (2005) and de Paoli (2009). More critical for our results, as seen below, is the parametrization of the price elasticity of foreign demand for the home aggregate, γ. Previous studies have assumed that $\gamma = \eta$, although there is no compelling reason to impose the equality. To preserve comparability, we present results when the model is indeed calibrated with $\gamma = \eta$, though letting η span a reasonably wide range, from 0.75 to 5[13]. But also provide results allowing γ to differ from η . This may be particularly important in the context of specialization, allowing for the possibility, for instance, that our model economy produces and exports fix-price goods with high export price elasticity (e.g. lightly processed manufacturing goods) while it imports essential commodities (food and oil) that cannot be easily substituted away in consumption or production. That raises the question of what values of γ to consider. Using aggregate data from advanced economies, Hooper, Johnson and Marquez (2000) reported estimates around one. However, the relevant elasticity in our model is that of a sticky price sector; if that sector is manufacturing in an emerging economy, it is likely to produce less complex/differentiated varieties than in advanced countries, arguably facing a much flatter world demand schedule.[14] Cross-country econometric studies report estimates of the price elasticity of manufacturing goods of around 5 (Lai and Trefler 2002, Harrigan 1993). Given these considerations, we take $\gamma = 5$ as a sensible baseline.

Still regarding imports, but turning to their role in production, we follow Arseneau and Leduc (2012) by calibrating the share of imported inputs in domestic production, $\varkappa$, to ten percent. Blanchard and Gali (2007) used a much lower share (two percent) for the U.S. But we regard the imported input in our model as a composite not limited to oil. And even if we restrict attention to oil, emerging market economies are probably much less energy efficient than the U.S. So ten percent seems a reasonable compromise for a benchmark. To check for

[13] The rationale for a low η is that when the share of imported consumption is made up of food and or oil, goods with a low price elasticity of demand, it seems sensible to consider values η below one. In fact, using food price data from the World Bank's World Development Indicators and from the U.S. Department of Agriculture, Anand and Prasad (2012) estimate a median price elasticity of about 0.25 for food, which is also used in Catao and Chang (2010). But the consumption basket in our model may contain non-food imported items with greater scope for substitutability, so we settle on 0.75 as the lower bound for that range.

[14] Indeed, it seems likely that lightly processed manufactures exported by many emerging countries are much more easily substitutable in world markets than, say, complex hardware and software equipment, optical and machine tool parts, and other items exported by, say, the US, Germany, and Japan.

robustness below, we also examine what happens when $\varkappa = 0$.

The inclusion of an "enclave" export sector is a main novelty of our model relative to others. We think of the enclave sector as comprising highly capital intensive industries, such as mining, in which the labor share in output is small but the value of the output can be substantial. Available United Nations data for Chile and Peru suggest that employment in enclave sectors is about one percent of total employment while the value of the sector's output is about ten percent of total value added. We set the parameters of the sector's production function, A_x and ϱ, at fifteen percent and ten percent respectively to roughly match these facts.

In our computations, we assume that C_t^* is constant, and then set κ and C^* to one (this can be shown to be just a normalization). And following the literature, we set the wage subsidy υ equal to the inverse of $\varepsilon(1 - \varkappa)$, which is the value consistent with the elimination of the monopolistic distortion in the differentiated goods sector.

Finally, we turn to the calibration of the stochastic processes for the different shocks in the model. We set the quarterly standard deviation of shocks to world prices of competitive exports, $\sigma_{z_x^*}$, at seven percent, and its autorregresive coefficient, $\rho_{z_x^*}$, at 0.75. These values are consistent with Arseneau and Leduc (2012) as well as our own estimations based on the IMF commodity price indices for non-food and non-oil commodities. To calibrate the process for the world relative price of imports, we borrow our own estimates (from CC) and set baseline values of the world import price volatility, σ_{z^*} , at five percent, with an AR(1) coefficient of 0.75. We also examine the implications of alternative (lower) values for these AR(1) process.

We based our calibration of non-price shocks on estimates from Chile, a prototype small open emerging economy for which there is reasonably long quarterly data of good quality. Accordingly, we set the standard deviation of productivity shocks at 1.2 percent per quarter and the AR(1) coefficient for productivity at 0.7. The latter is very similar to that of Gali and Monacelli (2005) assumed based on Canadian data. The same paper reported standard deviations of Canadian TFP shocks of 0.7 percent, which is consistent with the fact that Chile's output has been about twice more volatile Canada's.

4.2 Monetary Rules

Given that our theoretical discussion has emphasized that PPI targeting may not deliver optimal outcomes in our model, the rest of the paper discusses dynamics and welfare under alternative policy rules that have featured prominently in central bank practices and/or recent debates on monetary policy.

Two of those are standard Taylor rules with a target of *actual* inflation. The first follows the usual prescription from the theoretical literature in setting the policy interest rate as a function of realized PPI inflation and possibly the output gap:

$$\log(1+i_t) = -\log\beta + \phi_\pi \pi_{ht} + \phi_y(\log Y_{ht} - \log Y_{ht}^n) + v_t \tag{24}$$

where $\pi_{ht} = (P_{ht}/P_{ht-1}) - 1$ denotes the rate of domestic inflation and Y_{ht}^n denotes natural output. The alternative, widely practiced by central banks around the globe, targets the broad consumer price index (CPI) inflation:

$$\log(1+i_t) = -\log\beta + \phi_\pi \pi_t + \phi_y(\log Y_{ht} - \log Y_{ht}^n) + v_t \tag{25}$$

In these and other cases, v_t is a conventional monetary shock, assumed to follow a first order autorregresive process calibrated as discussed in the previous section.

We also consider two other rules that have featured in recent policy discussions but have not been studied in the literature reviewed in the introduction. One of them, usually called CPI inflation *forecast* targeting, targets expected CPI inflation over a given horizon. In practice, this typically involves a complex macro forecast apparatus by central banks (as discussed e.g. in Laxton et al. 2009) and a choice of the relevant forecast horizon during which inflation is targeted. As discussed recently in central bank inflation reports around the world, the targeting horizon choice involves non-trivial trade-offs that have been mostly influenced by developments in global commodity markets.[15] While an analysis of targeting horizons is beyond the scope

[15] See, for instance, http://www.bankofengland.co.uk/publications/Pages/inflationreport/infrep.aspx. In-

of this paper, our setting does allow to implement forecast targeting rules in a model-based forecasting structure that takes into account the underlying stochastic processes of commodity price shocks. To the best of our knowledge, this is novel in the small open economy New Keynesian literature.

We implement the CPI forecast targeting rule – which we henceforth label expected CPI targeting – by replacing realized inflation by one-period ahead expected CPI inflation as a target in an otherwise conventional rule:

$$\log(1+i_t) = -\log\beta + \phi_\pi E_t\pi_{t+1} + \phi_y E_t(\log Y_{ht+1} - \log Y^n_{ht+1}) + v_t \tag{26}$$

In order to calibrate each of these Taylor rules, we computed "optimal" coefficients on inflation and the output gap as follows. Using a baseline calibration for other parameters described above (with $\gamma = 5$ and $\sigma = 2$, but letting η vary) we computed discounted utility values resulting from varying the coefficients of the PPI and the CPI rules over a grid, spanning from 1.5 to 5 (with 0.25 increments) for the coefficient on inflation (ϕ_π) and from 0 to 0.5 (with 0.125 increments)f or the coefficient on the output gap (ϕ_y). We did so for PPI and CPI rules. For the PPI rule, a non-zero weight on the output gap consistently delivered higher welfare than zero weight (the so-called "strict IT"); values of ϕ_π between 1.5 to 2.5 were found to optimize the rule when ϕ_y =0.25. For the (conventional) CPI rule, the optimizing coefficient on inflation was a little lower, around $\phi_\pi = 1.5$. Accordingly, in what follows we set $\phi_\pi = 2.0$ for the PPI rule and $\phi_\pi = 1.5$ for the CPI rule, with ϕ_y=0.25 for both rules. For the expected CPI rule, the calibration was not as smooth due to convergence problems when the inflation coefficient rose above 3. Hence we simply set ϕ_π to 2, as with the PPI rule, and hence a bit more agressive relative to the current CPI rule.

Lastly, we consider a version of the so-called "export price targeting" (EPT) rule, proposed by Frankel (2010, 2011). Frankel's proposal was for monetary policy to stabilize the domestic

deed, the recent attractiveness of such a forecast targeting rule in the wake of commodity price boom and bust of 2006-09 lies in its potentially more accommodative stance towards commodity price shocks than the standard Taylor rules with either PPI or CPI targeting.

price of commodity exports. However, as discussed in Catão (2011), strict implementation of such a price level-based rule in countries with export price indices of rapidly changing composition, and with individual components that are highly volatile and hard to forecast at high frequencies, poses formidable challenges, not the least for reserve management policies. A milder and more easily implemented version of that rule is that of stabilizing domestic export price *inflation*. Thus we implement this variant of the EPT rule by replacing the previous Taylor rules by the following exchange rate setting equation:

$$\frac{S_t}{S_{t-1}}\frac{P_t^*}{P_{t-1}^*} = \frac{Z_{xt-1}^*}{Z_{xt}^*} \tag{27}$$

Note that for trivial levels of world inflation (i.e., $P_t^* = P_{t-1}^*$) and in the absence of relative shocks to the world export price, i.e. Z_{xt}^* constant, this rule coincides with an exchange rate peg.

