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World Food Prices and Monetary Policy

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Abstract

The large swings in world food prices in recent years renew interest in the question of how monetary policy in small open economies should react to such imported price shocks. We examine this issue in a canonical open economy setting with sticky prices and where food plays a distinctive role in utility. We show how world food price shocks affect natural output and other aggregates, and derive a second order approximation to welfare. Numerical calibrations show broad CPI targeting to be welfare-superior to alternative policy rules once the variance of food price shocks is sufficiently large as in real world data.

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1 Introduction

The dramatic swings in world commodity prices in recent years have renewed interest in the issue of how monetary policy in small open economies should react to imported price shocks. Wide fluctuations in food prices have been of particular concern. Given the large weight of food on households' consumption baskets and its limited substitutability by other goods, food price fluctuations often have a sizeable impact on overall consumer prices as well as on terms of trade.

While much has been written on the inflationary effects of oil price shocks and their role in monetary policy (see e.g. Bodenstein, Erceg and Guerrieri 2008 and Kiliam 2009), there is striking prima-facie evidence that food price shocks have been no less important as drivers of global inflation. This is illustrated in Figure 1, which correlates relative food prices against the world price level since 1960.[1] The correlation coefficient is sizeable (0.54). Also, fluctuations in the global relative price of food lead fluctuations in the overall WPI. More formally, Tables 1 and 2 present correlations and Granger causality tests, to allow for a horse-race comparison with the inflationary effects of oil price shocks. Confining the evidence to the past two decades as in Bodenstein, Erceg and Guerrieri (2008), which coincides with the gradual worldwide adoption of inflation targeting regimes, Table 1 shows that food price cycles ("zgap") bear a closer correlation than oil price cycles, either contemporaneous or lagged, with most indicators of global inflation. Over the entire 1960-2008 period, Granger causality tests in Table 2 reject the hypothesis that food prices do not Granger-cause global WPI (proxied by US WPI), whereas the same hypothesis is not rejected for oil prices. Further, the attendant F-tests suggest that, if anything, food prices Granger-cause oil prices and not the other way around. In short, in spite of the considerable attention usually being devoted to fuel commodities as a main source of global inflationary pressures, there more compelling evidence that food price shocks have been at the center of global inflation.

The swings in world food prices have translated into dramatic variations of inflation rates in small open economies. Unlike earlier episodes of commodity price swings, when small open economies often operated looser monetary regimes, the latest hike in global food prices, between late 2006 and mid-2008, took place under the discipline of inflation targeting (IT). Yet, it still resulted in breaches of central targets for consumer price inflation (CPI), with inflation rates rapidly approaching or exceeding the upper IT tolerance bands in several countries. Conversely,

[1] More precisely, the figure displays HP-filter detrended fluctuations in the IMF index of US$ price of non-fuel commodities relative to the overall US wholesale price index (WPI), and the year-on-year fluctuations in the absolute global WPI.

the sharp decline in US dollar food prices since mid-2008 has been accompanied by rapidly receding national inflation rates despite some large currency depreciations relative to the dollar. The substantial pass-through of world food prices into broad CPI - both in the upswing and downswing of the cycle - has been particularly pronounced among emerging markets.[2]

Insofar as world food price shocks are exogenous to an small open economy, these developments pose an important question for central banks. Should the monetary authority tolerate a (possibly) temporary, albeit sizeable, fluctuation in CPI inflation, and accommodate the external relative price shock, provided that producer price inflation (PPI) remains within target? Or should it instead react forcefully to CPI inflation, possibly requiring much lower inflation (or even deflation) rates in non-commodity domestic sectors? To elucidate the answer, this paper studies the transmission mechanism from imported commodity price shocks to output and inflation in a small open economy and investigates the welfare superiority of different monetary policy rules. In particular, we ask which of the targeting rules typically employed by central banks, such as broad CPI targeting, domestic producer price index (PPI) targeting, or exchange rate targeting, delivers the highest welfare in this context.

Our analysis takes into account the peculiar nature of food commodities - something which has been glossed over in previous studies. First, food typically represents a large share in official CPI inflation baskets, and the more so in lower income countries, as shown in Table 3.[3] Second, food is likely to display low elasticities of substitution with other goods and, again, the more so in poorer countries. Combined with the average high share in spending, this implies that food price shocks should have a non-trivial impact on marginal rates of substitution and labor supply. Third, food is a highly competitive industry, displaying fast pass-through from cost shocks to prices, and high volatility (see, e.g., Gouveia, 2007). This makes food very different from the typical composite good variety in models featuring staggered sectoral prices, where the case for low and stable inflation lies in eliminating the relative price distortion generated by the nominal

[2] The Chilean experience provides a vivid illustration. Between 2007 and early 2008 12-month CPI inflation rose from low single digits to close to 10 percent, even though indicators of long-term inflation expectation hovered around 3 percent. As commodity prices collapsed since, inflation has receeded to low single digit levels despite a depreciation of the peso relative to the US dollar.

[3] The weight is also higher among poorer households within these poorer countries (Rigobon, 2008). This in turn implies that the weight of foodstuff on official (expenditure-based) CPI measures is likely to understate by a large margin the true (non-expenditure based) average weight of foodstuff in national consumer baskets (Deaton 2003). So, food price shocks clearly have potentially far-reaching distributional effects and attendant welfare implications, both across and within countries.

rigidities. Fourth, many IT countries are large net food importers or exporters. In these cases, swings in the relative world price of food can entail large terms of trade variations.

We focus on the case of a small open economy which is a net food importer and where food accounts for a sizeable and relatively stable share of household spending. Our basic setting is that of a stripped-down dynamic stochastic general equilibrium (DSGE) model akin to those typically employed in much of the recent literature on monetary policy (e.g.,Woodford, 2003; Walsh, 2004; and Gali, 2008). We find that broad CPI targeting is often the welfare-dominant policy rule when the unconditional volatility of world commodity prices is sufficiently high, as it typically is in practice. This finding contrast with previous studies, which have mostly found that CPI targeting is dominated by PPI targeting or an exchange rate peg.

We argue that two factors are key to the superiority of CPI targeting: the large weight and peculiar nature of food in aggregate utility and the fact that world relative food price shocks are sizeable relative to the menu of monetary and technology shocks considered in previous studies. Food price shocks give rise to a distinct pattern of covariances between cost-push and demand shocks, as well as to a degree of real exchange rate volatility, such that it becomes suboptimal to target either PPI or the exchange rate for sufficiently high risk aversion and high disutility of work. But the welfare dominance of broad CPI targeting is heavily dependent on the large variance of external food price shocks: when that variance is very low, strict PPI targeting or exchange pegging rules are typically superior, as previous studies have found.

Finally, we also show that, even under large food price shocks, the welfare gap between CPI and PPI targeting can be narrowed if the weight of the output gap in the monetary policy rule increases, provided that the output gap is properly measured. But this is because the correct (model-based) measure of natural output takes into account fluctuations in the world relative price of food. Hence, a policy rule that responds to the correct output gap must be reacting to such fluctuations, thus in fact approximating CPI targeting.

Since many small open economy central banks - particularly those striving to bolster monetary policy credibility - practice broad CPI rather than PPI or exchange rate targeting, our findings provide further theoretical and empirical support for this practice. Further, since CPI targeting entails a less lenient attitude towards imported inflation more generally, it is also more conducive to a lower volatility in global inflation.

The remainder of the paper is structured as follows. Section 2 lays out the model, its recursive equilibrium representation and Phillips curve relationships, fleshing out how inflation and the appropriate measure of the output gap are affected by changes in world relative food prices. Section 3 presents the cannonical representation of the model's linearized version and the respecte impulse-responses. This enables us to trace the effects of the three types of shocks we consider - monetary policy shocks, world food price shocks, and technological shocks - on the main variables of interest. Section 4 derives the second order approximation to welfare and its non-stochastic steady state and examines the welfare ranking of distinct policy rules for a wide range of numerical calibrations. Section 5 summarizes the results and discusses policy implications.

2 Model

We study a small open economy populated by identical agents who consume a domestic good and imported food. The domestic good is an aggregate of intermediate varieties that are produced at home with domestic labor. The intermediates sector is characterized by monopolistic competition and nominal rigidities, as in recent New Keynesian (NK) models. There is imperfect competition in international goods markets, implying that PPP does not necessarily hold. Hence domestic policy can affect the real exchange rate (REER) and the terms of trade (TOT), and can thus manipulate the latter to the country's advantage (the so-called terms of trade externality). While marginal costs will depend on openness and the terms of trade as in the canonical NK setting, a main distinction here is that TOT will depend on the exogenous relative world price of food.

2.1 Households

The economy under study has a representative agent with preferences:

$$E\sum_{t=0}^{\infty}\beta^t U_t$$

where $0 < \beta < 1$, $E(.)$ is the expectation operator, and

$$U_t = \frac{C_t^{1-\sigma}}{\varsigma(1-\sigma)} - \int_0^1 \frac{N_t(j)^{1+\varphi}}{1+\varphi}dj$$

σ, φ, and ς are parameters, C_t denotes consumption, and $N_t(j)$ is the supply of labor employed by a firm belonging to industry $j \in [0,1]$. As in Woodford (2003), we assume that different industries employ different kinds of labor, and that the latter are not perfect substitutes from the viewpoint of the household.

Consumption is a C.E.S. aggregate of a home final good C_h and an imported good (food) C_f :

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

where η is the elasticity of substitution between home and foreign goods, and α is a measure of the degree of openness.

The price index associated with C, or CPI, expressed in domestic currency, is

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

where P_{ht} and P_{ft} are the domestic currency prices of the home good and imports. Also, given total consumption C_t and prices P_{ht} and P_{ft}, optimal demands for home goods and foreign goods are given by

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

$$C_{ft} = \alpha\left(\frac{P_{ft}}{P_t}\right)^{-\eta} C_t$$

Note that, if $P_{ht} = P_{ft}$, α equals the fraction of all consumption that is imported. In this sense, α is a measure of openness.

The agent chooses consumption and labor effort taking prices and wages as given, and having unfettered access to the world financial market. We assume that the latter is characterized by complete markets. Finally, the agent owns domestic firms and receives their profits.

The resulting maximization problem is well known (see e.g. Gali and Monacelli 2005). One implication is that, if $W_t(j)$ is the domestic wage for labor of type j, optimal labor supply is given by the equality of the marginal disutility of labor with the marginal utility of the real wage:

$$\varsigma C_t^{\sigma} N(j)_t^{\varphi} = \frac{W_t(j)}{P_t} \tag{3}$$

Also, complete financial markets imply that

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

where κ is a positive constant, C_t^* is an index of world consumption, and X_t is the *real exchange rate*, that is, the ratio of the price of the world consumption index to the domestic CPI, measured in a common currency.[4]

[4] To be sure, we have employed the assumption that the marginal utility of consumption in the rest of the world is proportional to $C_t^{*-\sigma}$.

Finally, the domestic safe interest rate is given by

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

2.2 Prices

For simplicity, we assume that all food is imported, and that the world price of food is exogenously given in terms of a world currency. Using asterisks to denote prices denominated in world currency, the domestic currency price of food is then

$$P_{ft} = S_t P_{ft}^*$$

where S_t is the (nominal) exchange rate (domestic currency per unit of foreign currency). So, there is full pass through from world to domestic food prices.

Likewise, we assume that the world currency price of the world consumption index is exogenous.[5] Denoting it by P_t^*, the real exchange rate is then:

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

For future reference, note that inserting the last two expressions into the consumer price index (1) implies the following relation between the real exchange rate and the relative price of home final goods:

$$1 = (1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{1-\eta} + \alpha X_t^{1-\eta} Z_t^{*1-\eta} \tag{6}$$

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

The home final good can be obtained by assembling intermediate goods varieties, indexed by $j \in [0,1]$:

$$Y_{ht} = \left[\int_0^1 Y_t(j)^{(\varepsilon-1)/\varepsilon} dj \right]^{\varepsilon/(\varepsilon-1)}$$

[5] To simplify the algebra, we also assume that food has a trivial share in the world consumer basket compared with that in the domestic economy. As a result, changes in world food prices will have virtually no effect on world CPI relative to domestic CPI. A higher share of food in domestic consumption basket relative to the world basket is all we need for the model's results to go through. As shown in Table 3, the food share in CPI in small open emerging economies is typically substantially higher than those in advanced countries, so this assumption is especially relevant in this context.

Minimizing the cost of producing the aggregate implies that, given Y_{ht}, the demand for each variety is given by

$$Y_t(j) = \left(\frac{P_t(j)}{P_{ht}}\right)^{-\varepsilon} Y_{ht}$$

where $P_t(j)$ is the price of variety j, and P_{ht} is the relevant price index:

$$P_{ht} = \left[\int_0^1 P_t(j)^{1-\varepsilon} dj\right]^{1/(1-\varepsilon)} \tag{7}$$

2.3 Domestic Production

Variety j of intermediates is produced by only labor of type j according to the production function

$$Y_t(j) = A_t N_t(j)$$

where $N_t(j)$ is the employment of type j labor and A_t is a productivity shock, common to all firms in the economy.

Firms take wages as given. We allow for the existence of a subsidy to employment at constant rate υ. Hence nominal marginal cost is given by

$$\Psi_{jt} = (1-\upsilon)W_t(j)/A_t \tag{8}$$

where $W_t(j)$ is the wage rate for type j labor.

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 producers with the opportunity to reset prices in period t will choose the same price, say $\bar{P}_t$, which satisfies:

$$\sum_{k=0}^{\infty} \theta^k E_t \left[M_{t,t+k} Y_{t+k|t} (\bar{P}_t - \frac{\varepsilon}{\varepsilon-1} \Psi_{t+k|t})\right] = 0 \tag{9}$$

where $Y_{t+k|t}$ is the demand in period $t+k$ for a producer that last set her price in period $t:$

$$Y_{t+k|t} = \left(\frac{\bar{P}_t}{P_{ht+k}}\right)^{-\varepsilon} Y_{ht+k} \tag{10}$$

$M_{t,t+j}$ is the period t pricing kernel applicable to nominal payoffs in period $t+j$, and $\Psi_{t+k|t}$ is the nominal marginal cost of production at $t+k$ for producers that set their prices at t.