4.3 Dynamics

The dynamics of our model can be glanced from studying its responses to different shocks, in particular shocks to relative world prices. Figure 1 displays impulse responses of key variables (in logs) to a one standard deviation positive shock to the world price of imports. The figure assumes a strict PPI targeting rule with $\phi_\pi = 1.5$ and perfect international risk sharing. In order to highlight the crucial impact of elasticities of world demand, we examine two values, $\gamma = 0.75$ and $\gamma = 5$, for the elasticity of world demand for the home aggregate. In contrast, η is kept at 0.75. Finally, the figure assumes that the share of imported inputs in home production of differentiated goods, $\varkappa$, is ten percent.

Focus first on the case $\gamma = \eta = 0.75$ (solid line). The responses in the first row can be interpreted readily with reference to CC. CC show that, in the absence of nominal rigidities, a positive shock to the price of imports must be accommodated with a terms of trade deterioration and a real exchange rate appreciation. Figure 1 then shows that, in the present model, the terms of trade and the real exchange rate follow their natural counterparts. Note that the two variables move in opposite directions, as stressed by CC.

Because of perfect risk sharing, consumption falls as it tracks the behavior of the real exchange rate. Correspondingly, consumption growth increases, which implies that the real interest rate goes up.

The response of output and employment shows that there are significant differences between CC and the present model. In CC, the condition $\eta > 1/\sigma$, as assumed for Figure 1, implies that natural output must increase in response to a positive z^* shock. But Figure 1 shows that natural output falls in the present model. The difference is due to the fact that imports are assumed to be an input to production. Since the relative price of imports has increased, real marginal cost goes up in the differentiated goods sector. On the other hand, the real wage goes down on impact, reflecting both the increase in the relative price of imports and the fall in consumption, the latter leading to an increase in the supply of labor. The net implication of these effects in that output falls but employment increases in the differentiated goods sector.

While output of the home aggregate falls, it does not fall as much as natural output. As a consequence, the output gap becomes positive and PPI inflation picks up. The monetary response is to increase the nominal interest rate. CPI inflation, on the other hand, increases on impact, but falls afterwards. This reflects the combined impact of the increase in the price of imports and exchange rate appreciation.

Figure 1 shows that employment in the homogeneous exports sector falls in response to the imports price shock. This reflects that the product wage increases in that sector: recall that, in terms of the homogeneous export good, the wage is $W/SP^*_{xt} = (W/P)(1/XZ^*_{xt})$. As Figure 1 reveals, while W/P falls, the real exchange rate falls by more, and hence the product wage increases.

For the parameters of Figure 1, the employment increase in the differentiated goods sector dominates the fall of employment in the homogeneous exports sector. Hence total employment goes up. Falling consumption and rising labor effort mean a fall in welfare, as shown by the last panel in Figure 1.

The dashed line in Figure 1 shows the implications of a higher γ, which emphasizes the crucial role of elasticities of demand in the model. The first row of responses shows that the responses of the real exchange rate, the terms of trade, and consumption are about the same as when $\gamma = 0.75$, but that natural output falls by much more. This happens because, with a higher γ, the same response of relative prices to the z^* shock now results in a much bigger reduction in the world demand for the home aggregate. Accordingly, output in the differentiated goods sector falls much much more and labor employment in the sector increases by much less than when $\gamma = 0.75$. The fall in the real wage is steeper also, which cushions the fall in employment in the homogeneous exports sector. All in all, total employment increases by much less when $\gamma = 5$ than with $\gamma = 0.75$ and, since consumption is about the same, welfare falls by less.

In the same case as in Figure 1, Figure 2 displays responses to a one standard deviation (seven percent) shock to the world price of exports. All of the responses are quantitatively insignificant except for that of employment in the homogeneous exports sector, which increases by about eight percent. To understand this, suppose for a moment that ϱ had been zero, that is, that the competitive export had been just a pure endowment. In that case, perfect risk sharing implies that a favorable export price shock would have no impact whatsoever on home variables, since any windfall gain or loss from export price fluctuations would have been insured away. In our case, ϱ is not zero but small. Hence an efficient response to the favorable export price shock involves an increase in labor employment in the homogeneous export sector; the magnitude of the increase is essentially equal to $1/(1-\varrho) = 1/0.9$ times the size of the shock. This is transmitted to the rest of the economy via the labor market, as the real wage increases to accommodate increased employment. This explains the rest of the responses, in particular the contraction of employment and labor in the differentiated goods sector. That contraction, the difference between the solid and the dashed lines reveals, is more marked if γ is high, since the associated real exchange appreciation implies a stronger contraction in the world demand for the home aggregate. However, the responses are quantitatively tiny regardless of the value of γ. Note that welfare falls, if only a tiny amount, reflecting increased labor effort.

In order to assess the role of capital mobility, Figure 3 compares impulse responses to an imports price shock under perfect international risk sharing (solid line) and financial autarky (dotted line). The figure assumes that $\gamma = \eta = 0.75$, and otherwise the same parameters as in Figure 1. Consequently, the solid line in Figure 3 is the same as the solid line in Figure 1. Responses under financial autarky, however, are markedly different. The increase in the world price of imports leads to a larger terms of trade deterioration and smaller real appreciation than under perfect risk sharing. This, in turn, leads to a large reduction in real value added and, hence, of consumption. Lower consumption exacerbates the fall in the real wage, which leads to a significant expansion in labor employment and output in all sectors. This leads to a larger increase in the output gap and PPI inflation than under perfect risk sharing, and a larger interest rate response. Finally, welfare falls more steeply than under perfect risk sharing, reflecting the stronger responses of both consumption and labor effort.

Figure 4 compares responses to a favorable exports price shock under perfect risk sharing and financial autarky. Again, the solid lines correspond to perfect risk sharing and are, accordingly, the same as the solid lines in Figure 3. The difference with the dotted lines reveal that the responses under financial autarky are different and much bigger. Under financial autarky, the favorable shock to the price of homogeneous exports increase real value added directly, leading to a large increase in consumption. There is a large real appreciation and improved terms of trade, and a large increase in the real wage. Accordingly, employment and output in the differentiated goods sector fall, leading to a fall in PPI inflation which is followed by a lower nominal interest rate. Employment in the competitive export sector increases but not by as much as under perfect risk sharing, reflecting the opposite effects of higher export prices against a higher real wage. Total employment falls which, together with increased consumption, implies that welfare increases, in contrast with the perfect risk sharing case.

Figures 1 to 4 assume that a Taylor monetary rule of strict PPI targeting, and help establishing that responses to shocks depend in a very sensitive way on parameters such as elasticities of demand, as well as on assumptions about international risk sharing. Our theoretical discussion on monetary choices then suggests at least two conjectures: first, that rules other than PPI targeting may attain higher welfare; and second, that whether a competing rule can or cannot beat PPI targeting may depend on the parameters of the model and on the completeness of international financial markets. We examine both conjectures fully in the next section. But before turning to that section, Figures 5 to 8 offer some additional impulse responses that can add intuition on monetary choices.

Specifically, Figure 5 compares consumption, labor, and real exchange rate responses to a one standard deviation shock to import prices assuming PPI targeting (dotted green lines) vis a vis expected CPI targeting (thick dashed blue). In addition, the figure displays the responses of the natural (flex price) corresponding variables (thin solid blue), as well as the optimal Ramsey allocations (thick solid red), computed as indicated in the Appendix. The parametrization is the same as in Figures 1-4, with $\eta = 0.75$ and $\gamma = 5$ to enhance contrast.

The figure reveals, not too surprisingly, that PPI targeting approximates the flex price allocation. But it also shows that there are quantitatively significant differences between those responses and the Ramsey optimal response. An optimal response requires, in particular, a smaller appreciation of the real exchange rate (about one percent, as opposed to more than 1.5 percent for PPI targeting and flex prices), which results in a smaller fall of consumption (0.6 percent as opposed to more than 0.8 percent). The Ramsey allocation also results in a small increase in labor effort, while PPI targeting/flex prices leave labor effort essentially unaffected in response to the imports price shock. Essentially, these responses reflect that the planner exploits more heavily the "terms of trade externality" than PPI targeting to cushion the impact of the shock.

Figure 5 also tells us that the targeting expected CPI delivers exchange rate and consumption responses that are closer to the optimal ones than targeting PPI. This is intuitive, since stabilizing expected CPI is bound to have stabilizing effects on exchange rates. On the other hand, expected CPI targeting exacerbates the response of labor beyond the planner's. The labor responses are quite small, however, which suggests that expected CPI targeting should deliver higher welfare than PPI targeting if imports prices are more volatile and there is perfect capital mobility.

Figure 6 conducts the same experiment for shocks to exports prices. Two aspects of the figure are revealing: both PPI targeting and expected CPI targeting lead to similar responses, which are quite close to the responses under flexible prices; and all three responses are quite different from the Ramsey response, although quantitatively the difference is small.

Taken together, Figures 5 and 6 suggest that expected CPI targeting is welfare superior to PPI targeting if imports prices are dominant, while there is little advantage to one or the other if exports prices are the main source of shocks.

The importance of capital mobility for the comparison, however, is highlighted by Figures 7 and 8, which ask the same questions assuming portfolio autarky. The figures suggest that PPI targeting approximates flex price responses quite well, and both sets of responses are not too far from the Ramsey responses. On the other hand, expected CPI targeting delivers responses that seem decidedly out of line with the others. The suggestion, then, is that PPI targeting is likely to beat expected CPI targeting under portfolio autarky.

Summarizing: impulse response analysis highlights that the tradeoffs of the monetary authority depend sensitively on elasticities and international risk sharing. Under perfect risk sharing, Ramsey allocations may prescribe more real exchange rate stability than flexible price allocations, suggesting that PPI targeting is probably dominated by other monetary rules. Under portfolio autarky, PPI targeting appears less likely to be defeated. A final comparison of the different rules, however, requires computing the welfare values associated with each rule. The next section does exactly that.