It also follows (from 7) that the price of the home final good is given by:

$$P_{ht} = \left[(1-\theta)\bar{P}_t^{1-\varepsilon} + \theta P_{h,t-1}^{1-\varepsilon}\right]^{1/(1-\varepsilon)} \tag{11}$$

2.4 Equilibrium: Recursive Representation

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 aggregate requires:

$$Y_{ht} = C_{ht} + \phi \left(\frac{P_{ht}}{S_t P_t^*} \right)^{-\gamma} C_t^* \tag{12}$$

where ϕ is a constant and γ is the price elasticity of the foreign demand for home exports.

Equilibrium is determined once a rule for monetary policy is specified. It will be convenient to simplify the equilibrium conditions somewhat. First, combine the preceding expression with (2) and the definition of the real exchange rate to get:

$$Y_{ht} = (1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{-\eta} C_t + \phi X_t^{\gamma} \left(\frac{P_{ht}}{P_t} \right)^{-\gamma} C_t^* \tag{13}$$

Second, write the solution for intermediates pricing as follows: from (11),

$$1 = (1-\theta) \left(\frac{\bar{P}_t}{P_{ht}} \right)^{1-\varepsilon} + \theta \Pi_{ht}^{\varepsilon-1} \tag{14}$$

where $\Pi_{ht} = P_{ht}/P_{h,t-1}$ is domestic goods inflation. The optimal pricing condition (9) can be written as:

$$\frac{\bar{P}_t}{P_{ht}} J_t = \frac{\varepsilon}{\varepsilon - 1} H_t \tag{15}$$

where, as shown in the Appendix, J_t and H_t are accounting variables that can be written recursively as:

$$J_t = \left(\frac{\bar{P}_t}{P_{ht}} \right)^{-\varepsilon} Y_{ht} + \theta E_t M_{t+1} \left(\frac{\bar{P}_t/P_{ht}}{\bar{P}_{t+1}/P_{h,t+1}} \right)^{-\varepsilon} \Pi_{h,t+1}^{\varepsilon} J_{t+1} \tag{16}$$

$$H_t = F_t \left(\frac{\bar{P}_t}{P_{ht}} \right)^{-\varepsilon(1+\varphi)} Y_{ht}^{1+\varphi} + \theta E_t M_{t+1} \left(\frac{\bar{P}_t/P_{ht}}{\bar{P}_{t+1}/P_{h,t+1}} \right)^{-\varepsilon(1+\varphi)} \Pi_{h,t+1}^{1+\varepsilon(1+\varphi)} H_{t+1} \tag{17}$$

with

$$\frac{1}{1+i_t} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t/P_{ht}}{P_{t+1}/P_{ht+1}} \Pi_{h,t+1}^{-1} \tag{18}$$

and

$$F_t = (1-\upsilon)\varsigma C_t^{\sigma} A_t^{-(1+\varphi)} (P_t/P_{ht}) \tag{19}$$

Thus formulated, 4, 6, 13, 14, 15, 16, 17, 18, 19 are nine equations in the ten variables $C, X, (P_h/P), Y_h, (\bar{P}/P_h)$, As mentioned, the system is completed with the specification of monetary policy (and the Euler equation 5, if needed).

2.5 Marginal Costs

The possibility of imported inflation has a significant effect on the derivation of the aggregate supply relation characterizing the tradeoffs between output and inflation in the economy. To understand this, here we examine a first order log linear approximation of the model around a nonstochastic steady state with zero inflation.

We shall use lowercase variables to denote logs. Starting with the pricing equations, and following Gali (2008, p.45), one can rewrite 9 as

$$\sum_{k=0}^{\infty} \theta^k E_t \left[M_{t,t+k} Y_{t+k|t} \left(\frac{\bar{P}_t}{P_{h,t-1}} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k|t} \Pi^h_{t-1,t+k} \right) \right] = 0$$

where

$$MC_{t+k|t} = \Psi_{t+k|t} / P_{h,t+k}$$

denotes real marginal cost for firms that set prices in period t. A first order approximation then yields:

$$\bar{p}_t - p_{h,t-1} = (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t (mc_{t+k|t} - mc) + (p_{h,t+k} - p_{h,t-1}) \tag{20}$$

where $mc = \log(\varepsilon - 1)/\varepsilon = -\mu$ is the steady state value of marginal costs.

In turn, 11 can be written as:

$$p_{ht} = (1 - \theta)\bar{p}_t + \theta p_{h,t-1} \tag{21}$$

To simplify the previous expressions, note that

$$\begin{aligned} mc_{t+k|t} &= \log \Psi_{t+k|t} - p_{h,t+k} \\ &= -\upsilon + w_{t+k|t} - a_{t+k} - p_{h,t+k} \\ &= -\upsilon + w_{t+k|t} - p_{t+k} - a_{t+k} + p_{t+k} - p_{h,t+k} \\ &= -\upsilon + \left[\log \varsigma + \sigma c_{t+k} + \varphi n_{t+k|t} \right] - a_{t+k} + p_{t+k} - p_{h,t+k} \end{aligned}$$

where the last equation follows from taking logs in 3. Here, $w_{t+k|t}$ denotes the nominal wage at $t + k$ for labor of industries that change their prices at t, and $n_{t+k|t}$ the corresponding supply of labor.

Now, from the production function and 10,

$$\begin{aligned} n_{t+k|t} &= y_{t+k|t} - a_{t+k} \\ &= \varepsilon(p_{ht+k} - \bar{p}_t) + y_{ht+k} - a_{t+k} \end{aligned}$$

Hence real marginal cost for firms that set prices in period t can be expressed as:

$$\begin{aligned} mc_{t+k|t} &= -\upsilon + \log\varsigma + \sigma c_{t+k} + \varphi\varepsilon(p_{ht+k} - \bar{p}_t) + \varphi y_{ht+k} - (1+\varphi)a_{t+k} + p_{t+k} - p_{h,t+k} \\ &\equiv mc_{t+k} + \varphi\varepsilon(p_{ht+k} - \bar{p}_t) \end{aligned} \tag{22}$$

where

$$mc_t = -\upsilon + \log\varsigma + \sigma c_t + \varphi y_{ht} - (1+\varphi)a_t + (p_t - p_{ht})$$

is a measure of marginal costs averaged across firms.

This says that marginal costs increase with consumption, domestic output, and the price of home produce relative to consumption. Consumption and domestic output matter because they affect the utility value of wages: increases in consumption raise the value of leisure, and hence firms must pay higher wages for a given level of effort; increases in output require additional effort and, hence, higher wages.

Finally, the $(p_t - p_{ht})$ appears because workers care about the consumption value of wages, not the product wage. It is useful to define now the domestic price of food relative to the price of home output, or (the inverse of) the *terms of trade*, by

$$Q_t = \frac{P_{ft}}{P_{ht}} = \frac{S_t P_{ft}^*}{P_{ht}}$$

A log linear approximation to 1 then yields:

$$p_t - p_{ht} = \alpha q_t$$

Marginal costs depend on the marginal utility of wages. But with complete markets, marginal utility is given by world consumption and the real exchange rate, as given by (4). Taking logs and inserting into the preceding expression for mc_t one gets

$$mc_t = -\upsilon + \log\varsigma + \sigma\log\kappa + \sigma c_t^* + \varphi y_{ht} + (x_t + \alpha q_t) - (1+\varphi)a_t \tag{23}$$

Summarizing, domestic marginal costs depend on the term $(x_t + \alpha q_t)$, that is, on the real exchange rate and the terms of trade, in addition to domestic production y_{ht} and exogenous shocks. As already mentioned, the αq_t term matters because of the discrepancy between the product wage and the consumption wage. The real exchange rate x affects marginal costs because of its impact on domestic consumption (via international risk sharing) and, therefore, the disutility of labor.

Note that, here, the relation between the real exchange rate and the terms of trade is given by:

$$x_t = (1-\alpha)q_t + (p_t^* - p_{ft}^*) = (1-\alpha)q_t - z_t^* \tag{24}$$

where $z_t^* = p_{ft}^* - p_t^*$ can be thought of as a shock to the *world* relative price of imports. If world relative prices were constant, z_t^* would be zero, and the real exchange rate would be proportional to the terms of trade. Indeed, this is what is assumed in most other models. But here world relative price changes do matter and have to be taken into account. One consequence is that x_t and q_t can move in opposite directions, in response to shocks in the relative price of food.

We are ready to obtain a relation between domestic (producer) inflation and marginal costs of the kind emphasized in the NK literature. Replacing 22 in 20 and rearranging we obtain:

$$(\bar{p}_t - p_{ht-1}) = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t \frac{1}{1+\varphi\varepsilon}(mc_{t+k} - mc) + \sum_{k=0}^{\infty}(\beta\theta)^k E_t \pi_{ht+k}$$

Combining this expression and 21 leads to:

$$\pi_{ht} = \beta E_t \pi_{h,t+1} + \lambda(mc_t + \mu) \tag{25}$$

where

$$\lambda = \frac{(1-\beta\theta)(1-\theta)}{\theta}\frac{1}{1+\varphi\varepsilon}$$

As mentioned, this says that domestic inflation depends on its own expected future value as well as marginal costs. In contrast with previous papers, however, marginal costs depend not only on domestic production but also on the relative price term $x_t + \alpha q_t = q_t - z_t^*$, that is, on the terms of trade and the real exchange rate. At least one of these has to be treated as an endogenous variable.

2.6 Output and Relative Prices

To proceed, we relate the terms of trade and domestic output. Going back to the market clearing condition (12):

$$\begin{aligned} Y_{ht} &= C_{ht} + \phi \left(\frac{P_{ht}}{S_t P_t^*} \right)^{-\gamma} C_t^* \\ &= (1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{-\eta} C_t + \phi \left(\frac{P_{ht}}{S_t P_t^*} \right)^{-\gamma} C_t^* \\ &= C_t^* \left[\kappa(1-\alpha) \left(\frac{P_{ht}}{P_t} \right)^{-\eta} X_t^{1/\sigma} + \phi \left(\frac{P_{ht}}{S_t P_t^*} \right)^{-\gamma} \right] \end{aligned} \tag{26}$$

where we have used (2) for the second equality and (4) for the third equality. Log linearizing, we get

$$\begin{aligned} y_{ht} &= c_t^* + \{\omega[\eta(p_t - p_{ht}) + \frac{1}{\sigma} x_t] + (1-\omega)\gamma(s_t - p_t^* - p_{ht})\} \\ &= c_t^* + \{\omega[\eta \alpha q_t + \frac{1}{\sigma} x_t] + (1-\omega)\gamma(x_t + \alpha q_t)\} \\ &= c_t^* + \{\omega[\eta \alpha q_t + \frac{1}{\sigma}((1-\alpha) q_t - z_t^*)] + (1-\omega)\gamma(q_t - z_t^*)\} \\ y_{ht} &= c_t^* + q_t \left[\omega \left(\eta\alpha + \frac{(1-\alpha)}{\sigma} \right) + (1-\omega)\gamma \right] - z_t^* (\frac{\omega}{\sigma} + (1-\omega)\gamma) \end{aligned} \tag{27}$$

where $\omega = C_h/Y_h$ is the steady state ratio of home consumption of home goods to domestic production. Equation 27 is a key equation that establishes the equilibrium link between domestic production and the terms of trade. It implies that increases in domestic production must be associated with a deterioration in the terms of trade (an increase in q), which reflects the need for relative price changes to accommodate the increased production. The magnitude of the terms of trade fall depends on various elasticities and shares in the model. Importantly for our purposes, the link is shifted by changes in world demand, c^*, *and* by changes in the relative price of imports z^*.

2.7 The Phillips Curve

Going back to the aggregate supply curve, we can proceed as in the recent work of Woodford (2003) and others to usefully summarize the impact of exogenous shocks with the concept of *output gap*. Here, another gap turns out to be useful, that of a *terms of trade gap.*

In an equilibrium with flexible prices, monopolistic competitors would set prices to be a constant markup over marginal costs. This implies that the log of marginal cost would be equal to

$-\mu$. In such a *natural* equilibrium, therefore, domestic output and the terms of trade would have to satisfy the corresponding version of (23)[6]:

$$-\mu = -\upsilon + \log \varsigma + \sigma \log \kappa + \varphi y_{ht}^n + q_t^n + \sigma c_t^* - z_t^* - (1+\varphi)a_t \tag{28}$$

where output and the terms of trade have been given a superscript n to indicate "natural".

Substracting the last equation from (23) then gives:

$$mc_t + \mu = \varphi(y_t - y_{ht}^n) + (q_t - q_t^n)$$

This says that the deviation of marginal costs from their flexible price value depends on the departures of domestic output and the terms of trade from their natural values. The first term is the one emphasized in the conventional literature, but the second term is not.

One can then insert the last equation into (25) to obtain an equation:

$$\pi_{ht} = \beta E_t \pi_{h,t+1} + \lambda\varphi(y_t - y_{ht}^n) + \lambda(q_t - q_t^n) \tag{29}$$

which can be seen as a version of the New Keynesian Phillips Curve. This in fact is rather similar to others found in the literature (e.g. Gali and Monacelli 2005), except that the tradeoff between inflation and domestic production is shifted by the terms of trade gap. In this setup, however, such a deviation is endogenous, with significant implications.