5 Welfare Implications of Alternative Rules

Having parameterized the model, we use the numerical procedures and programs of Schmitt Grohe and Uribe (2004), as implemented via DYNARE, to compute a second order approximation of the equilibrium and the welfare level associated with each policy under study. We follow Schmitt-Grohe and Uribe (2007) in comparing welfare values "conditional" on the same starting point which, as in these previous studies, is the non-stochastic steady state. Besides the obvious theoretical appeal of this metric, it also simplifies the computational burden considerably.[16]

As standard, we express welfare losses in each case as the percentage of nonstochastic steady state consumption that the representative home agent would be willing to give up to live in the resulting steady state. For PPI, for instance, the relevant formula is:

$$\lambda_{ppi} = 1 - \frac{(1-\sigma)^{1/(1-\sigma)}}{C_{ss}} \left[U_{ppi}(1-\beta) + \zeta \frac{N_{ss}^{1+\varphi}}{1+\varphi} \right]^{1/(1-\sigma)}$$

where U_{ppi} is the welfare level associated with the PPI rule, and C_{ss} and N_{ss} are the steady state values of consumption and labor effort.

5.1 Comparison Across Rules

Table 2 reports the various welfare gaps between policy rules when commodity price shocks are all set to zero. The table assumes full international risk sharing and, therefore, reduces to the case usually considered in previous work, giving a useful benchmark against which one can gauge the role of commodity price shocks in altering the welfare rankings. The table allows σ and η to take different values and assumes that $\gamma = \eta$. Otherwise the parametrization is the baseline one. Each of the top six panels compares two rules for the various configurations of η and σ; entries in, say, the PPI-CPI panel reports $\lambda_{cpi} - \lambda_{ppi}$, so that a positive number means that the PPI rule entails lower welfare losses (again, always measured relative to steady state consumption) than its CPI counterpart. The bottom panel in the table identifies the "winning"

[16] This has been emphasized by Wang (2006).

rule for each $\eta - \sigma$ configuration.

Several aspects of Table 2 are noteworthy. PPI dominates if η is sufficiently low, but not for higher values of η. This is consistent with previous studies, such as Cova and Sondegaard (2004) and de Paoli (2009). Cova and Sondegaard (2004) and de Paoli (2009) find that a rule that pegs the nominal exchange rate often entails lower welfare losses relative to both PPI targeting and CPI targeting when $\eta = \gamma$ is high enough. This in fact is confirmed by Table 2, since EPT becomes a nominal exchange rate peg when shocks to export prices are shut off, as mentioned earlier. A novelty in Table 2 is that, when expected CPI targeting is included in the set of alternative rules, it wins out at the upper range of η values even when commodity price shocks are trivial.[17] As usual, Table 2 also shows that the welfare gaps are typically small, accounting for less (and often much less) than 0.1 percent of steady state consumption.

Turning now to the main case of our model, Table 3a report results when both export and import price shocks are turned on, maintaining the other assumptions of Table 2, including full international risk sharing. Three features of Table 3 are then notable. First, for $\eta < 5$, PPI still wins out. Second, for higher η values (and $\sigma \geq 2$), Frankel's EPT rule beats all others. Third, the EPT rule is, however, typically welfare inferior to both PPI and CPI rules for lower η=γ. [18] In separate calibrations (not shown here to conserve on space), we also find that the same welfare ranking obtains if shocks to the relative price of imports are turned off. This suggests that, in spite of the export sector's low share in total employment, the combination of highly volatile export prices and domestic labor mobility ensures that exogenous shocks to the world price of exports can significantly affect welfare and the relative desirability of alternative policy rules. Recall, however, that import price volatility imparts an extra welfare wedge between PPI and the other rules relative to the social planner's allocation (cf. Figure 5), thus further accounting for differences in welfare rankings between Tables 2 and 3a.

[17] Consistent with the analytical results discussed in section 3, when all elasticities equal and unitary, the numerical results show PPI dominance across the board. The case of $\sigma = 1$ is not reported to save space but available from the authors upon request.

[18] Given that pegging the nominal exchange rate is widely regarded an inferior rule for commodity exporters (cf. Cashin et al, 2004; Frankel, 2010, 2011) and to keep the table presentation concise, we do not report results for the peg rule. However, they are available from the authors upon request.

In order to evaluate the influence of international capital mobility, Table 3b reports results under the same parametrization but assuming portfolio autarky. The main result is not only that that the PPI rule becomes generally more dominant but also that it delivers much large welfare gains relative to the competing rules. A few times these gains approach one percent of steady state consumption, and even more for the extreme cases involving EPT comparisons and high $\eta = \gamma$. In short, financial autarky generally reinforces the welfare-dominance of PPI targeting over all rules, EPT included. Indeed, as just noted, the EPT rule becomes less desirable relative to all other rules as η grows larger. The clear dominance of the PPI rule under financial autarky is consistent with the evidence presented in Figures 7 and 8 of section 4, showing that PPI delivers responses for consumption and employment that are quite close to the social planner's optimum.

Tables 2, 3a, and 3b assume that $\gamma = \eta$, which is common in the literature. However, there seems to be no obvious reason to impose such equality. In fact, cases in which $\gamma > \eta$ may be particularly relevant, as many small open economies (as well large and less open emerging market economies) have a relatively large domestic manufacturing sector but, at the same time, are also heavy importers and/or exporters of commodities. For such economies, domestic sticky price producers face an elastic demand curve for their exports, so γ can easily be higher than η. To examine this possibility, Tables 4a and 4b report results for $\gamma = 5$.

Table 4a assumes perfect risk sharing. For the Ramsey planner, this means that the benefit of depreciating the real exchange rate, in terms of increased consumption, will need to be balanced against the loss associated with higher employment. If the export price elasticity is high enough, this can potentially lower the ratio of consumption to employment by enough to lower welfare. So, a rule that exploits the terms of externality by appreciating the real exchange rate may have an edge: even though consumption will fall, employment can potentially fall by much more, raising utility. In addition, with greater import penetration of the home-good varieties in the CPI basket, the impact of the domestic price stickiness distortion on consumer choice is mitigated and, the higher σ, the smaller the impact of the real appreciation on overall consumption.

Consistent with this intuition, Table 4a shows that, under full risk sharing, PPI targeting loses much of its lustre unless both σ and η are low enough. In particular, for intermediate values of η and σ, the dominant rule is expected CPI targeting. Figure 5 in section 4 indicates why this is so: under complete markets, when γ is high ($= 5$ in this case) and import price shocks are non-trivial, the expected CPI rule does a better job in stabilizing the real exchange rate and consumption, getting these two variables closer to the social planner's allocation than the PPI rule. True, while Figure 5 also shows that the expected CPI rule raises employment beyond what the social planner optimum, the PPI rule flattens employment too much below that what planner's solutions deems optimal, so on both fronts expected CPI wins out. If η is high enough, however, Table 4a shows that EPT turns out to have an edge over the expected CPI rule, while both dominate PPI. It is interesting to notice that even *current* CPI targeting also beats PPI when $\eta > 1$ and $\sigma > 2$, and more broadly when $\sigma \geq 6$ (see the first panel of Figure 4a).

Table 4b assumes financial autarky and corroborates earlier results: PPI wins out handily. This is completely consistent with our discussion and our analysis of impulse responses, specifically Figure 7 and 8.

Overall, these simulation exercises bring to bear an important policy implication: when a commodity trading country faces a sufficiently high export price elasticity for its exports, it stands to gain by stabilizing expected CPI inflation or, if η is high enough, the relative price of exports via the EPT rule. Yet, this is so only if it faces complete (or near complete) international financial markets. Otherwise, targeting overall PPI is likely to deliver higher aggregate welfare.[19]

[19] Further sensitivity analysis undertaken by us suggest that these results – and in particular the expected CPI dominance for intermediate values of η and σ under complete markets – are broadly robust to some non-trivial (but not unrealistic) reduction in the persistence of commodity price shocks. As one might expect, however, if the persistence of commodity price is set to trivial values [say AR(1) for z^* and z_x^* well below 0.5 on a quartely basis], expected CPI targeting loses its welfare dominance. But such scenario would be highly unrealistic, as commodity price shocks are well known to be highly persistent.

6 Final Remarks

Recent swings in world commodity prices have posed considerable challenges to central banks in their mandate to stabilize headline CPI inflation around an explicit and pre-announced quantitative annual target. Such challenges have been particularly taxing for small economies that export and/or import mainly primary commodities. Facing sharp commodity price upswings and downswings, many of these countries have undergone significant deviations from pre-announced targets.[20] These failings have fueled growing debate on the *de facto* suitability of CPI inflation targeting, particularly among commodity trading economies, and on new proposals for alternative monetary rules. Yet, there has been a dearth of model-based analyses on both the specifics of the relevant commodity price transmission mechanism and the attendant welfare implications of monetary policy choices in this context.

This paper extends our previous framework in Catão and Chang (2010) to an economy that is small in world commodity markets, thus facing exogenous world commodity price shocks, but that is also a commodity exporter and uses commodity imports as input to production. Relative to the literature, a key contribution of this paper has been to undertake a welfare-based assessment of competing monetary rules for the distinct contexts of complete international financial markets and portfolio autarky. Unlike previous work, Ramsey allocations are fully characterized and compared to those implied by alternative policy rules under either full international risk sharing and financial autarky. Another main contribution has been the computation of welfare gaps for a fuller menu of alternative rules and on the basis of extensive and empirically driven model-based calibrations, with particular attention to the underlying stochastic process driving actual commodity price shocks. While other recent work (Hevia and Nicolini 2012) has also characterized Ramsey allocations for the commodity importing economy and assessed welfare implications of both monetary and fiscal policies in this context, it has been limited to the full risk sharing case and relied on special and perhaps unrealistic assumptions about the

[20] See Catão and Chang (2011) for cross-country evidence on such deviations from targeted inflation in the wake of commodity price shocks and their relation to structural breaks in Taylor rules.

availability of fiscal instruments.

We show that the welfare ranking of the different rules depends crucially on the international financial structure and on intra-temporal substitution elasticities, notably the export price elasticity. If risks are fully shared internationally and commodity price shocks are smoothed out efficiently, PPI inflation targeting delivers the highest welfare among the rules considered when commodity price volatility is high and intra-temporal elasticities are low. Conversely, when the export price elasticity is high – a realistic scenario for many small economies that import commodities and export mainly manufacturing goods – expected CPI targeting often delivers welfare levels closer to the Ramsey allocation. Further, when the country has an enclave exporting commodity sector, an export-price targeting rule tends to deliver superior welfare when the export price elasticity is high enough (two or above in our calibrations); but export price targeting fares much worse than other rules under other parametrizations. Crucially, welfare rankings change drastically under portfolio financial autarky: the PPI rule appears superior to over current and expected CPI targeting as well as over export price targeting.

Appendix

This Appendix shows how the analysis of section 3 can be extended to the full model, allowing for imported inputs and the homogeneous exports sector. The key is to recognize that the Ramsey planner must choose imported inputs and competitive exports efficiently. Hence, in particular, the planner will choose labor effort in the competitive export sector so as to equate marginal product in that sector to the implicit real wage, given by the marginal rate of substitution between labor effort and consumption:

$$XZ\alpha_x A_x L_x^{\alpha_x - 1} = \frac{v'(N)}{u'(C)}$$

that is,

$$L_x = \left[\alpha_x A_x Z_x X \frac{u'(C)}{v'(N)}\right]^{1/(1-\alpha_x)} \equiv H(C, N, X), \text{ say} \tag{28}$$

where for convenience we have suppressed time subscripts and the dependence of H on exogenous shocks.

Likewise, the planner will choose the imported input M efficiently so

$$\frac{M}{L} = \frac{\varkappa}{1-\varkappa} \frac{v'(N)}{u'(C)} \frac{1}{XZ}$$

which implies that $Y_h = AL\psi(C, N, X)$, where

$$\psi(C, N, X) = \frac{1}{1-\varkappa} \left\{ \frac{v'(N)}{u'(C)} \frac{1}{XZ} \right\}^{\varkappa} \tag{29}$$

A Perfect Risk Sharing

If risk sharing is perfect, the planner's problem is to choose C, N, L, L_x, and X to maximize $u(C) - v(N)$ subject to the risk sharing constraint 4, the labor supply constraint 15, efficient choice of labor input in the homogenous exports sector:

$$L_x = H(C, N, X) \tag{30}$$

and equilibrium in the market for the home aggregate

$$AL\psi(C, N, X) = C^*\Theta(X)$$

Some tedious but straightforward derivations yield the optimality condition

$$\begin{aligned} & \left[1 + \frac{L}{N} El_N\psi - \frac{L_x}{N} El_N H\right] Cu'(C) \\ = \quad & Nv'(N)\left[\sigma\left(\frac{L_x}{N} El_X H - \frac{L}{N}(El_X\psi - El_X\Theta)\right) + \frac{L_x}{N} El_C H - \frac{L}{N} El_C\psi\right] \end{aligned} \tag{31}$$

where $El_C H$ denotes the partial elasticity of H with respect to C, etc.

This generalizes 20 and, as the reader can check, it coincides with it if $\varkappa = 0$ and $L_x = 0$. This and the four constraints completely characterize the Ramsey allocation. The optimality condition is interpreted in a similar way as in the simpler case.

Expressing the elasticities in full,the expression simplifies drastically and I get:

$$\frac{1}{\sigma} Cu'(C) = \frac{Nv'(N) El_X\Theta}{1 + \left(\frac{L}{N}\varkappa + \frac{L_x}{N}\frac{1}{1-\alpha_x}\right)\varphi}$$

The LHS is, as before, the utility increase due to a one percent real depreciation. This increases the demand for the home aggregate by $El_X\Theta$, but the overall increase in the demand for labor is less because the associated cost in the implicit real wage induces substitution towards imported inputs (the $\frac{L}{N}\varkappa$ term) and a reduction in employment in the homogeneous exports sector (the $\frac{L_x}{N}\frac{1}{1-\alpha_x}$ term).

B Financial Autarky

To express the financial autarky constraint $V_t/P_t = C_t$, note that optimality requires $(P_{ht}/P_t)\,Y_{ht} - (P_{mt}/P_t)M_t = (1-\varkappa)P_{ht}Y_{ht}/P_t$, and that $P_{xt}/P_t = X_t Z_{xt}$. Then one can define real value added as (suppressing time subscripts):

$$\frac{V}{P} = \varpi(C,N,X,L,L_x) = \frac{(1-\varkappa)AL\psi(C,N,X)}{g(XZ)} + Z_x X A_x L_x^{\alpha_x}$$

The planner's problem is to choose C, N, L, L_x, and X to maximize $u(C) - v(N)$ subject to the labor supply constraint 15, efficient choice of labor input in the homogenous exports sector (30), the financial autarky constraint:

$$\varpi(C,N,X,L,L_x) = C$$

and equilibrium in the market for the home aggregate

$$AL\psi(C,N,X) = D(C,X)$$

where $D(C,X)$ is the RHS of 17, as defined in section 3.

After some tedious work, the optimality condition can be expressed as follows:

$$\begin{aligned} & \frac{1}{Cu'(C)}\left\{(El_c H)(\frac{L_x}{L}El_L\varpi - El_{L_x}\varpi) + 1 - El_c\varpi + \Upsilon[\frac{L_x}{L}El_c H - (El_C\psi - El_c D)]\right\} \\ = & \frac{1}{Nv'(N)}\{El_N\varpi + (1+\frac{L_x}{L})El_L\varpi - (El_N H)\left(\frac{L_x}{L}El_L\varpi - El_{L_x}\varpi\right) \\ & +\Upsilon\left[El_N\psi + (1+\frac{L_x}{L}) - \frac{L_x}{L}El_N H\right]\} \end{aligned}$$

where Υ is an auxiliary variable defined by:

$$\Upsilon = \frac{(El_X H)\left(\frac{L_x}{L}El_L\varpi - El_{L_x}\varpi\right) - El_X\varpi}{El_X\psi - El_X D - \frac{L_x}{L}El_X H}$$

Note that the elasticities are functions of stochastic variables, and hence will be generally time varying. Indeed one can show that $El_C H = \frac{1}{1-\alpha_x}(-\sigma)$, $El_N H = -\frac{1}{1-\alpha_x}\varphi$, $El_X H = \frac{1}{1-\alpha_x}$, $El_C\psi = \varkappa\sigma$, $El_N\psi = \varkappa\varphi$, $El_X\psi = -\varkappa$, while

$$El_C\varpi = \Lambda El_C\psi = \Lambda\varkappa\sigma$$

$$El_N\varpi = \Lambda El_N\psi = \Lambda\varkappa\varphi$$

$$El_X\varpi = \Lambda(El_X\psi - El_{XZ}g) + (1-\Lambda) = \Lambda(-\varkappa - El_{XZ}g) + (1-\Lambda)$$

$$El_L\varpi = \Lambda$$

$$El_{L_x}\varpi = \alpha_x(1-\Lambda)$$

where

$$\Lambda = \frac{(1-\varkappa)AL\psi(C,N,X)}{\varpi(.)g(XZ)}$$

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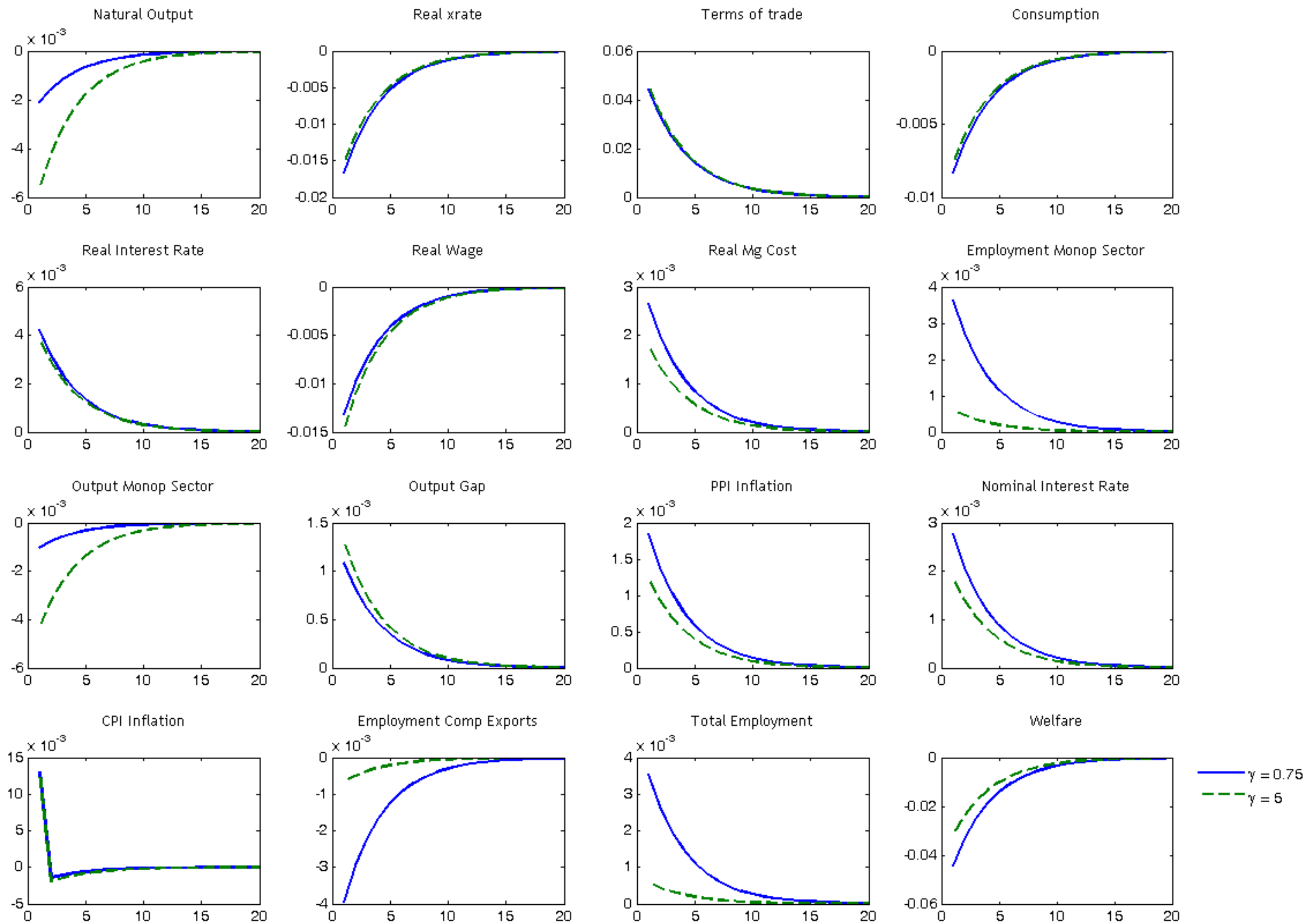