To proceed, note that the market clearing condition (27) must hold under flexible prices. Hence the natural levels of output and terms of trade must satisfy:

$$y_{ht}^n = c_t^* + q_t^n \left[\omega\left(\eta\alpha + \frac{(1-\alpha)}{\sigma}\right) + (1-\omega)\gamma\right] - z_t^*(\frac{\omega}{\sigma} + (1-\omega)\gamma) \tag{30}$$

Substracting from 27 then implies

$$\Theta(y_t - y_{ht}^n) = (q_t - q_t^n) \tag{31}$$

where

$$1/\Theta = \left[\omega\left(\eta\alpha + \frac{(1-\alpha)}{\sigma}\right) + (1-\omega)\gamma\right]$$

Inserting in 29 yields a Phillips curve that finally looks like a conventional one:

$$\pi_{ht} = \beta E_t \pi_{h,t+1} + \chi(y_t - y_{ht}^n)$$

[6] We use $(x_t + \alpha q_t) = q_t - z_t^*$

where

$$\chi = \lambda\{\varphi + \Theta\}$$

While the preceding form of the Phillips curve agrees with conventional ones, the similarity is misleading. First, the slope of the Phillips Curve (given by χ) depends on various elasticities and parameters of the model, including the degree of openness α. This is because our final Phillips curve summarizes not only the conventional effect of the output gap on marginal costs and domestic inflation, but also the effects of the terms of trade gap on the latter.

Second, and more importantly, the natural rate of output moves around with the shocks in the model, including the world relative price shocks z_t^*. Some straightforward algebra yields the solution for the natural rate of output:

$$y_{ht}^n = \frac{1}{(\varphi + \Theta)} \left(-\mu - (\sigma - \Theta)c_t^* + \Theta\left[\omega\alpha(\eta - 1/\sigma)\right] z_t^* + \upsilon - \log\varsigma - \sigma\log\kappa + (1+\varphi)a_t\right) \tag{32}$$

It is straightforward to show that, if $\eta = \gamma = 1/\sigma$,the coefficients on foreign demand (c_t^*) and world food prices (z_t^*) will be zero. In this case, this model economy becomes isomorphic to a closed economy where natural output fluctuates only in response to productivity shocks.

To understand these results, refer to Figure 2. Under flexible prices, the marginal cost equation 28 implies a relationship such as MM between q_t^n and y_t^n, with slope $-\varphi$. In turn, the market clearing condition 30 induces a relationship such as DD, with slope Θ. The natural levels of output and the terms of trade are then given by a point such as E in the figure. An increase in the relative price of food, say a unit shock to z_t^*, shifts MM up by the same amount (one unit). The same shock shifts DD up by $\Theta(\frac{\omega}{\sigma} + (1-\omega)\gamma)$. Accordingly, a positive shock to z_t^* always causes an increase in q_t^n (a deterioration in the natural terms of trade). And the shock will result in an increase in y_t^n if and only if $\Theta(\frac{\omega}{\sigma} + (1-\omega)\gamma)$ is less than unity, as in that case the vertical shift of DD will be smaller that of MM. But the sign of $[1 - \Theta(\frac{\omega}{\sigma} + (1-\omega)\gamma)]$ is equal to the sign of $\eta - 1/\sigma$.

Why is the relation between η and $1/\sigma$ the key one? Use the definition of the real exchange rate $X_t = S_t P_t^*/P_t$ to rewrite the market clearing condition 12 as

$$Y_{ht} = C_t^* \left[\kappa(1-\alpha)\left(\frac{P_{ht}}{S_t P_t^*}\right)^{-\eta} X_t^{\frac{1}{\sigma}-\eta} + \phi\left(\frac{P_{ht}}{S_t P_t^*}\right)^{-\gamma}\right]$$

This expression says that the demand for home goods depends on three factors. The first one is world consumption, which affects not only the scale of foreign demand for home produce but also domestic consumption and demand, through the risk sharing equation 4. The second factor is the world relative price of home goods, $P_{ht}/S_tP_t^*$. This price affects foreign demand for home goods and it can also affect the domestic demand, depending on the real exchange rate X_t, which is the third factor. Note that, given the world relative price of home goods, the real exchange rate may increase or reduce Y_{ht}, depending on $\eta - 1/\sigma$. A one percent increase in X_t (a depreciation) increases domestic consumption by $1/\sigma$ percent via risk sharing. But, given $P_{ht}/S_tP_t^*$, a one percent increase in X_t implies a one percent increase in the domestic relative price of home output, P_{ht}/P_t. This leads to substitution away from home goods and causes domestic demand to fall by η percent.

Now, suppose that there is a shock to world food prices, say a one percent increase in z_t^*. Under flexible prices, that shock can be accommodated by only relative price movements, with no changes in home output, if $\eta = 1/\sigma$. In that case, 28 says that the terms of trade q_t^n would increase by one percent. Since $x_t = (1-\alpha)q_t - z_t^*$, the real exchange rate would then fall by α percent. But, as we have just seen, this would have no effect on demand if $\eta = 1/\sigma$. If $\eta > 1/\sigma$, however, substitution effects would prevail and the fall in the real exchange rate would result in an increase in demand. In that case, the accommodation of the shock requires an increase in the natural rate of output. Note the strength of this would depend not only on $\eta - 1/\sigma$ but also on α and, further, on the domestic share ω in the demand for home goods. This explains why the impact of z_t^* on y_t^n in 32 depends on $\omega\alpha(\eta - 1/\sigma)$.

3 Impulse Responses

The model is closed by adding a monetary policy rule and by specifying stochastic processes for the exogenous shocks. To gain insight on the transmission from the external price shock to domestic aggregates and illustrate the attendant dynamics, we solve for a linear approximation of the model assuming a standard Taylor rule and compute the impulse–responses for shocks to the relative price of food, z_t^*.

The natural levels of output and the terms of trade can be solved for easily from 28 and 30. Ignoring irrelevant constants, they imply that:

$$y_{ht}^n = \varrho_y z_t^*$$

$$q_t^n = \varrho_q z_t^*$$

where

$$\varrho_y = \frac{\Theta\left[\omega\alpha(\eta - 1/\sigma)\right]}{(\varphi + \Theta)}$$

and

$$\varrho_q = \frac{\Theta\left[1 + \varphi(\frac{\omega}{\sigma} + (1-\omega)\gamma)\right]}{(\varphi + \Theta)}$$

To proceed, we will solve for the output gap, inflation, and the terms of trade as function of z_t^*. We start by using the risk-sharing condition $\sigma c_t = \sigma c_t^* + x_t$ to substitute out c_t^* in equation 27, and then expressing c_t as a function of the policy rate i_t and CPI inflation π_t using the linearized version of 5, i.e., $i_t = E_t\left[\sigma\Delta c_{t+1} + \pi_{t+1}\right]$. Making use of 31, some algebra yields a "dynamic IS equation ":

$$\tilde{y}_t = E_t\tilde{y}_{t+1} + \frac{1}{\Theta(1-\alpha)}[i_t - E_t\pi_{t+1}] + \left(\frac{\Theta\omega\alpha(\eta - 1/\sigma)}{\varphi + \Theta} + \Phi - \frac{1}{\Theta(1-\alpha)}\right) E_t\Delta z_{t+1}^* \tag{33}$$

where $\Phi = \frac{\omega}{\sigma} + (1-\omega)\gamma$. This equation says that the demand for home output depends, among other variables, on the real interest rate $i_t - E_t\pi_{t+1}$. It is useful, however, to rewrite the equation in terms of PPI inflation instead of CPI inflation. To do this, recall that CPI inflation is given by:

$$\pi_t = \pi_{ht} + \alpha\Delta q_t \tag{34}$$

while, from 31 and $q_t^n = \varrho_q z_t^*$:

$$\begin{aligned} \Delta q_t &= \Delta q_t^n + \Theta\Delta\tilde{y}_t \\ &= \varrho_q\Delta z_t^* + \Theta\Delta\tilde{y}_t \end{aligned}$$

Plugging this back into 33 yields:

$$\tilde{y}_t = E_t\tilde{y}_{t+1} + \frac{1}{\Theta}[i_t - E_t\pi_{h,t+1}] + \left((1-\alpha)(\Phi + \varrho_y) - \frac{1-\alpha\varrho_q}{\Theta}\right) E_t\Delta z_{t+1}^* \tag{35}$$

Now, recall the NK Phillips curve:

$$\pi_{ht} = \beta E_t\pi_{h,t+1} + \chi\tilde{y}_t \tag{36}$$

where $\tilde{y}_t = y_t - y_t^n$ is the output gap. The previous two equations are a dynamic expectational system on $\tilde{y}_t$ and π_{ht} which is closed once a policy rule pins down i_t .

Accordingly, consider first a PPI-based Taylor rule:

$$i_t = \phi_y \tilde{y}_t + \phi_{\pi h} \pi_{ht}$$

Assuming $z_t^* = \rho_z z_{t-1}^* + \varepsilon_t^z$, one can conjecture that the solution of the last three equations takes the form $\tilde{y}_{ht} = \psi_y^{PPI} z_t^*$ and $\pi_{PPI}{}_{ht} = \psi_{\pi h} z_t^*$. This is indeed the case, and ψ_y and $\psi_{\pi h}$ are given by:

$$\psi_y^{PPI} = \frac{1}{\Omega_{PPI}}\left[1 + \Theta/\varphi - \frac{(\varphi+\Theta)}{\varphi}\varrho_q - \Theta\varrho_y\right] \tag{37}$$

$$= \frac{1}{\Omega_{PPI}}\left[1 - \Phi\Theta - \frac{\Theta^2\omega\alpha(\eta - 1/\sigma)}{(\varphi+\Theta)}\right] \tag{38}$$

$$\psi_{\pi h}^{PPI} = \frac{\lambda(\varphi+\theta)}{(1-\beta\rho_z)}\psi_y^{PPI} \tag{39}$$

and $\Omega_{PPI} = \left[\Theta - \frac{1}{(1-\rho_z)}\left(\phi_y + \frac{(\phi_{\pi h}-\rho_z)\lambda(\varphi+\theta)}{(1-\beta\rho_z)}\right)\right]$. Note that, since $\frac{\lambda(\varphi+\theta)}{(1-\beta\rho_z)} > 0$, this implies that the PPI inflation will move in tandem with the output gap.

We are now in a position to understand the responses to z^* shocks under PPI targeting. For concreteness, focus on a calibrated example, allowing for alternative configurations of η and σ. Baseline parameters are given by Table 4 and a steady-state ratio of food expenditures to consumption set to 25% so that $\omega = 0.75$ (based on cross-country data underlying Rigobon, 2008, as kindly supplied by the author). Figure 2 shows dynamic responses, under a PPI rule, to a unit (in logs) shock in z^*, implying a doubling of world food prices. The elasticity of intratemporal substitution η between food and non-food goods is allowed to vary between 0.25 and two, and the coefficient of risk version, σ, is set to 2. The remaining parameter choices in Table 4 are similar to the ones found in Gali and Monacelli (2005) and de Paoli (2009) as well other studies.

Start with the special case $\eta = 1/\sigma$, which implies, as we already saw, that $\varrho_q = 1$ and hence that $\Phi\Theta = 1$. From 37 and 39 it follows that $\psi_{\pi h}^{PPI} = \psi_y^{PPI} = 0$ (or, alternatively, that the coefficient of $E_t\Delta z_{t+1}^*$ in 35 is zero), meaning that neither the output gap nor PPI inflation are affected by food shocks. Accordingly, given the PPI policy rule, the interest rate does not move either, now or in the future (since in the absence of new shocks $\tilde{y}_{t+1} = E_t\tilde{y}_{t+1} = \psi_y^{PPI} E_t z_{t+1}^* = \psi_{\pi h}^{PPI} E_t z_{t+1}^* = 0$). Since $\varrho_q = 1$, from 31 we have that the terms of trade will follow their natural counterpart, which in turn follow exactly the path of z_t^*. Since the real exchange rate is $x_t = (1-\alpha)q_t - z_t^* = -\alpha q_t$ in this case, it appreciates on impact by $\alpha = 0.4$ percent, and then depreciates. Consumption must then fall by $\alpha(1/\sigma)$, reflecting risk sharing. Finally, **??** implies that CPI inflation increases by α on impact, but falls by $\alpha\Delta q_t$ in subsequent periods. This explains the sudden jump on CPI inflation followed by small negative inflation in Figure 2.

In the more general case $\eta \neq 1/\sigma$, the output gap and PPI inflation do react to food price shocks. Consider the case of limited substitutability between food and non-food goods, so that $\eta < 1/\sigma$. Then $\varrho_y < 0$ and $\varrho_q < 1$: natural output falls in response to the z_t^* shock, and the natural terms of trade undershoots the shock. To see what happens to the output gap and PPI inflation, one could conjecture that actual output could still equal natural output, in which case PPI inflation would be zero (given 39). The Phillips curve 36 would then hold. The IS equation **??** would not hold, however, since $\varrho_q < 1$ implying that the last term of the equation would not be zero. To restore equality in **??**, the output gap and PPI inflation must then be different from zero. Since Θ decreases in η, it follows from 37 that ψ_y^{PPI} turns negative as η falls below $1/\sigma$. So, the output gap and PPI inflation both decline with the z_t^* shock. The intuition is that, with low intra-temporal substitutability between the home good and food imports, the demand for the home good arising from the lower price of the home good relative imports does not rise enough to compensate for the fall in overall demand due to the contractionary effect due to inter-temporal substitution. The policy rule then implies that the nominal interest rate falls. The converse happens with $\eta < 1/\sigma$, i.e., positive world food price shocks are expansionary. Notice that in these simulations we are holding the inverse of the elasticity of labor supply φ constant, but from 37 it is clear that a higher elasticity is expansionary and could potentially compensate for lower values of η -1/σ.