Figure 1: Responses to Imports Price Shock, PPI Rule, Perfect Risk Sharing

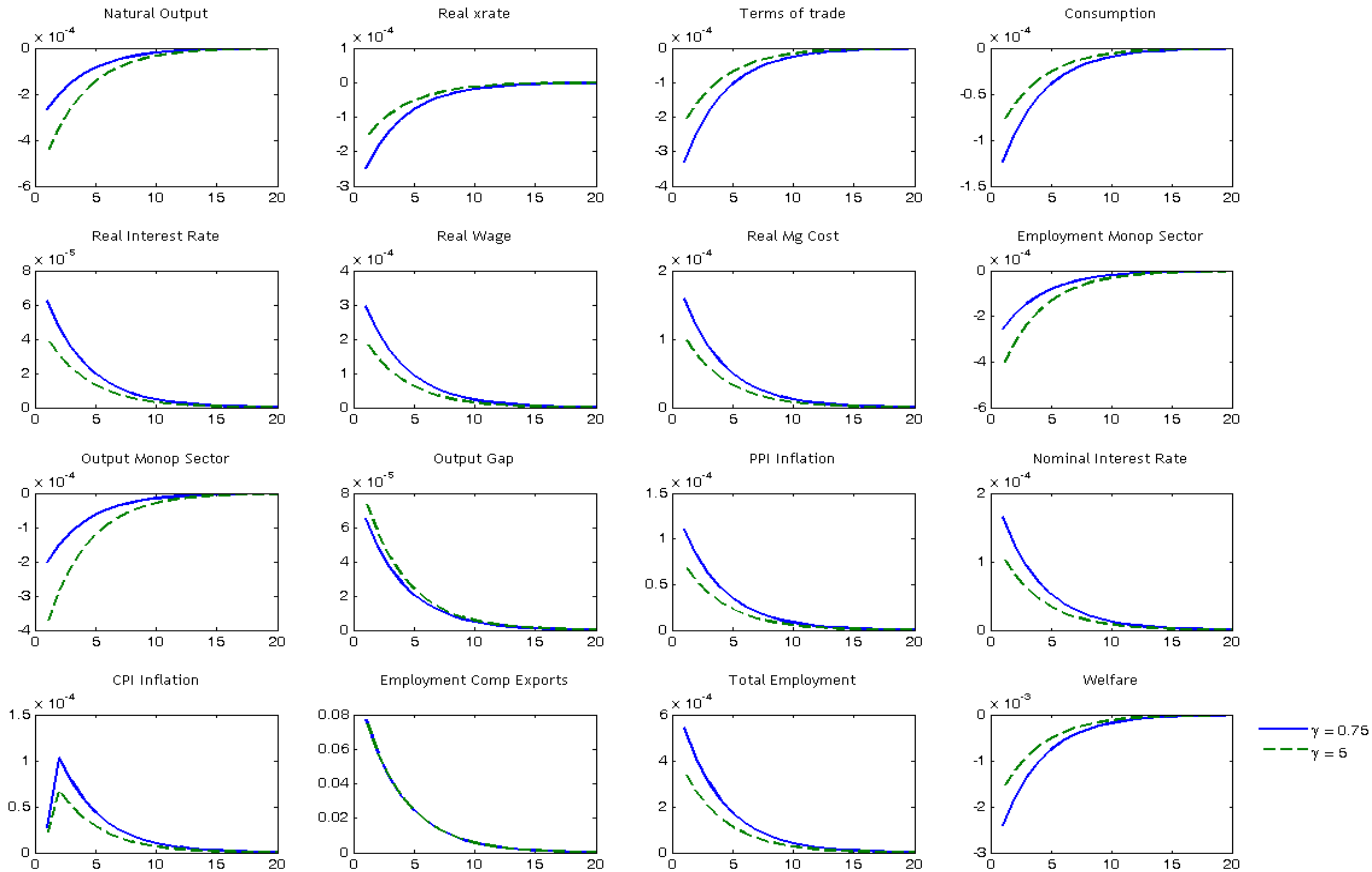

Figure 2: Responses to Exports Price Shock, PPI Rule, Perfect Risk Sharing

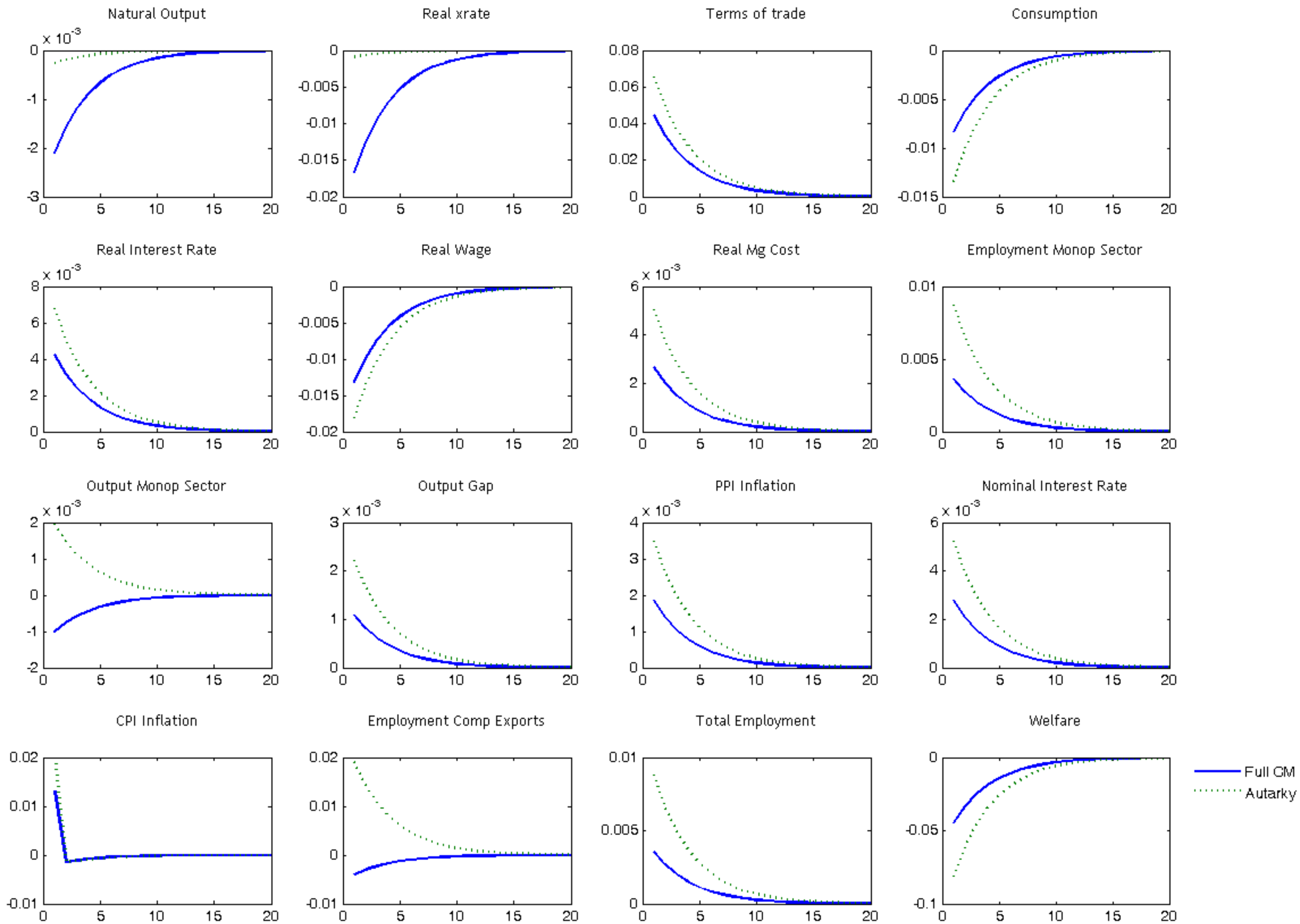

Figure 3: Responses to Imports Price Shock, PPI Rule, Full Capital Mobility vs Financial Autarky