Figure 3 shows the impulse responses in the case of a CPI rule:

$$i_t = \phi_y \tilde{y}_t + \phi_\pi \pi_t \tag{40}$$

(Note that, abusing notation, we now use ϕ_π to denote the coefficient of the CPI in the rule.) From 36, **??**, and **??**, the system to be solved is:

$$\pi_{ht} = \beta E_t \pi_{h,t+1} + \chi \tilde{y}_t$$

$$\pi_t = \pi_{ht} + \alpha(\varrho_q \Delta z_t^* + \Theta \Delta \tilde{y}_t)$$

$$\phi_y \tilde{y}_t + \phi_\pi \pi_t = E_t \left[(\varrho_q - 1)\Delta z^*_{t+1} + \Theta \Delta \tilde{y}_{t+1} + \pi_{ht+1} \right]$$

In the special case $\eta = 1/\sigma$, $\varrho_q = 1$ and the last two equations reduce to

$$\pi_t = \pi_{ht} + \alpha(\Delta z^*_t + \Theta \Delta \tilde{y}_t) \tag{41}$$

$$\phi_y \tilde{y}_t + \phi_\pi \pi_t = E_t \left[\Theta \Delta \tilde{y}_{t+1} + \pi_{ht+1} \right]$$

Combining the two:

$$\phi_y \tilde{y}_t + \phi_\pi \pi_{ht} + \phi_\pi \alpha(\Delta z^*_t + \Theta \Delta \tilde{y}_t) = E_t \left[\Theta \Delta \tilde{y}_{t+1} + \pi_{ht+1} \right]$$

This equation, together with 36, determines the path of the output gap and PPI inflation; CPI inflation is then given by 41. In contrast with the analysis of the PPI rule, Δz^*_t appears in this system irrespective of whether $\eta = 1/\sigma$ and $\varrho_q = 1$. Hence the output gap and PPI inflation can never stay the same in response to a food price shock. More especifically, the output gap response the food price shock will be given by:

$$\psi_y^{CPI} = \frac{1}{\Omega_{CPI}} \left[\frac{\rho_z}{(\rho_z - \alpha\phi_\pi)} - \Phi\Theta - \frac{\Theta^2 \omega \alpha (\eta - 1/\sigma)}{(\varphi + \Theta)} \right] \tag{42}$$

Comparing 42 with 37 we see that the output gap responds more strongly under a CPI policy rule once $0 < \alpha\phi_\pi < 1$,since $\frac{\rho_z}{(\rho_z - \alpha\phi_\pi)} > 1$. In particular, the more open the economy (higher α), the stronger the response under CPI targeting. In fact, for sufficiently high values of ρ_z and $\alpha\phi_\pi$, the output gap will not contract for z^* shocks even if $\eta < 1/\sigma$, and hence PPI inflation will always be positive. Figure 3 confirms this intuition, as it shows that both the output gap and PPI will expand more, and often substantially more, under CPI targeting than under PPI targeting. So, CPI targeting is typically less contractionary than PPI when the economy is faced with z^* shocks. As with PPI targeting, the output gap and PPI inflation will be higher the higher the intra-temporal elasticity relative to the inter-temporal one - i.e. the larger $\eta - 1/\sigma$. This is also illustrated in Figure 3.

To see the response of other aggregates to food price shocks under CPI targeting, consider the log-linearized market clearing equation for domestic output where c^*_t has been substituted out using $\sigma c_t = \sigma c^*_t + x_t$ and with irrelevant constants ignored:

$$y_{ht} = c_t - \frac{1}{\sigma}x_t + \frac{1}{\Theta}q_t - \Phi z_t^*$$

Adding and subtracting from above, using $x_t = (1-\alpha)q_t - z_t^*$, $y_{ht}^n = \varrho_y z_t^*$, $q_t^n = \varrho_q z_t^*$, and $\tilde{y}_{ht} = \psi_y^{CPI} z_t^*$ yields:

$$c_t = \psi_c^{CPI} z_t^*$$

where for the particular case of $\eta = 1/\sigma$ we have that:

$$\psi_c^{CPI} = \frac{1}{\sigma}\left(\Theta(1-\alpha)\psi_y^{CPI} - \alpha\right)$$

Under CPI targeting, whether current consumption falls depends on whether $\alpha > \Theta(1-\alpha)\psi_y^{CPI}$, an inequality more likely to hold the more open the economy. Figure 3 illustrates that for all parametrizations current consumption falls, as with the PPI case. As c_t falls, the risk-sharing condition implies that the CPI-based real exchange rate x_t must appreciate (i.e, x_t must fall). This is also shown in Figure 3

To gain further insight, combine 40and 41 to see that $i_t = \phi_y \tilde{y}_{ht} + \phi_{cpi}\ (\pi_{ht} + \alpha(\Delta z_t^* + \Theta \Delta \tilde{y}_t))$. This means that CPI targeting makes the interest rate react not just to π_{ht} but also to Δz_t^*. In addition, the response to the output gap is stronger than in the PPI case (with a coefficient $\phi_{cpi}\Theta + \phi_y$ where $\phi_{cpi} > 1$ and $\Theta > 0$). Even if the gap and PPI inflation remain zero (which is not the case, as we have seen), i_t will rise after a positive z^* shock. Also, since $E_t \pi_{t+1} = \rho_z \psi_\pi z_t^*$, $E_t \pi_{t+1}$ rises by less than π_t.So, the real interest rate $i_t - E_t \pi_{t+1}$must rise and, by the Euler equation, consumption growth $E_t \Delta c_{t+1}$will also rise. But, as we saw, c_t must fall. How can the output gap and PPI inflation rise despite the drop in c_t? The answer is that the nominal exchange rate depreciates: $\Delta s_t = \Delta x_t + \pi_t = -\sigma \Delta c_t + \pi_t$.

Finally, to see what happens to output, define the real domestic producer exchange rate $K_t = \frac{S_t P_t^*}{P_{ht}}$. Overall demand for domestic output can then be written as $Y_t = C_t^* \left[\kappa(1-\alpha) K_t^\eta X_t^{1/\sigma - \eta} + \phi K_t^\gamma\right]$. If $\eta = 1/\sigma$, Y_t then moves in tandem with K_t. If domestic prices do not move (i.e., π_{ht}=0) and S_t rises, K_t rises and Y_t must then rise too. Since, as discussed above, natural output does not move when $\eta = 1/\sigma$,the output gap should rise in tandem with actual output Y_t. So, the output gap will be positive, as in Figure 3. As noted above, this contrasts with the unchanged output gap under the PPI rule when $\eta = 1/\sigma$. But as the output gap turns positive, marginal costs rise at the time of shock. Domestic firms will then seek to reset their prices but, under Calvo pricing, only a fraction of them will be able to do so. So, domestic prices rise, but not to the same extent as marginal costs or the exchange rate depreciation. As with the case of PPI targeting $\psi_{\pi h}^{PPI} = \frac{\lambda(\varphi+\theta)}{(1-\beta\rho_z)}\psi_y^{CPI}$,implying that output and home inflation move in the same direction with CPI targeting. Hence CPI targeting implies that both $\psi_{\pi h}^{PPI}$ and ψ_y^{CPI} being positive even if $\eta = 1/\sigma$. Finally, also as with the PPI case, the strength of the output gap and home inflation response to z^* increases with $\eta - 1/\sigma$, as illustrated in Figure 3. With both the output gap and home inflation positive, and since $i_t = (\Theta\phi_{cpi} + \phi_y\tilde{y}_{ht}) + \phi_{cpi}\ (\pi_{ht} + \alpha\Delta z_t^*)$ under CPI targeting, as opposed to $i_t = \phi_y\tilde{y}_t + \phi_{\pi h}\pi_{ht}$ under PPI targeting, i_t responses to z^* shocks will typically be significantly stronger under CPI targeting.

4 Welfare

Evaluation of the welfare implications of monetary policy can be based on a second order approximation of the utility function of the representative agent, here the expected utility function $E\sum\beta^t U_t$. We follow Gali (2008) and Woodford (2003). Ignoring higher order terms here and in the rest of this section, a second order approximation of the consumption part is easy:

$$\frac{C_t^{1-\sigma}}{\varsigma(1-\sigma)} = \frac{C^{1-\sigma}}{\varsigma(1-\sigma)} + \frac{C^{1-\sigma}}{\varsigma}(c_t + \frac{1-\sigma}{2}c_t^2)$$

with lowercase letters referring to log deviations from nonstochastic steady states henceforth.

The term in labor effort is approximated as follows:

$$\begin{aligned}\frac{N_t(j)^{1+\varphi}}{1+\varphi} &= \frac{N^{1+\varphi}}{(1+\varphi)} + N^{1+\varphi}[n_t(j) + \frac{1+\varphi}{2}n_t(j)^2] \\ &= \frac{N^{1+\varphi}}{(1+\varphi)} + N^{1+\varphi}\left[y_t(j) + \frac{1+\varphi}{2}y_t^2(j) - (1+\varphi)a_t y_t(j) + \frac{1+\varphi}{2}a_t^2 - a_t\right]\end{aligned}$$

The last line comes from $y_t(j) = n_t(j) + a_t$.

Hence,

$$\begin{aligned}\int\frac{N_t(j)^{1+\varphi}}{1+\varphi}dj &= \frac{N^{1+\varphi}}{(1+\varphi)} \\ &\quad +N^{1+\varphi}\left[E_j y_t(j) + \frac{1+\varphi}{2}E_j y_t^2(j) - (1+\varphi)a_t E_j y_t(j) + \frac{1+\varphi}{2}a_t^2 - a_t\right]\end{aligned}$$

where $E_j y_t(j)$ denotes the cross sectional average of the $y_t(j)'s$. Use

$$y_{ht} = E_j y_t(j) + \frac{1}{2}(1-\frac{1}{\varepsilon})var_j y_t(j)$$

to second order and get:

$$\int \frac{N_t(j)^{1+\varphi}}{1+\varphi}dj = \frac{N^{1+\varphi}}{(1+\varphi)} + N^{1+\varphi}\left[y_{ht} - a_t + \frac{1+\varphi}{2}y_{ht}^2 - (1+\varphi)a_t y_{ht} + \frac{1}{2}(\frac{1}{\varepsilon} + \varphi)var_j y_t(j) + \frac{1+\varphi}{2}a_t^2\right]$$

Now,

$$var_j y_t(j) = \varepsilon^2 var_j(\log p_t(j))$$

and hence:

$$\int \frac{N_t(j)^{1+\varphi}}{1+\varphi}dj = \frac{N^{1+\varphi}}{1+\varphi} + N^{1+\varphi}[y_{ht} - a_t + \frac{1+\varphi}{2}y_{ht}^2 - (1+\varphi)a_t y_{ht} + \frac{1+\varphi}{2}a_t^2 + \frac{1}{2}\varepsilon(1+\varphi\varepsilon)var_j(\log p_t(j))$$

Finally, one uses the result in Woodford (2003, p. 400):

$$E\sum_{t=0}^{\infty}\beta^t var_j(\log p_t(j)) = \frac{\theta}{(1-\theta)(1-\beta\theta)}E\sum_{t=0}^{\infty}\beta^t \pi_{ht}^2$$

to get

$$E\sum_{t=0}^{\infty}\beta^t \int \frac{N_t(j)^{1+\varphi}}{1+\varphi}dj = N^{1+\varphi}E\sum_{t=0}^{\infty}\beta^t\left[y_{ht} - a_t + \frac{1+\varphi}{2}y_{ht}^2 - (1+\varphi)a_t y_{ht} + \frac{1+\varphi}{2}a_t^2 + \Theta\pi_{ht}^2\right] + \frac{N^{1+\varphi}}{(1+\varphi)(1-\beta)}$$

where

$$\Theta = \frac{1}{2}\varepsilon(1+\varphi\varepsilon)\frac{\theta}{(1-\theta)(1-\beta\theta)}$$

In sum, the relevant part of the utility function is:

$$U_t = U + E\sum_{t=0}^{\infty}\beta^t\{\frac{C^{1-\sigma}}{\varsigma}(c_t + \frac{1-\sigma}{2}c_t^2) - N^{1+\varphi}[y_{ht} - a_t + \frac{1+\varphi}{2}y_{ht}^2 - (1+\varphi)a_t y_{ht} + \frac{1+\varphi}{2}a_t^2 + \Theta\pi_{ht}^2]\} \quad (43)$$

where:

$$U = \frac{1}{(1-\beta)}\left(\frac{C^{1-\sigma}}{\varsigma(1-\sigma)} - \frac{N^{1+\varphi}}{(1+\varphi)}\right)$$

Now we have expressed the objective function without idiosyncratic variables, only in terms of aggregate ones.

To deal with the presence of the linear terms c_t and y_{ht} one needs to solve for equilibria to second order, as discussed by Woodford (2003). We employ the procedure and programs of Schmitt Grohe and Uribe (2004) to the original nonlinear representation of the model equilibrium.

5 Policy Comparisons

5.1 Definining the Policy Rules

As discussed in the introduction, previous work in closed as well as small open economies settings find that PPI or "core" inflation targeting is generally a superior policy rule to CPI inflation and/or an exchange rate peg. Further, between CPI targeting and exchange rate pegging rules, the latter has been found to generate higher welfare levels (cf. de Paoli, 2009). Our aim here is to examine whether these results still hold in a small open economy subject to shocks in the world relative price of food commodities - over and above the more conventional shocks to domestic productivity and interest rates - and in a context where food represents a non-trivial (and somewhat stable) share of aggregate consumption.

Our strategy is to evaluate numerically the second order approximation to welfare of the previous section assuming distinct policy rules considered in previous studies (and widely adopted in practice). The model has to be solved via a second order approximation of the equilibrium equations in subsection 2.4, plus a description of monetary policy. If monetary policy is an interest rate rule, we need to append the Euler equation 5 to the equilibrium system. The model is then closed by specifying different rules relating the domestic interest rate to other variables.

The first rule we consider is a domestic inflation (PPI) Taylor rule:

$$\log(1+i_t) = (\rho + \phi_\pi(\Pi_{ht} - 1) + \phi_y(y_{ht} - y_{ht}^n) + v_t)$$

where $Y_{ht}^n$is natural output[7] We also study a CPI Taylor rule, given by:

$$\log(1+i_t) = (\rho + \phi_\pi(\Pi_t - 1) + \phi_y(y_{ht} - y_{ht}^n) + v_t)$$

where $\Pi_{t+1} = P_{t+1}/P_t$.

Finally, we consider a nominal exchange rate peg rule, in which the monetary authority fixes the nominal exchange rate S_t to a constant S. Then the real exchange rate must satisfy $X_t = SP_t^*/P_t$, which implies:

$$X_t P_{ht} = SP_t^*(\frac{P_{ht}}{P_t})$$

[7] Natural output is obtained, together with other natural variables, by setting $\theta = 0$ in equations 14 to 17 > This yields a static 4-equation system which can be solved for C_t^n, Q_t^n, X_t^n, and Y_{ht}^n given the exogenous variables Z_t^*, C_t^*, and A_t.

where by definition,

$$\Pi_{h,t} = \frac{P_{ht}}{P_{h,t-1}}$$

Introducing these equations in the system, and withdrawing the Euler equation in the monetary policy rule that we had for the CPI and PPI cases, we are now left with eleven equations in the eleven variables:$C, X, (P_h/P), Y_h, (\bar{P}/P_h)$, Π_h, Z, H, M, F *and* P_h Having the level of P_h as a new variable to solve for, and with a constant S,the domestic price level is pinned-down by introducing a stochastic process the (log of) world price, given by: $p_t^* = a + bp_{t-1}^* + \epsilon_t$, where ϵ_t is white noise.

5.2 Policy Rankings

As discussed above, we use the numerical procedure and programs of Schmitt Grohe and Uribe (2004) to calculated the respective utility yielded by each of these three policy rules.In doing so, we follow Schmitt-Grohe and Uribe (2007) and Wang (2006) and ensure that these comparisons are undertaken for an economy at the same starting point for all policies. In other words, we compute welfare comparisons that are "conditional " on the same starting point which, as in these previous studies, is that all state variables are in their non-stochastic steady state. Besides the obvious theoretical appeal of this metric, Wang (2006) shows that it also simplifies the computational burden considerably. Specifically, he shows that the second-order of approximation of the instantenous discounted value of the representative agent's welfare, once made conditional on such a starting point, will take the form of:

$$V_t = V + \frac{1}{2} g_{\sigma\sigma}(\bar{x}, 0)\sigma$$

where V is steady state conditional utility, x is a vector of the state variables in this case associated with V_t and evaluated at the model's non-stochastic steady state, $g_{\sigma\sigma}$ is the second derivative of the g function with respect to the variance of the shocks (once the system is set so that the vector of control variables takes the form $y_t = g(x_t, \sigma)$), and σ is a scalar on the distribution of the shocks. Intuitively, the last term in the above equation captures the adjustment of initial positions associated with each policy rule due to uncertainty. Depending on large this term is, there may be considerable differences between this metric and the "unconditional" welfare metric.

Computationally, this calculation amounts to a simple addition of a control variable V_t to the system of equations entering the S-U algorithm, which will evolve according to the law of motion $V_t - \beta V_t = U(C_t, L_t)$.Then, the relative welfare loss of policy rule "1" relative to policy rule "2", expressed in percentage units of steady state consumption, will be given by:

$$\tau = 100 \times (1 - e^{(1-\beta)(V_1 - V_2)})$$

From 43, one can see that the welfare-superiority of a particular policy rule will depend on how it affects: 1) the volatility of consumption (negative effect) vs. the level of consumption (positive effect); 2) the variability in labor supply and the disutility of work (negative effects); 3) the variability of home good inflation (negative effect) - the respective weights thereof being given by the various intra- and inter-temporal elasticities as well as by the weight of consumption in utility (ς) and parameters pertaining to price stickiness and food share in consumption. With world consumption (C*) exogenously given, the risk sharing condition 4 implies that both the level and the volatility of domestic consumption will depend on the volatility of the real exchange rate X_t. As seen in 24, X_t will be directly affected by the world relative price of food and not necessarily in a one-to-one fashion with the terms of trade (see also I-Rs in section 3). Further, once we depart from certainty-equivalence setting, so that the volatility of relative prices can also affect mean prices and quantities, the variance of Z_t can affect the level of X_t and hence the level of consumption in this small open economy. With (albeit imperfect) international competition, the level and volatility of Z_t and hence of will X_t affect home output and hence both the level and volatility of work effort. And with some (albeit likely very low) domestic substitution between food and the non-food home, the volatility of will also affect home good prices depending on their degree of stickness. So, as extensively illustrated in the numerical calibrations presented below, critical to the welfare ranking of policy rules is the way each rule responds to the volatility of world food prices.

In the calibrations that follows, we examine the net balance of such trade-offs on welfare using benchmarks from a prototype emerging market (Chile) as well as other international data to calibrate the stochastic processes for the relative world price of food, TFP, domestic and external interest rate shocks. We also assume Taylor rule coefficients that are close to those estimated in practice for economies operating inflation targeting regimes. Specifics on the estimation and data sources are available from the author upon request. We evaluate the robustness of the results for a wide range of alternative parametrizations, including that of the standard deviation and persistence of the various shocks as well as various combinations of the intra-temporal elasticity of consumption, which we let take on values between 0.25 and 4, and the coefficient of risk aversion (the inverse of the inter-temporal elasticity), which we let take on values between 0.5 and 4, consistent with the range of estimates found in empirical macro studies.

Baseline parameter values are reported in Table 5. All parameters are computed on a quarterly frequency and the ratio of home good consumption to income in steady-state (ω) is set to 0.75. We show later the effects of varying it within a wide but still reasonable range (0.6 to 0.9). Since in the non-linear representation of the model's steady state ω is a function of ς, κ,and Y^*, we must fix only two of these three parameters and allow one of them to adjust across distinct combinations of the substitution elasticities. Since we have no evidence of what a realistic calibration for ς might be (something complicated by its dependence on the unit of measurement with which one evaluates the weight of consumption and leisure in utility), we fix both world income Y^* and the initial level of net foreign assets that pins down κ, and let ς adjust so as keep $1 - \omega$ fixed. The other parameter of interest is world consumer price index. Initially we fix it to unity but let it later to evolve according to a stochastic process with considerable persistence ($\rho = 0.99$) and (quarterly) standard deviation of 1.3%, as obtained from a quarterly AR(1) regression of an unweighted average of advanced countries (G-8) PPIs during the 1990-2008 period.

Critical to our results is the volatility of world food prices relative to world CPI. We parameterize z* as displaying a conditional (quarterly) standard deviation of 4.5% and an AR(1) coefficient of 0.85, consistent with regressions of the IFS-IMF index of food commodity prices relative to world (G-8) WPI between 1990 and 2008. Based on estimates using Chilean data, the standard deviation of productivity shocks is set at 1.2% per quarter and its AR(1) coefficient at 0.7. The latter is very similar to one used by Gali and Monacelli (2005) using Canadian data, whereas their reported standard deviations of TFP shocks for Canada is nearly half (0.7%), consistent with the fact that output in the Chilean economy has been about twice or so more volatile than in Canada. Further below, we also examine the robustness of the results to changes in such TFP parameters. Finally, we calibrate v_t by running a Taylor rule-type regression with Chilean data from 1991 to 2008. We obtain a standard deviation of v_t of 0.62% per quarter and and AR(1) coefficient of 0.6. Again, we examine the sensitivity of results to alternative calibrations. In calibrating labor supply ($1/\varphi$) and export price (γ) elasticities, we take values used in other studies (e.g. Bergin et al, 2007; Gali, 2008) with acknowledgement that they appear to vary widely in the data. So, we let their range vary from 1 (benchmark) to 1/3 and from 1 to 5, respectively.

We start with the baseline parametrization ïn Table 6 with the coefficient on the output gap set to zero, so that we have "strict" (as opposed to the so-called "flexible") inflation targeting. As with all subsequent welfare ranking tables, we report the values of τ for pair-wise comparison between rules that lead to the overall relative rankings between PPI ("rule 1), CPI targeting ("rule 2") and and exchange rate peg ("rule 3). As usual with welfare comparisons, τ values are generally low, albeit generally of an order of magnitude higher than those featuring in Lucas" (1987) classical illustration of the negligibility of the welfare cost of business cycles. Be that as it may, the classic closed-economy result on PPI dominance is clearly overruled. As illustrated in the overall ranking matrix at the bottom of Table 6, CPI ("rule 2") is the superior rule for the majority of $\eta - \sigma$ configurations, and particularly among the arguably more realistic cases where η is low and σ is high.

A key question in this regard is how important is the allowance for international relative price shocks (in our case food price shocks) in accounting for this result. Tables 7 and 8 provide some insight. Keeping the same parametrization as in Table 6, but setting the variance of world food price shocks to near zero, Table 7 recovers the results of previous authors: either exchange rate peg or a PPI targeting dominates. In particular, for the unit elasticity case ($\eta = \sigma = \gamma = 1$), it can be shown by combining 12, 4 with $\kappa = 1$ and a fixed ω, that trade will be balanced at all times. With the variance of z* shocks negligible, this economy is then isomorphic to the Gali-Monacelli benchmark, for which they show analytically that PPI is the dominant policy rule. This is precisely what our numerical results also show. So, once relative food price shocks are negligible, PPI is the dominant rule once agents are risk avin erse and more generally when intra-temporal substitution elasticities are not too low.

Table 8 helps gaining further insight into this result. It computes means and standard deviations for the model variables that have a key bearing on welfare. These moments are computed by feeding the second-order approximation solution to the model with a 20,000 random draws of z*, a, and v shocks. Importantly, we do so for the case in which only food shocks are present, as well as for the cases where only productivity and only monetary policy shocks are present. Columns (1) to (6) show that, if only food price shocks are present, CPI targeting yields lower RER and consumption volatility as well as lower output (and hence lower effort) and a higher consumption to output ratio. The table also points to what is behind such a higher C/Y ratio, namely a more appreciated RER on average (0.32% above SS). This allows the country to explore its terms of trade externality, thus enabling it to afford a higher consumption level for a given unit of output. This is so generally (for $\sigma = 2$ or $\sigma = 4$ in the table but further parametrizations available from the authors upon request). So, the welfare superiority of CPI targeting shown in Table 6 appears to reflect this rule's edge in generating more consumption relative to output and lower consumption volatility relative to both PPI and PEG rules, at least when only food price shocks are present.

However, Table 8 also indicates that this is not case if only productivity or monetary shocks are present. In the productivity shock-only case, PPI targeting is the rule that produces lowest consumption and real exchange rate volatility as well as (marginally) higher C/Y. So, in a world where domestic productivity are of overwhelming importance, PPI targeting ought to be preferred. The reason as to why PPI target generates a more appreciated RER under productivity-only shocks can be gleaned from the relationship between the level of the home price index and the covariance between income and marginal cost shocks under Calvo-pricing, which we flesh out in Appendix 2. With productivity shocks only, that co-variance will be negative. Because the overriding goal of PPI rule is to stabilize Ph, PPI will react in a stronger procyclical manner to a shocks than CPI targeting. This will prevent marginal costs from falling as much as it would so the co-variance will be less negative than under CPI targeting. So, as per equation 44 the home price level will be higher, and hence the RER will be more appreciated under PPI rules. With a more appreciated RER, the ratio of C/Y will be higher, all else constant. This is indeed what columns 7-9 of Table 8 show. So, only when food price re-enter the picture, as in the last three columns of Table 8, do the reasons for a more clear-cut CPI dominance re-emerge.

Table 9 examines what happens to relative welfare rankings once the volatility of monetary policy (interest rate) shocks about doubles, from 0.6% per quarter to 1.2% per quarter, keeping otherwise the same baseline parametrization as in Table 6. As expected, the result is to increase the attractiveness of the peg rule. A similar result obtains if monetary policy shocks become more persistent, once the persistence of v increases from 0.6 to 0.8 (Table 10). A noticeable feature in both tables is that, as monetary policy shocks become larger, the numerical magnitudes of welfare differences also grow larger, in some cases reaching 0.6% of steady state consumption.

Tables 11 and 12 move the volatility and persistence of domestic TFP shocks. For the reasons already discussed, this increases the attractiveness of PPI relative to other rules. Yet, keeping the standard deviation of z* shocks at non-trivial levels (4.5% a quarter), this does not translate into far-reaching PPI dominance.

Table 13 goes back to the baseline specification of Table 6 except that we have now a more agressive policy reaction to inflation, with $\phi_\pi = 3.0$. What this does is basically to increase the attractiveness of exchange rate pegs. But focusing only on the CPI-PPI trade-offs, a more hawkish anti-inflation stance increases the dominance of PPI over CPI, although the welfare gaps are particularly tiny for more realistic values of σ (i.e. above 1). The converse happens when monetary policy becomes more dovish, as shown in Table 14. In this case, the numerical magnitudes between PPI and CPI targeting welfare gaps also rise, further favouring CPI targeting.

Table 15 moves away from strict inflation targeting by placing some weight on output stabilization.What this does is to reduce even further the numerical gaps between rules: with (the correct measure of) output weighting on monetary policy decisions, all the rule become more similar in terms of welfare losses, with the differences between CPI and PPI shriking considerably for higher values of η.

Table 16 moves the export price elasticity parameter from $\gamma = 1$ to $\gamma = 5$, as sometimes found in empirical work (see Harrigan, 1993). One might expect that this would decrease the attractiveness of CPI targeting under z* shocks, since a higher substitutability between domestic and foreign non-food goods offers less scope for the small open economy to explore its terms of trade externality.However, a higher γ also implies that greater RER volatility brings about greater domestic output volatility (as domestic goods become more substitutable by foreign ones) and hence higher employment volatility, which hurts welfare (see equation 43). Overall, the upper panel in Table 16 clearly indicates that this latter effect dominates: CPI becomes even more attractive than PPI targeting, with the numerical welfare gaps (τ) being not so negligible at times. By the same token, CPI beats PEG more often, implying that the dominance of CPI targeting rises relative to the baseline of Table 6 with $\gamma = 1$.