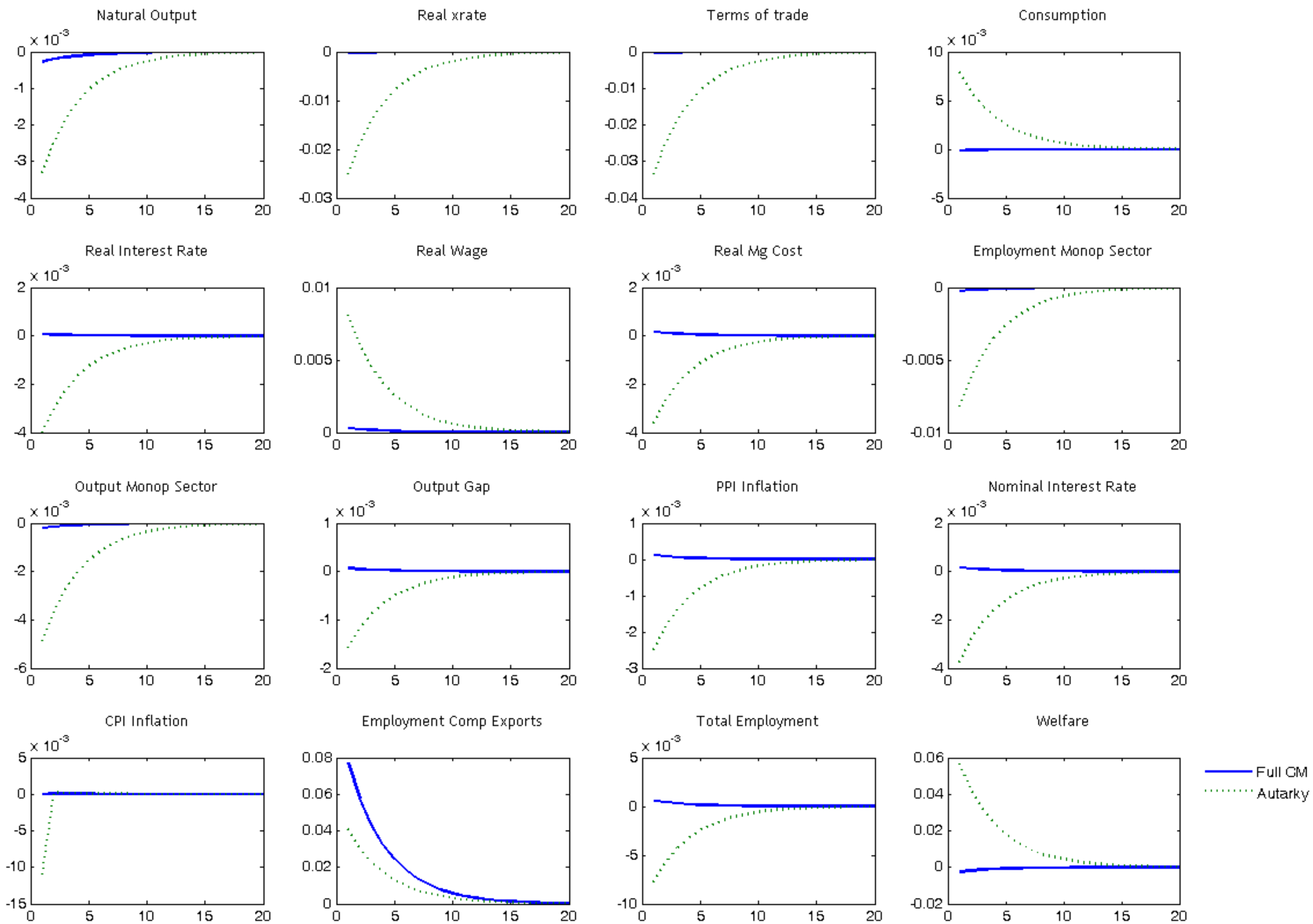

Figure 4: Responses to Exports Price Shock, PPI Rule, Full Capital Mobility vs Financial Autarky

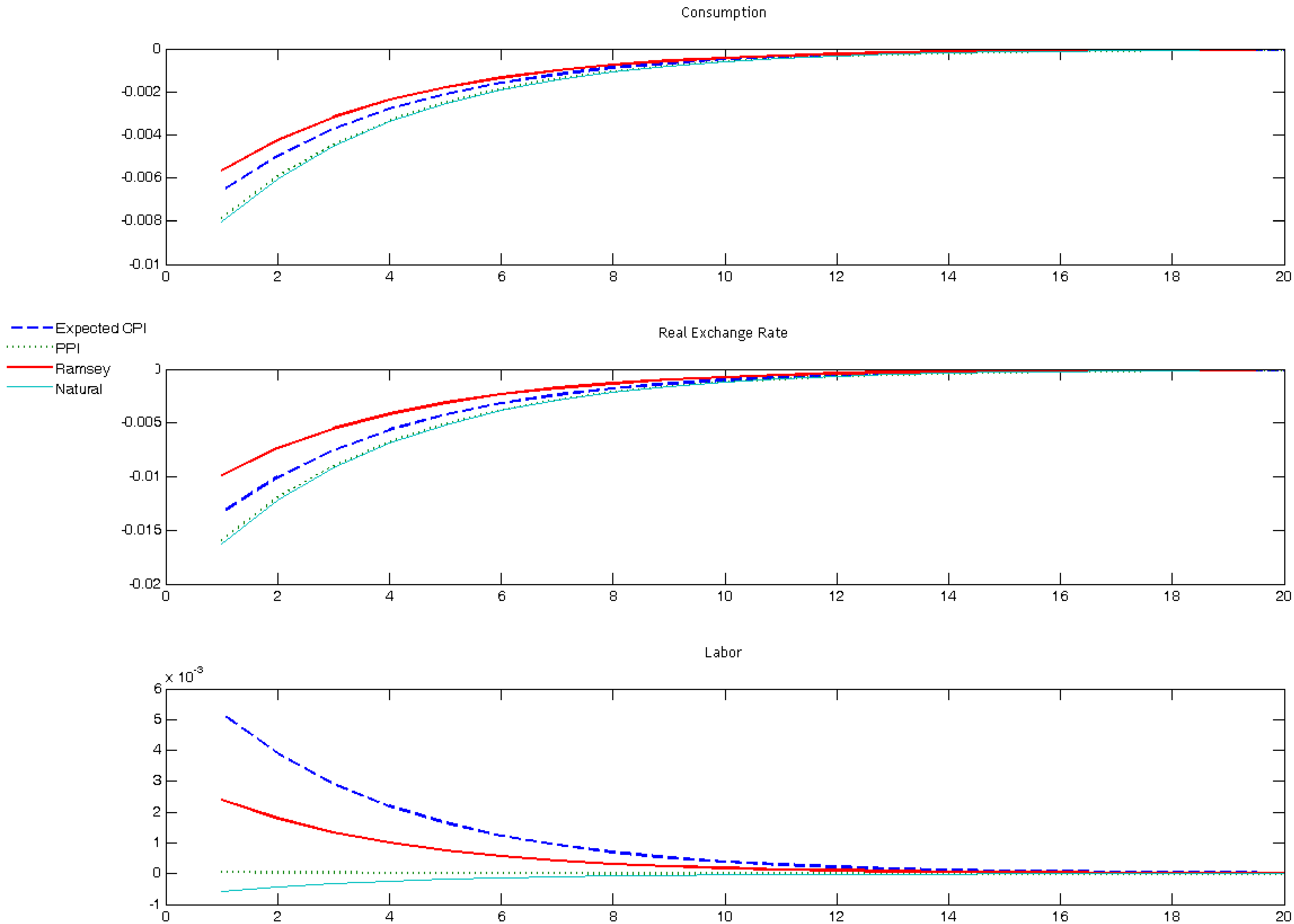

Figure 5: Responses to Imports Price Shock, PPI Rule Versus Expected CPI Rule, Full Capital Mobility