In Table 17, we lower the labor supply elasticity to a third (i.e. raise φ from 1 to 3), keeping otherwise the baseline parametrization of Table. As expected, main result is to reduce the attractiveness of the peg relative to both CPI and PPI.

Thus far, from Table 6 to 17, we have set the volatility of world price p* to zero, thus increasing the stabilization properties of exchange rate pegging for given z* and a shock volatility. In the subsequent tables we change this by letting p* be driven by a very persistent stochastic process with a quarterly variance of 1.3% which is around that found in real data. Table 18 shows that this results in greater dominance of CPI and PPI relative to peg. Yet, for the combination of higher σ and lower η, CPI dominates as before.

A final experiment we undertake is to change ω, hence letting the economy be more or less open in steady state relative to the baseline ω =0.75. Table 19 reproduces the same calibration as Table 6 but now with ω =0.6. This high openness scenario entails even greater CPI rule dominance, which becomes overwhelming for above σ 0.5. No less importantly, for the more empirically more realistic combination of higher σ and lower η , the welfare gains relative CPI to PPI are not so trivial, ranging between 0.33 ($\sigma = 2$ and $\eta = 0.25$) and 0.62 ($\sigma = 2$ and $\eta = 0.75$) of steady state consumption. Conversely and as expected, Table 20 shows that the low openness scenario ω =0.9 leads PPI targeting becoming more dominant, although the respective welfare gains are relatively tiny.

6 Conclusion

One concern about the nature of the global economic recovery in the wake of the recent financial crisis is the resurgence of food price pressures.[8] Thus analyses of optimal monetary policy and targeting rules in a small open economy subject to such a shock is of clear interest looking forward.This paper has examined this issue in the context of a now standard small open economy model with differentiated varieties, monopolistic competition with Calvo pricing, and complete asset markets similar to the setting analysed by previous authors (e.g. Gali and Monacelli, 2005; de Paoli, 2009). While such a model can be used for analyzing the effects of international relative price changes when domestic varieties and imported goods are imperfect substitutes, we adapted it to capture some essential features of food - namely, its large weight and limited substitutability in household consumption as well as high price volatility. We also focused on the case of net food importing countries where high food price volatility translate into high terms of trade volatility, a scenario akin to that facing many small open economies.

The main question we seek to answer in this connection is that of how far monetary policy should lean against the wind of shocks to relative world food prices. With food having a large weight and low substitutability in the representative consumption basket, this maps onto the question of what monetary policy should target: under broad CPI targeting, monetary policy would tend to be far more responsive to world food price shocks than under PPI targeting or

[8] See, e.g., http://www.ft.com/foodprices for recent developments in world food supply and prices as well as on debate on the resurgence of food price pressures.

exchange rate pegging. So, the relevant question from a policy perspective is which rule delivers the highest welfare. As is now well-known, in a typical closed economy setting featuring monopolistic competition and sticky prices as key distortions, it has been shown that stabilizing the producer price index (PPI) is the desirable policy once the monopolistic competition distortion is offset with a suitable tax. Variants of this closed economy setting featuring a domestic commodity price sector suggest that the more competitive structure and lower price rigidity in this commodity sector may justify a more lenient attitude towards volatile commodity price inflation and a monetary policy mandate of targeting non-commodity (i.e. PPI in our setting) or "core" inflation (Aoki, 2001). While subsequent research incorporating other open economy features makes occasional concessions for the welfare dominance of exchange rate pegging over PPI targeting, broad CPI targeting is never welfare-superior in these studies either. In this literature, food is like any other (infinite-variety) good, displaying a high intertemporal elasticity of substitution and sticky prices; as such, shocks to relative world food price play no distinctive role. Indeed, to the best of our knowledge, external shocks to the relative price of food are simply not considered in the existing DSGE model calibration exercises.

Against this background, the main novelty of our results is to show that allowance for the distinctive role of food in household utility and the high volatility of world food price shocks relative to other shocks can overturn this welfare ranking. The main reason pertains to the relative importance of shocks to world food prices relative to other shocks in shifting the marginal rate of substitution between consumption and work, thus inducing cost push shifts as well as the real exchange rate volatility. When food price shocks are large relative to monetary and productivity shocks and the weight of food in utility sufficiently high, both PPI and nominal exchange rate targeting entail high real exchange rate volatility and more depreciated external terms of trade on average than CPI targeting. Insofar as higher real exchange rate volatility translates into higher consumption volatility and a lower terms of trade lowers the ratio of consumption to output of domestic households, CPI targeting is bound to be welfare superior provided that risk aversion and the disutility of domestic production are sufficiently high. In other words, CPI targeting allows the country to better explore its terms of trade externality, i.e., the fact that imperfect international competition gives the possibility for the domestic policy maker to gain from an appreciation of the real exchange rate. In this context, therefore, the domestic central bank would tighten (loosen) monetary policy more agressively when faced with an unexpected rise (fall) in world food prices (relative to world CPI) than a central bank which is PPI-targeter or pegger.

Such a more aggressive response to world food price shocks would lead to greater real exchange rate stability, a more appreciated real exchange rate, and higher consumption-to-output ratio on average. The trade-off from the viewpoint of aggregate welfare is whether these benefits would offset those of lower output and employment and less than the full offset of the domestic sticky price distortion entailed by PPI targeting.

An important question that we also address is whether a higher weight on the output gap in the monetary policy reaction function could narrow or even overturn the welfare superiority of CPI relative to PPI targeting under food price shocks. We show that this is the case provided that the central bank uses the theoretically (model) correct measure of natural output. We show that such a measure for a net food importing country should include fluctuations in the terms of trade and hence in the relative world price of food. Once this correct measure of the output gap is introduced in the monetary policy reaction with empirically sensible weights, welfare differences between PPI and CPI targeting are narrowed and the CPI welfare superiority even overturned under certain parametrizations. A practical problem of such a reinstatement of an output-gap adjusted PPI targeting is of course its reliance on the correct measure of the output gap, which is known to be highly non-trivial in practice.

Some salient policy implications follow. One is that the rationale for broad CPI targeting as currently adopted by many central banks is strenghtened once we allow for the role of food in utility. This rationale reinforces considerations related to transparency and avoidance of ad hoc criteria to define the "core" component in CPI, as well as the credibility gains that might arise from targeting a broader price index.

Second, the case provided here for CPI targeting and implicit partial offset of imported food inflation therein also rectifies some of the regressive distributional bias associated with the usual prescription that monetary policy should focus on offsetting the sticky-price distortion. To the extent that food and other commodity prices are less sticky and determined under a more competitive market structure, this prescription implies that central banks should be more lenient towards inflation or deflation in those sectors. Yet, we know that the weight of food in overall spending is higher among poorer households which are also precisely the ones with more limited access to credit markets to smooth real purchasing power fluctuations arising from shocks to relative food prices. Thus strict PPI targeting has a regressive distributional bias that CPI targeting mitigates. While a model like ours featuring identical households is not suitable to address such distributional effects on welfare, it seems important to note here that this might be an non-trivial extra benefit of CPI targeting predicated by our calibrations in a representative agent setting.

Third and finally, our results suggest that central banks should not be too lenient to shocks to food prices even if they are imported and that choosing a target that leads to more accomodative response to such a shock can be welfare inferior. If all central banks follow this prescription, this would help mitigate the externality problem associated with uncordinated/inward oriented policy responses to world price shocks when central banks target PPI or the exchange rate. Less accomodative policy based on broad CPI stabilization would thus be more conducive to keep global inflationary pressures in check - as well as its converse (deflation) whenever commodity prices tank. This might mitigate the need for greater international policy coordination that are not easily attainable in practice.

7 Appendix 1: Recursive Representation of the Model

Consider the pricing function:

$$\sum_{k=0}^{\infty}\theta^k E_t\left[M_{t,t+k}Y_{t+k|t}(\frac{\bar{P}_t}{P_{ht}}-\frac{\varepsilon}{\varepsilon-1}MC_{t+k|t}\Pi^h_{t,t+k})\right]=0$$

Here,

$$\begin{aligned}
MC_{t+k|t} &= \Psi_{t+k|t}/P_{h,t+k} \\
&= (1-\upsilon)W_{t+k|t}/A_{t+k}P_{h,t+k} \\
&= (1-\upsilon)\varsigma C^{\sigma}_{t+k}N^{\varphi}_{t+k|t}P_{t+k}/A_{t+k}P_{h,t+k} \\
&= [(1-\upsilon)\varsigma C^{\sigma}_{t+k}P_{t+k}/A^{1+\varphi}_{t+k}P_{h,t+k}]Y^{\varphi}_{t+k|t} \\
&= [(1-\upsilon)\varsigma C^{\sigma}_{t+k}P_{t+k}/A^{1+\varphi}_{t+k}P_{h,t+k}]\left(\frac{\bar{P}_t}{P_{ht+k}}\right)^{-\varphi\varepsilon}Y^{\varphi}_{ht+k} \\
&= [(1-\upsilon)\varsigma C^{\sigma}_{t+k}P_{t+k}/A^{1+\varphi}_{t+k}P_{h,t+k}]\left(\frac{\bar{P}_t}{P_{ht}}\right)^{-\varphi\varepsilon}\left(\Pi^h_{t,t+k}\right)^{\varphi\varepsilon}Y^{\varphi}_{ht+k}
\end{aligned}$$

Let us write the previous expression in a recursive way:

$$\frac{\bar{P}_t}{P_{ht}}J_t=\frac{\varepsilon}{\varepsilon-1}H_t$$

where

$$J_t=E_t\sum_{k=0}^{\infty}\theta^k M_{t,t+k}Y_{t+k|t}$$

and

$$H_t=E_t\sum_{k=0}^{\infty}\theta^k M_{t,t+k}Y_{t+k|t}MC_{t+k|t}\Pi^h_{t,t+k}$$

Recall

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

and

$$Y_{t+k|t}=\left(\frac{\bar{P}_t}{P_{ht+k}}\right)^{-\varepsilon}Y_{ht+k}$$

to derive:

$$\begin{aligned}
J_t &= Y_{t|t}+E_t\sum_{k=1}^{\infty}\theta^k M_{t,t+k}Y_{t+k|t} \\
&= \left(\frac{\bar{P}_t}{P_{ht}}\right)^{-\varepsilon}Y_{ht}+E_t\sum_{k=1}^{\infty}(\beta\theta)^k\left(\frac{C_{t+k}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+k}}\right)\left(\frac{\bar{P}_t}{P_{ht+k}}\right)^{-\varepsilon}Y_{ht+k} \\
J_t &= \left(\frac{\bar{P}_t}{P_{ht}}\right)^{-\varepsilon}Y_{ht}+\beta\theta E_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{\bar{P}_t}{\bar{P}_{t+1}}\right)^{-\varepsilon}J_{t+1}
\end{aligned}$$

To express H_t recursively, it is convenient to write:

$$\begin{aligned} MC_{t+k|t} &= [(1-\upsilon)\varsigma C_{t+k}^{\sigma} P_{t+k}/A_{t+k}^{1+\varphi} P_{h,t+k}] Y_{t+k|t}^{\varphi} \\ &= F_{t+k} Y_{t+k|t}^{\varphi} \end{aligned}$$

where

$$F_t = (1-\upsilon)\varsigma C_t^{\sigma} P_t / A_t^{1+\varphi} P_{ht}$$

so that:

$$\begin{aligned} H_t &= E_t \sum_{k=0}^{\infty} \theta^k M_{t,t+k} F_{t+k} Y_{t+k|t}^{1+\varphi} \Pi_{t,t+k}^{h} \\ &= F_t Y_{t|t}^{1+\varphi} + E_t \sum_{k=1}^{\infty} \theta^k M_{t,t+k} F_{t+k} Y_{t+k|t}^{1+\varphi} \Pi_{t,t+k}^{h} \\ H_t &= F_t \left(\frac{\bar{P}_t}{P_{ht}}\right)^{-\varepsilon(1+\varphi)} Y_{ht}^{1+\varphi} + \beta\theta E_t \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) \left(\frac{\bar{P}_t}{\bar{P}_{t+1}}\right)^{-\varepsilon(1+\varphi)} \frac{P_{ht+1}}{P_{ht}} H_{t+1} \end{aligned}$$

Nine equations in the ten variables: C, X, (P_h/P), Y_h, $(\bar{P}/P_h)$, Π_h, Z, H, M, F.

The system is completed with the specification of monetary policy.