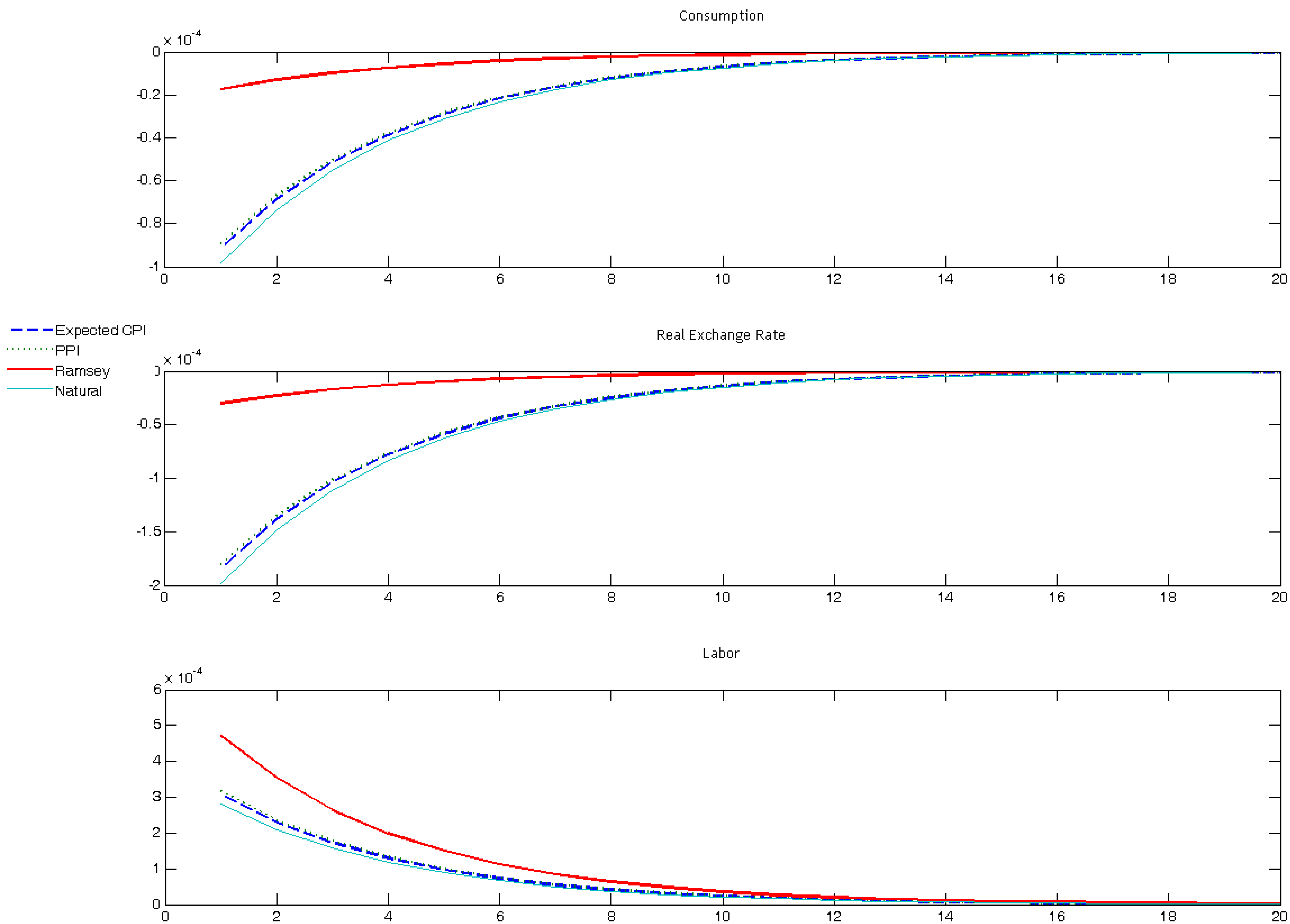

Figure 6: Responses to Exports Price Shock, PPI Rule Versus Expected CPI Rule, Full Capital Mobility

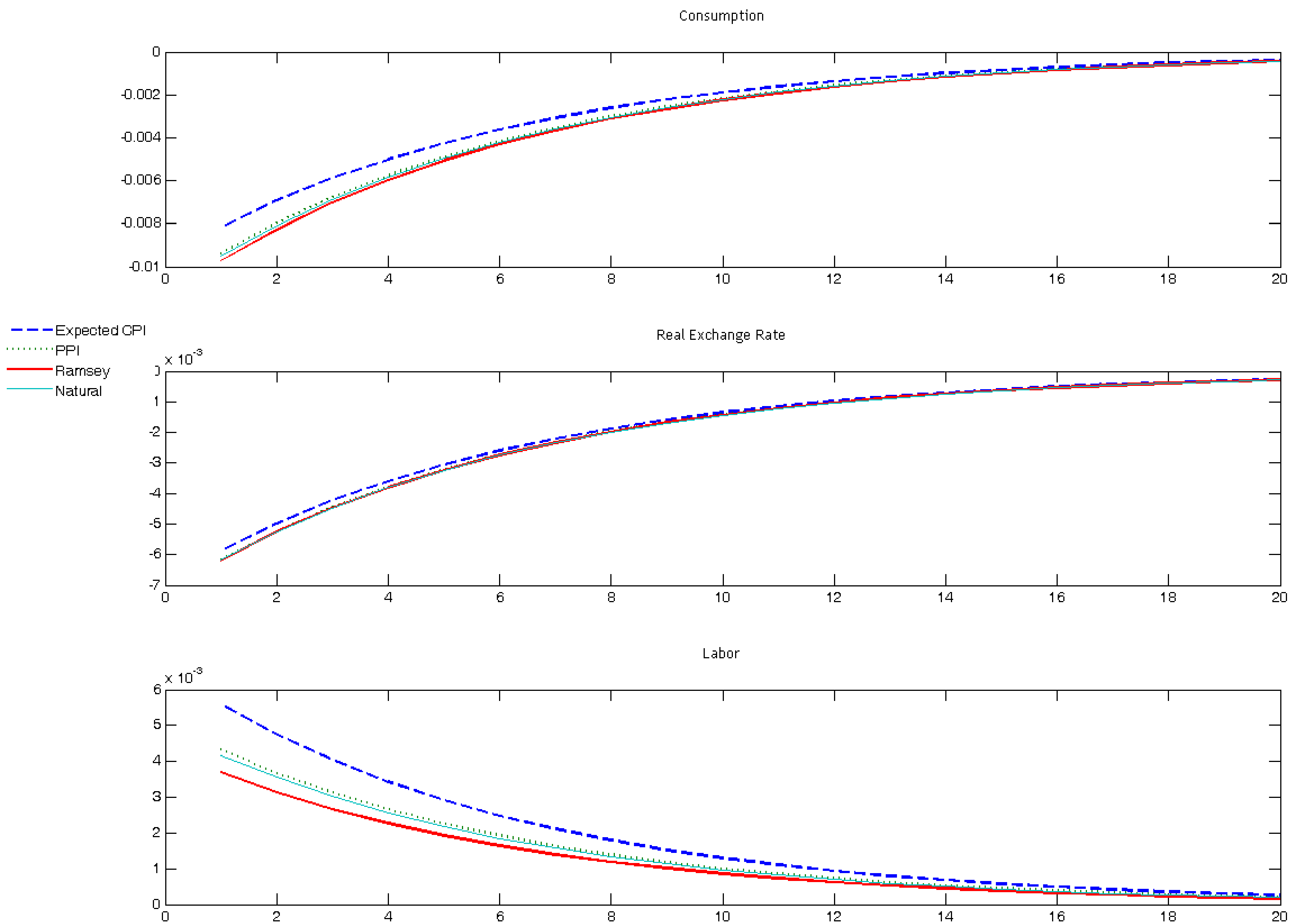

Figure 7: Responses to Imports Price Shock, PPI Rule Versus Expected CPI Rule, Financial Autarky

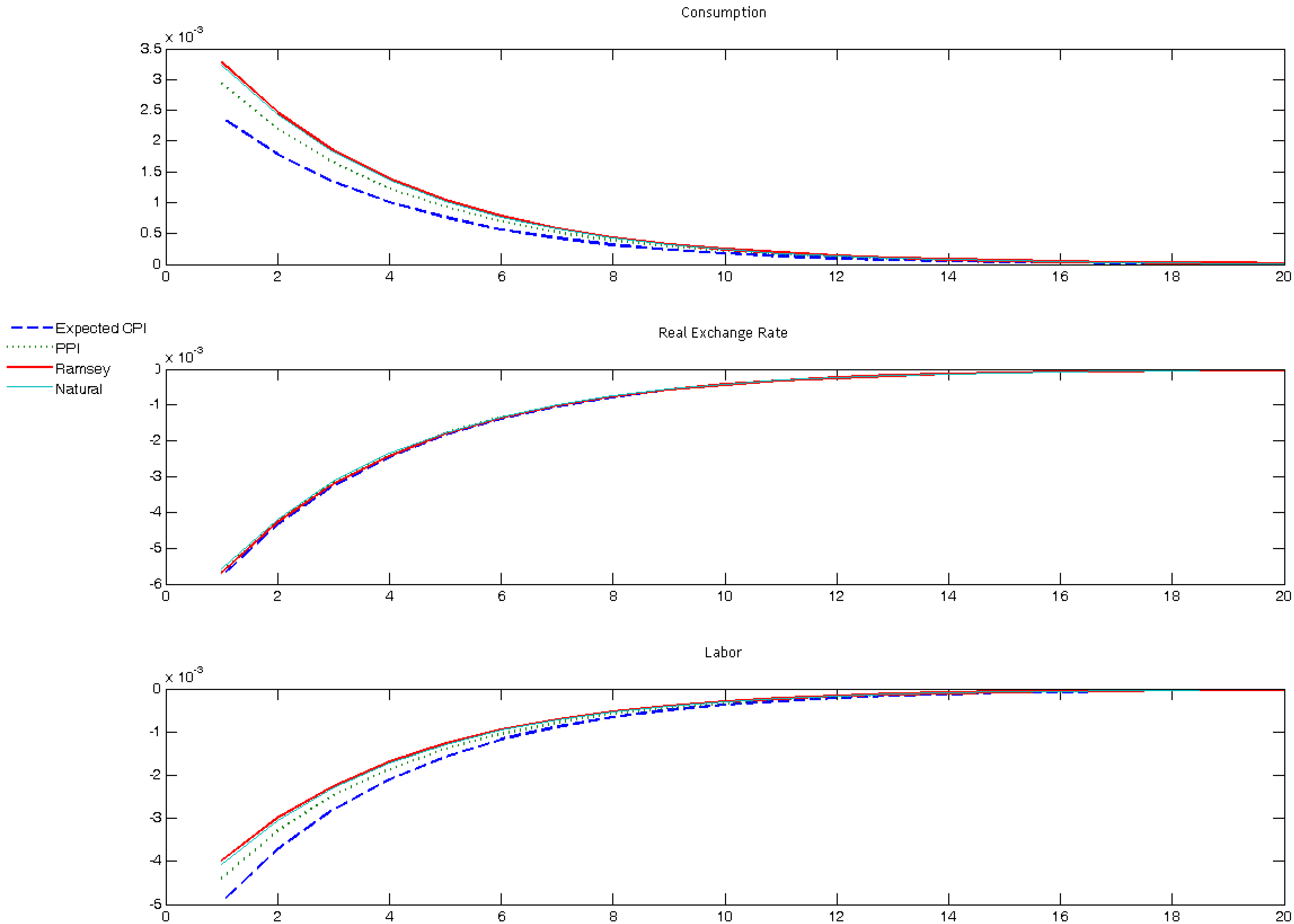

Figure 8: Responses to Exports Price Shock, PPI Rule Versus Expected CPI Rule, Financial Autarky