8 Appendix 2: Relationship between Home Pricing and Covariance of Income and Cost Shocks

$$\begin{aligned} L &= \sum_{k=0}^{\infty} \theta^k E_t \left[M_{t,t+k} Y_{t+k|t} \left(\frac{\bar{P}_t}{P_{ht}} - \frac{\varepsilon}{\varepsilon-1} MC^n_{t+k|t} \right) \right] = 0 \\ &= \sum_{k=0}^{\infty} \theta^k E_t \left[M_{t,t+k} \left(\frac{\bar{P}_t}{P_{ht+k}} \right)^{-\varepsilon} Y_{ht+k} \left(\bar{P}_t - \frac{\varepsilon}{\varepsilon-1} MC^n_{t+k} \left(\frac{\bar{P}_t}{P_{ht+k}} \right)^{-\varphi\varepsilon} \right) \right] = 0 \end{aligned}$$

$$\sum_{k=0}^{\infty} \theta^k E_t M_{t,t+k} \left(\frac{\bar{P}_t}{P_{ht+k}} \right)^{-\varepsilon} Y_{ht+k} \bar{P}_t = \frac{\varepsilon}{\varepsilon-1} \sum_{k=0}^{\infty} \theta^k E_t M_{t,t+k} Y_{ht+k} MC^n_{t+k} \left(\frac{\bar{P}_t}{P_{ht+k}} \right)^{-\varepsilon} \left(\frac{\bar{P}_t}{P_{ht+k}} \right)^{-\varphi\varepsilon}$$

$$\sum_{k=0}^{\infty} \theta^k E_t M_{t,t+k} \frac{\bar{P}_t^{-\varepsilon+1}}{P_{ht+k}^{-\varepsilon}} Y_{ht+k} = \frac{\varepsilon}{\varepsilon-1} \sum_{k=0}^{\infty} \theta^k E_t M_{t,t+k} Y_{ht+k} MC^n_{t+k} \left(\frac{\bar{P}_t^{-\varphi\varepsilon-\varepsilon}}{P_{ht+k}^{-\varphi\varepsilon-\varepsilon}} \right)$$

Let: $\Xi^d_{t,t+k} = M_{t,t+k} Y_{ht+k} P^{\varepsilon}_{ht+k}$

$$\sum_{k=0}^{\infty} \theta^k E_t \Xi_{t,t+k} = \frac{\varepsilon}{\varepsilon-1} \sum_{k=0}^{\infty} \theta^k E_t M_{t,t+k} Y_{ht+k} MC^n_{t+k} \left(\frac{\bar{P}_t^{-\varphi\varepsilon-\varepsilon+\varepsilon-1}}{P_{ht+k}^{-\varphi\varepsilon-\varepsilon}} \right)$$

$$\sum_{k=0}^{\infty} \theta^k E_t \Xi^d_{t,t+k} = \frac{\varepsilon}{\varepsilon-1} \sum_{k=0}^{\infty} \theta^k E_t \Xi^d_{t,t+k} P^{\varphi\varepsilon}_{ht+k} MC^n_{t+k} \bar{P}_t^{-\varphi\varepsilon-1}$$

$$\bar{P}_t^{\varphi\varepsilon+1} = \frac{\varepsilon}{\varepsilon-1} \frac{\sum_{k=0}^{\infty} \theta^k E_t M_{t,t+k} Y_{ht+k} P^{(\varphi+1)\varepsilon}_{ht+k} MC^n_{t+k}}{\sum_{k=0}^{\infty} \theta^k E_t \Xi^d_{t,t+k}} \tag{44}$$

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Table 1: Correlations between World Inflation Indicators and Food and Oil Prices, 1990-2008 (all series HP detrended)

a) Contemporary Correlations

	USWPI	World WPI	World CPI	Pfood	Poil
USWPI	1	0.83689	0.74349	0.61911	0.7255
World WPI	0.83689	1	0.66171	0.63273	0.46531
World CPI	0.74349	0.66171	1	0.5597	0.39451
Pfood	0.61911	0.63273	0.5597	1	0.17133
Poil	0.7255	0.46531	0.39451	0.17133	1

a) Lagged Correlations

	USWPI	World WPI	World CPI	Pfood	Poil
USWPI	1	0.83689	0.74349	0.44189	0.29036
World WPI	0.83689	1	0.66171	0.46337	0.27692
World CPI	0.74349	0.66171	1	0.36737	0.52542
Pfood_{t-1}	0.44189	0.46337	0.36737	1	-0.03128
Poil_{t-1}	0.29036	0.27692	0.52542	-0.03128	1

Table 2: Causality Tests

47 observations used for estimation from 1962 to 2008

a) Food Prices -US WPI

Dependent variable is	WPIGAP
Independent variables:	ZGAP(-1) -ZGAP(-2)
Lagrange Multiplier Statistic	CHSQ(2)= 10.4873[.005]
Likelihood Ratio Statistic	CHSQ(2)= 11.8668[.003]
F Statistic	F(2, 42)= 6.0317[.005]

b) Oil Prices -US WPI

Dependent variable is	WPIGAP
Independent variables:	PROILGAP(-1) -PROILGAP(-2)
Lagrange Multiplier Statistic	CHSQ(2)= 1.4879[.475]
Likelihood Ratio Statistic	CHSQ(2)= 1.5119[.470]
F Statistic	F(2, 42)= .68653[.509]

c) Oil -Food

Dependent variable is	ZGAP
Independent variables:	PROILGAP(-1) -PROILGAP(-2)
Lagrange Multiplier Statistic	CHSQ(2)= 1.1923[.551]
Likelihood Ratio Statistic	CHSQ(2)= 1.2077[.547]
F Statistic	F(2, 42)= .54659[.583]

d) Food -Oil

Dependent variable is	PROILGAP
Independent variables:	ZGAP(-1) -ZGAP(-2)
Lagrange Multiplier Statistic	CHSQ(2)= 14.1011[.001]
Likelihood Ratio Statistic	CHSQ(2)= 16.7653[.000]
F Statistic	F(2, 42)= 9.0010[.001]

Table 3: Food Expenditure Shares

Austria	15.50%	**Latvia**	40.40%
Belgium	16.10%	**Lithuania**	45.45%
Bulgaria	43.36%	**Luxemburg**	13.60%
Costa Rica	13.11%	**Malta**	34.17%
Cyprus	26.40%	**Mexico**	32.69%
Czech Republic	24.20%	**Netherlands**	11.92%
Denmark	14.03%	**Panama**	34.90%
Estonia	30.83%	**Poland**	30.41%
Finland	15.63%	**Portugal**	22.20%
France	15.08%	**Romania**	58.74%
Germany	15.60%	**Slovakia**	33.33%
Greece	21.28%	**Slovenia**	22.91%
Hungary	29.40%	**Spain**	25.40%
Ireland	17.98%	**Sweden**	12.05%
Italy	28.26%	**United Kingdom**	12.91%

Overall Median	23.55%
Overall Mean	25.26%
EM Median	32.69%
EM Mean	33.95%
Advanced Median	15.55%
Advanced Mean	16.81%

Table 4: Calibration of parameters

Discount Factor	β	0.99
Coefficient of risk aversion	σ	[1,4]
Inverse of elasticity of labor supply	φ	1
Degree of Openness	α	0.4
Average period between price adjustments	θ	0.66
Coefficient on domestic inflation in Taylor Rule	ϕ_π	1.5
Coefficient on output gap in Taylor Rule	ϕ_y	0.125
Parameter of persistence associated with moderately persistent monetary policy shock	ρ_v	0.6
Parameter of persistence associated with moderately persistent world relative food price shock	ρ_z	0.85
Price Elasticity of Foreign Demand for the home goods	γ	[0.2,5]
Elasticity of substitution between varieties produced within country	ϵ	6
Elasticity of substitution between domestic and foreign goods	η	[0.25,1]
Ratio C_h/Y_h in steady state	ω	0.75

Table 5: Calibration of parameters in Welfare Comparison of policy rules

Discount Factor	β	0.99
Coefficient of risk aversion	σ	[0.5,4]
Inverse of elasticity of labor supply	φ	[0.5,1]
Degree of Openness	α	0.4
Average period between price adjustments	θ	0.66
Coefficient on domestic inflation in Taylor Rule	ϕ_π	[1.1,2]
Coefficient on output gap in Taylor Rule	ϕ_y	0
Parameter of persistence associated with persistent monetary policy shock	ρ_v	[0.6,0.8]
Parameter of persistence associated with persistent relative food's price shock	ρ_z	[0.85,0.9]
Elasticity of substitution between varieties produced within any given country	ϵ	6
Elasticity of substitution between domestic and foreign goods	η	[0.25,2]
Ratio C_h/Y_h en equilibrium	ω	[0.75,0.85]
Index of foreign demand	C^*	0.27
Parameter associated with tastes and preferences	ς	[0.04,7]
Constant on Perfect Risk Sharing Condition	$\varkappa$	1
Price Elasticity of Foreign Demand for the home goods	γ	[0.2,5]
Standar Deviation associated with monetary policy shock	σ_v	[0.0062,0.0167]
Standar Deviation associated with relative food's price shock	σ_z	0.05
Standar Deviation associated with productivity shock	σ_a	0.012

Table 6: Welfare Comparisons with Baseline Calibration

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%\phi_y = 0.0, \rho_z = 0.85,$

$\rho_a = 0.7, \sigma_a = 1.2\%, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

σ \ η	0.25	0.5	0.75	1	2
0.5	-0.2165	-0.2166	-0.2146	-0.0067	-0.1801
0.75	-0.0222	-0.0102	0.0052	-0.0024	0.1153
1	0.0068	0.0232	0.043	-0.0023	0.1729
2	0.061	0.0859	0.114	-0.0026	0.2784
4	0.0955	0.1256	0.1585	-0.0032	0.3422

CPI Inflation -PEG

σ \ η	0.25	0.5	0.75	1	2
0.5	0.2107	0.2218	0.2285	0.0477	0.2142
0.75	0.025	0.0135	-0.0021	0.0052	-0.1184
1	-0.0069	-0.0236	-0.0442	0	-0.183
2	-0.0673	-0.0937	-0.1236	-0.0083	-0.3046
4	-0.1062	-0.1386	-0.1745	-0.0127	-0.3817

Domestic Inflation-PEG

σ \ η	0.25	0.5	0.75	1	2
0.5	-0.0057	0.0052	0.014	0.041	0.0341
0.75	0.0028	0.0033	0.0031	0.0028	-0.0031
1	-0.0002	-0.0004	-0.0011	-0.0023	-0.01
2	-0.0063	-0.0077	-0.0097	-0.0109	-0.0262
4	-0.0107	-0.013	-0.016	-0.0159	-0.0395

Dominance relative to SS

σ \ η	0.25	0.5	0.75	1	2
0.5	1	3	3	3	3
0.75	3	3	2	3	2
1	2	2	2	1	2
2	2	2	2	1	2
4	2	2	2	1	2

Table 7: Welfare Comparisons with Low Variance of Food Prices

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 0.01\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	-0.008	-0.0076	-0.0072	-0.0067	-0.0049
0.75	-0.0028	-0.0027	-0.0026	-0.0024	-0.0012
1	-0.0025	-0.0025	-0.0024	-0.0023	-0.0011
2	-0.0026	-0.0027	-0.0027	-0.0026	-0.0015
4	-0.003	-0.0031	-0.0032	-0.0032	-0.0021

CPI Inflation -PEG

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	0.0507	0.0498	0.0489	0.0477	0.0426
0.75	0.0093	0.008	0.0067	0.0052	-0.0013
1	0.0043	0.0029	0.0015	0	-0.0068
2	-0.0035	-0.005	-0.0067	-0.0083	-0.0154
4	-0.0077	-0.0094	-0.0111	-0.0127	-0.02

Domestic Inflation-PEG

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	0.0427	0.0422	0.0417	0.041	0.0377
0.75	0.0065	0.0053	0.0041	0.0028	-0.0025
1	0.0018	0.0004	-0.0009	-0.0023	-0.008
2	-0.0061	-0.0077	-0.0093	-0.0109	-0.017
4	-0.0107	-0.0125	-0.0142	-0.0159	-0.0221

Dominance relative to SS

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	3	3	3	3	3
0.75	3	3	3	3	1
1	3	3	1	1	1
2	1	1	1	1	1
4	1	1	1	1	1

Table 8: Model statistics Under Simulated Random Shocks SS with Balance Trade and $\omega = 0.75$

	$\sigma = 2; \eta = 0.25; \gamma = 1$			$\sigma = 4; \eta = 0.25; \gamma = 1$		
	PPI rule Shocks to z_t	CPI rule Shocks to z_t	PEG ule Shocks to z_t	PPI rule Shocks to z_t	CPI rule Shocks to z_t	PEG ule Shocks to z_t
Standard deviations (in %)	(1)	(2)	(3)	(4)	(5)	(6)
Domestic Output	0.367	1.137	0.863	0.000	0.936	0.945
Consumption	1.154	1.152	0.546	0.606	0.584	0.292
CPI-based Real Exchange rate	2.307	2.298	1.091	2.420	2.328	1.164
Home Good Price/CPI	2.470	2.695	2.956	2.432	2.684	2.940
Domestic Inflation	0.035	0.529	0.204	0.000	0.540	0.213
Means in % of SS deviation						
Domestic Output	-0.0044	-0.2327	-0.0445	0.000	-0.194	-0.033
Consumption	-0.0119	-0.1699	-0.0577	-0.008	-0.097	-0.034
CPI-based Real Exchange rate	-0.0105	-0.3263	-0.1125	-0.008	-0.368	-0.129
Home Good Price/CPI	0.0709	-0.0115	0.0954	0.067	-0.027	0.088
Domestic Inflation	0.0003	-0.0135	0.0002	0.000	-0.014	0.000
Natural Consumption	-0.013	-0.0115	-0.013	-0.0076	-0.0076	-0.0076
Natural X_t	-0.0138	-0.0089	-0.0138	-0.0083	-0.0083	-0.0083
Consumption/Output ratio	**99.99**	**100.06**	**99.99**	**99.99**	**100.10**	**100.00**