Table 1: Model Calibration

Discount Factor	β	0.99
Coefficient of risk aversion	σ	[2,6]
Inverse of elasticity of labor supply	φ	1
Degree of Openness	α	0.25
Average period between price adjustments	θ	0.66
Coefficient on inflation in Taylor Rule	ϕ_π	[1.5,5.0]
Coefficient on output gap in Taylor Rule	ϕ_y	[0,0.5]
Persistence parameter associated with productivity shocks	ρ_v	0.7
Persistence parameter associated with monetary policy shocks	ρ_v	0.6
Persistence parameter associated with export and import price shocks	ρ_z	[0.5,0.85]
Elasticity of substitution between varieties produced within any given country	ϵ	6
Elasticity of substitution between domestic and foreign goods	η	[0.5,5]
Ratio of initial home to foreign consumption	κ	1
Weight of labor in utility	ς	1
Share of imported inputs in production	$\varkappa$	[0,0.1]
Share of Labor in Export Sector	ρ_x	0.1
Relative Size (TFP) coefficient on Export Sector	a_x	0.15
Price Elasticity of Foreign Demand for the home goods		[0.5,5]
Standard Deviation associated with monetary policy shock	σ_v	0.006
Standard Deviation associated with relative import price shock	σ_z	[0,0,05]
Standard Deviation associated with relative export price shock	σ_z	0.07
Standard Deviation associated with productivity shock	σ_a	0.012

Table 2. Welfare Gaps: Complete Markets with no Commodity Shocks

in % of Steady State Consumption

PPI-CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0205	0.0167	0.0076	-0.0041
4	0.0182	0.0144	0.005	-0.006
6	0.0173	0.0137	0.0041	-0.0067

CPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	-0.0181	-0.0152	-0.0076	0.0049
4	-0.0167	-0.0133	-0.0051	0.0073
6	-0.0162	-0.0127	-0.0042	0.0081

CPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0219	0.0188	0.0093	-0.0066
4	0.0192	0.0158	0.0063	-0.0093
6	0.0181	0.0145	0.0051	-0.0103

PPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0024	0.0016	0	0.0008
4	0.0011	0.0011	-0.0001	0.0013
6	0.0005	0.0009	-0.0001	0.0014

PPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0424	0.0355	0.0169	-0.0107
4	0.0373	0.0302	0.0113	-0.0153
6	0.0354	0.0282	0.0092	-0.0169

PEG-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.04	0.034	0.0168	-0.0115
4	0.0359	0.0291	0.0114	-0.0165
6	0.0343	0.0273	0.0093	-0.0183

Ranking matrix

sigma/eta	**0.75**	**1**	**2**	**5**
2	PPI	PPI	PPI	EXP(CPI)
4	PPI	PPI	EPT	EXP(CPI)
6	PPI	PPI	EPT	EXP(CPI)

Table 3a. Welfare Gaps: Complete Markets with All Shocks
in % of Steady State Consumption

PPI-CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0786	0.0677	0.0376	-0.0016
4	0.0716	0.0593	0.0262	-0.0143
6	0.0687	0.0558	0.0218	-0.019

CPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.6105	0.5783	0.3936	-0.4659
4	0.4532	0.4211	0.2318	-0.6404
6	0.4036	0.3713	0.1794	-0.6937

CPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0823	0.0676	0.0199	-0.0699
4	0.072	0.0561	0.0079	-0.0748
6	0.0679	0.0517	0.0037	-0.0763

PPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.6901	0.6468	0.4316	-0.4675
4	0.5262	0.4814	0.2583	-0.6544
6	0.474	0.4283	0.2014	-0.7119

PPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.161	0.1353	0.0575	-0.0715
4	0.1438	0.1155	0.0342	-0.0891
6	0.1368	0.1077	0.0255	-0.0952

EPT-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	-0.5219	-0.5049	-0.3709	0.3997
4	-0.3745	-0.3589	-0.2218	0.5804
6	-0.3278	-0.3126	-0.1739	0.6442

Ranking matrix

sigma/eta	**0.75**	**1**	**2**	**5**
2	PPI	PPI	PPI	EPT
4	PPI	PPI	PPI	EPT
6	PPI	PPI	PPI	EPT

Table 3b. Welfare Gaps: Financial Autarky with All Shocks
in % of Steady State Consumption

PPI-CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.214	0.1742	0.1213	0.0972
4	0.4096	0.289	0.1726	0.1289
6	0.5474	0.3588	0.1999	0.1448

CPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	-0.0502	0.2448	1.5332	4.7647
4	-0.2731	0.1274	1.6441	5.1442
6	-0.4125	0.0603	1.7261	5.5167

CPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.3383	0.1794	0.0805	0.0535
4	0.4729	0.2244	0.0927	0.0596
6	0.5477	0.2467	0.0982	0.0622

PPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.1636	0.4199	1.6582	4.8714
4	0.132	0.4178	1.8283	5.3019
6	0.1213	0.4204	1.9477	5.7168

PPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.5538	0.3542	0.202	0.1508
4	0.8904	0.5159	0.2659	0.1889
6	1.1136	0.6108	0.2992	0.2076

EPT-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.3889	-0.0651	-1.4095	-4.3012
4	0.7543	0.0965	-1.4555	-4.2155
6	0.9849	0.1857	-1.4747	-4.0926

Ranking matrix

sigma/eta	**0.75**	**1**	**2**	**5**
2	PPI	PPI	PPI	PPI
4	PPI	PPI	PPI	PPI
6	PPI	PPI	PPI	PPI

Table 4a. Welfare Gaps: Complete Markets with All Shocks and Fixed Export Price Elasticity = 5

PPI-CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.0112	0.0104	0.0073	-0.0016
4	0.001	0	-0.0037	-0.0143
6	-0.0029	-0.0039	-0.0077	-0.019

CPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.2809	0.2392	0.0751	-0.4659
4	0.0943	0.0526	-0.1108	-0.6404
6	0.0315	-0.01	-0.1725	-0.6937

CPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	-0.0102	-0.0145	-0.0301	-0.0699
4	-0.0223	-0.0261	-0.0403	-0.0748
6	-0.0263	-0.0301	-0.0437	-0.0763

PPI-EPT

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.2921	0.2496	0.0824	-0.4675
4	0.0953	0.0526	-0.1145	-0.6544
6	0.0286	-0.0139	-0.1802	-0.7119

PPI-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	0.001	-0.0041	-0.0228	-0.0715
4	-0.0212	-0.0261	-0.0439	-0.0891
6	-0.0292	-0.034	-0.0514	-0.0952

EPT-Expected CPI

sigma/eta	**0.75**	**1**	**2**	**5**
2	-0.2894	-0.2525	-0.1051	0.3997
4	-0.1161	-0.0786	0.0709	0.5804
6	-0.0577	-0.0201	0.1302	0.6442

Ranking matrix

sigma/eta	**0.75**	**1**	**2**	**5**
2	PPI	EXP(CPI)	EXP(CPI)	EPT
4	EXP(CPI)	EXP(CPI)	EPT	EPT
6	EXP(CPI)	EXP(CPI)	EPT	EPT

Table 4b. Welfare Gaps: Financial Autarky with All Shocks and Fixed Export Price Elasticity = 5

PPI-CPI

sigma/eta	**0.5**	**1**	**2**	**5**
2	0.1813	0.1718	0.1433	0.0972
4	0.2474	0.2338	0.1933	0.1289
6	0.2811	0.2654	0.2187	0.1448

CPI-EPT

sigma/eta	**0.5**	**1**	**2**	**5**
2	2.6466	2.7702	3.256	4.7647
4	2.8418	2.9757	3.5036	5.1442
6	3.0006	3.1444	3.7151	5.5167

CPI-Expected CPI

sigma/eta	**0.5**	**1**	**2**	**5**
2	0.1133	0.106	0.0849	0.0535
4	0.1269	0.1188	0.0952	0.0596
6	0.1321	0.1237	0.0992	0.0622

PPI-EPT

sigma/eta	**0.5**	**1**	**2**	**5**
2	2.8377	2.9516	3.4088	4.8714
4	3.1187	3.2387	3.7256	5.3019
6	3.3368	3.4644	3.9877	5.7168

PPI-Expected CPI

sigma/eta	**0.5**	**1**	**2**	**5**
2	0.295	0.2782	0.2285	0.1508
4	0.3756	0.3537	0.2893	0.1889
6	0.4155	0.3911	0.3192	0.2076

EPT-Expected CPI

sigma/eta	**0.5**	**1**	**2**	**5**
2	-2.4059	-2.5242	-2.9771	-4.3012
4	-2.4372	-2.5524	-2.9888	-4.2155
6	-2.4292	-2.5395	-2.9545	-4.0926

Ranking matrix

sigma/eta	**0.5**	**1**	**2**	**5**
2	PPI	PPI	PPI	PPI
4	PPI	PPI	PPI	PPI
6	PPI	PPI	PPI	PPI