	$\sigma = 4; \eta = 0.25; \gamma = 1$			$\sigma = 4; \eta = 0.25; \gamma = 1$		$\sigma = 4; \eta = 0.25; \gamma = 1$		
	PPI rule Shocks to a_t	CPI rule Shocks to a_t	PEG rule Shocks to a_t	PPI rule Shocks to v_t	CPI rule Shocks to v_t	To all Shocks	To all Shocks	To all Shocks
Standard deviations (in %)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Domestic Output	0.269	0.315	0.313	0.424	0.497	0.501	1.101	0.887
Consumption	0.115	0.135	0.134	0.182	0.213	0.642	0.634	0.725
CPI-based Real Exchange rate	0.461	0.539	0.537	0.726	0.851	2.562	2.525	2.898
Home Good Price/CPI	0.154	0.180	0.179	0.242	0.284	2.448	2.704	2.471
Domestic Inflation	0.224	0.192	0.142	0.088	0.132	0.241	0.593	0.398
Means in % of SS deviation								
Domestic Output	-0.048	-0.039	-0.031	-0.013	-0.022	-0.061	-0.254	0.005
Consumption	-0.021	-0.017	-0.013	-0.006	-0.010	-0.035	-0.124	-0.008
CPI-based Real Exchange rate	-0.082	-0.067	-0.053	-0.023	-0.039	-0.113	-0.472	0.000
Home Good Price/CPI	-0.027	-0.022	-0.017	-0.007	-0.012	0.033	-0.061	0.069
Domestic Inflation	0.001	0.001	0.000	-0.005	-0.005	-0.004	-0.018	0.002
Natural Consumption	-0.004	-0.004	-0.004	0	0	-0.0114	-0.0114	-0.0114
Natural X_t	-0.0038	-0.0038	-0.0038	0	0	-0.0107	-0.0107	-0.0107
Consumption/Output ratio	**100.03**	**100.02**	**100.02**	**100.01**	**100.01**	**100.03**	**100.13**	**99.99**

Table 9: Welfare Comparisons with Higher Variance of Monetary Shocks

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 1.25\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.2437	-0.2419	-0.2378	-0.0279	-0.1932
0.75	-0.0259	-0.012	0.0055	0	0.1264
1	0.0068	0.0252	0.047	0.0038	0.1878
2	0.0663	0.0933	0.1234	0.0089	0.299
4	0.1033	0.1355	0.1705	0.011	0.3655

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.3452	0.3532	0.3566	0.1721	0.3217
0.75	0.0478	0.0329	0.0137	0.017	-0.1254
1	0.0044	-0.0157	-0.04	0	-0.2021
2	-0.071	-0.101	-0.1349	-0.0239	-0.34
4	-0.1163	-0.1524	-0.1924	-0.035	-0.4241

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.1015	0.1113	0.1188	0.1442	0.1285
0.75	0.0219	0.021	0.0192	0.0169	0.001
1	0.0112	0.0095	0.007	0.0038	-0.0143
2	-0.0047	-0.0077	-0.0115	-0.0149	-0.041
4	-0.0129	-0.0169	-0.0219	-0.024	-0.0585

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	**3**	3	3	3	3
0.75	3	3	3	3	2
1	3	2	2	2	2
2	2	2	2	2	2
4	2	2	2	2	2

Table 10: Welfare Comparisons with Higher Persistence of Monetary Shocks

$\phi_\pi = 1.5, \rho_\nu = 0.8, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.2623	-0.257	-0.2496	-0.0366	-0.1909
0.75	-0.0199	0	0.0231	0.0229	0.1681
1	0.0215	0.0462	0.0741	0.0366	0.2405
2	0.0981	0.1319	0.1685	0.0603	0.3721
4	0.1454	0.1847	0.2266	0.0736	0.4509

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.4608	0.4535	0.4417	0.2425	0.3356
0.75	0.0403	0.0079	-0.0287	-0.0426	-0.2512
1	-0.028	-0.0659	-0.108	-0.0855	-0.3553
2	-0.1443	-0.1926	-0.2449	-0.152	-0.5385
4	-0.2111	-0.266	-0.3246	-0.1858	-0.6469

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.1985	0.1965	0.1921	0.2059	0.1448
0.75	0.0204	0.0079	-0.0056	-0.0197	-0.0831
1	-0.0064	-0.0197	-0.0339	-0.0489	-0.1149
2	-0.0462	-0.0607	-0.0764	-0.0917	-0.1664
4	-0.0657	-0.0812	-0.098	-0.1122	-0.1959

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	3	3	3	3	3
0.75	3	3	2	2	2
1	2	2	2	2	2
2	2	2	2	2	2
4	2	2	2	2	2

Table 11: Welfare Comparisons with Lower Variance of Productivity Shocks

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 0.7\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.2178	-0.2177	-0.2155	-0.0074	-0.1801
0.75	-0.0213	-0.0089	0.007	-0.0003	0.1188
1	0.0084	0.0253	0.0456	0.0007	0.1773
2	0.064	0.0895	0.118	0.0019	0.2845
4	0.0994	0.1301	0.1635	0.0023	0.3493

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.171	0.183	0.1908	0.0111	0.1825
0.75	0.0198	0.01	-0.0038	0.0052	-0.1114
1	-0.0074	-0.0222	-0.0409	0.005	-0.1705
2	-0.0598	-0.0841	-0.1121	0.0053	-0.2832
4	-0.0942	-0.1244	-0.1582	0.0057	-0.3553

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.0468	-0.0347	-0.0246	0.0037	0.0024
0.75	-0.0015	0.0011	0.0031	0.0049	0.0074
1	0.001	0.0031	0.0047	0.0057	0.0068
2	0.0042	0.0054	0.0059	0.0072	0.0012
4	0.0052	0.0057	0.0053	0.008	-0.006

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	1	1	1	3	3
0.75	1	3	2	3	2
1	2	2	2	3	2
2	2	2	2	3	2

Table 12: Welfare Comparisons with Higher Persistence of Productivity Shocks

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.85, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.2129	-0.2134	-0.2117	-0.0041	-0.1785
0.75	-0.0247	-0.014	0.0003	-0.0083	0.1067
1	0.0013	0.0163	0.0349	-0.0115	0.1606
2	0.0484	0.0716	0.0981	-0.0198	0.258
4	0.0774	0.1056	0.1369	-0.0261	0.316

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.1782	0.1911	0.1997	0.0207	0.1945
0.75	0.0271	0.0179	0.0047	0.0143	-0.1
1	-0.0011	-0.0154	-0.0336	0.0129	-0.1604
2	-0.0574	-0.0813	-0.1088	0.0092	-0.2768
4	-0.0955	-0.1254	-0.1587	0.0058	-0.3522

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.0347	-0.0223	-0.012	0.0165	0.016
0.75	0.0023	0.0039	0.005	0.006	0.0067
1	0.0002	0.0009	0.0013	0.0014	0.0003
2	-0.009	-0.0097	-0.0107	-0.0106	-0.0188
4	-0.0181	-0.0198	-0.0218	-0.0204	-0.0362

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	1	1	1	3	3
0.75	3	3	3	3	2
1	2	2	2	3	2
2	2	2	2	3	2
4	2	2	2	1	2

Table 13: Welfare Comparisons with "Hawkish" Taylor Rule

$\phi_\pi = 3, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \backslash \eta$	0.25	0.5		0.75	2
0.5	-0.5573	-0.5171	-0.4812	0.0076	-0.3568
0.75	-0.0923	-0.0777	-0.0653	0.0038	-0.0287
1	-0.0531	-0.0406	-0.03	0.003	0.0015
2	-0.0013	0.009	0.0179	0.0013	0.0459
4	0.0225	0.0323	0.0408	0	0.0687

CPI Inflation -PEG

$\sigma \backslash \eta$	0.25	0.5		0.75	2
0.5	0.4458	0.4329	0.4193	-0.0172	0.3522
0.75	0.0938	0.0851	0.0768	0.0108	0.0543
1	0.0607	0.0525	0.045	0.0145	0.0299
2	0.0149	0.0074	0.0012	0.0204	-0.0018
4	-0.0072	-0.0143	-0.0199	0.0234	-0.0165

Domestic Inflation-PEG

$\sigma \backslash \eta$	0.25	0.5	1	0.75	2
0.5	-0.1116	-0.0841	-0.0619	-0.0096	-0.0046
0.75	0.0015	0.0074	0.0115	0.0146	0.0256
1	0.0076	0.0119	0.015	0.0176	0.0315
2	0.0136	0.0164	0.0191	0.0217	0.044
4	0.0153	0.0179	0.0209	0.0233	0.0522

Dominance relative to SS

$\sigma \backslash \eta$	0.25	0.5	1	0.75	2
0.5	1	1	1	2	1
0.75	3	3	3	3	3
1	3	3	3	3	3
2	3	3	3	3	3
4	2	2	2	3	2

Table 14: Welfare Comparisons with "Dovish" Taylor Rule

$\phi_\pi = 1.1, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

σ \ η	0.25	0.5		0.75	2
0.5	0.0436	-0.0853	-0.1182	-0.0142	-0.1719
0.75	-0.0037	0.0095	0.0319	-0.0024	0.2529
1	0.0256	0.0494	0.0822	-0.0016	0.3515
2	0.0893	0.1309	0.1811	-0.0008	0.5291
4	0.1321	0.1835	0.2431	-0.0007	0.6331

CPI Inflation -PEG

σ \ η	0.25	0.5		0.75	2
0.5	0.1231	0.1492	0.1696	0.0354	0.1918
0.75	0.0023	-0.0123	-0.0352	-0.0004	-0.2635
1	-0.0302	-0.0545	-0.0875	-0.0044	-0.3737
2	-0.0975	-0.14	-0.1923	-0.0107	-0.587
4	-0.143	-0.1969	-0.2613	-0.0142	-0.723

Domestic Inflation-PEG

σ \ η	0.25	0.5	1	0.75	2
0.5	0.0795	0.064	0.0514	0.0212	0.0199
0.75	-0.0014	-0.0028	-0.0033	-0.0028	-0.0106
1	-0.0047	-0.0051	-0.0053	-0.006	-0.0222
2	-0.0082	-0.0091	-0.0112	-0.0116	-0.0578
4	-0.0109	-0.0134	-0.0182	-0.015	-0.0898

Dominance relative to SS

σ \ η	0.25	0.5	1	0.75	2
0.5	3	3	3	3	3
0.75	1	2	2	1	2
1	2	2	2	1	2
2	2	2	2	1	2
4	2	2	2	1	2

Table 15: Welfare Comparisons with Taylor Rule with Moderate Reaction to Output Gap

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.125, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.1187	-0.1146	-0.1102	0.0004	-0.0867
0.75	-0.0197	-0.0139	-0.0068	-0.0017	0.0384
1	-0.0035	0.0045	0.0137	-0.0022	0.0679
2	0.0311	0.0439	0.0577	-0.0035	0.1288
4	0.0574	0.0736	0.0904	-0.0044	0.171

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.0193	0.038	0.0523	-0.0119	0.0789
0.75	0.0194	0.0181	0.0144	0.0121	-0.0189
1	0.0074	0.0028	-0.0038	0.0143	-0.0457
2	-0.0244	-0.0351	-0.0471	0.0164	-0.1046
4	-0.0515	-0.0661	-0.0815	0.0164	-0.1487

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.0994	-0.0766	-0.0579	-0.0116	-0.0078
0.75	-0.0003	0.0042	0.0076	0.0104	0.0195
1	0.0039	0.0073	0.0099	0.012	0.0222
2	0.0067	0.0088	0.0106	0.0129	0.0242
4	0.006	0.0075	0.009	0.012	0.0223

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	1	1	1	2	1
0.75	1	3	3	3	2
1	3	3	2	3	2
2	2	2	2	3	2
4	2	2	2	3	2

Table 16: Welfare Comparisons with High Export Price Elasticity

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.857, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 5, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.1321	-0.1165	-0.1008	0.004	-0.0211
0.75	0.169	0.1975	0.226	0.0054	0.3638
1	0.2255	0.2569	0.2881	0.0052	0.4371
2	0.3273	0.3635	0.3991	0.0046	0.5655
4	0.388	0.4267	0.4646	0.0042	0.6397

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.0912	0.0854	0.0784	-0.0154	0.0323
0.75	-0.0767	-0.0979	-0.1193	0.1083	-0.2239
1	-0.1162	-0.1403	-0.1644	0.1253	-0.2805
2	-0.1916	-0.2208	-0.2497	0.152	-0.3864
4	-0.2389	-0.271	-0.3028	0.1662	-0.4517

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.0014	0.0065	0.0105	0.0165	0.0189
0.75	0.014	0.0153	0.0163	0.0172	0.0188
1	0.0144	0.0156	0.0164	0.0169	0.0179
2	0.0143	0.0149	0.0151	0.016	0.0129
4	0.0134	0.0135	0.0131	0.0152	0.0071

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	3	3	3	3	3
0.75	2	2	2	3	2
1	2	2	2	3	2
2	2	2	2	3	2
4	2	2	2	3	2

Table 17: Welfare Comparisons with Lower Elasticity of Labor Supply

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 3, \sigma_z = 5\%, \omega = 0.75$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	1	0.75	2
0.5	-0.505	-0.5177	-0.5236	-0.0193	-0.4773
0.75	-0.0589	-0.0355	-0.0012	-0.0059	0.2673
1	0.0033	0.0418	0.0909	-0.0048	0.4226
2	0.1305	0.2005	0.2794	-0.0047	0.7263
4	0.221	0.3119	0.4096	-0.0058	0.9226

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	1	0.75	2
0.5	0.3557	0.3957	0.4259	0.0322	0.462
0.75	0.0487	0.0321	0.0037	0.0146	-0.2577
1	-0.0078	-0.0404	-0.0849	0.0135	-0.4246
2	-0.1295	-0.1966	-0.2756	0.0121	-0.7777
4	-0.2211	-0.3131	-0.4169	0.0109	-1.0311

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	1	0.75	2
0.5	-0.1494	-0.122	-0.0977	0.0129	-0.0153
0.75	-0.0102	-0.0034	0.0025	0.0087	0.0096
1	-0.0044	0.0014	0.006	0.0087	-0.002
2	0.001	0.0039	0.0037	0.0074	-0.0513
4	-0.0002	-0.0013	-0.0072	0.0051	-0.1084

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	1	0.75	2
0.5	1	1	1	3	1
0.75	1	1	3	3	2
1	2	2	2	3	2
2	2	2	2	3	2
4	2	2	2	3	2

Table 18: Welfare Comparisons with World Inflation Variability

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.7, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.25, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.75$

$\sigma_p = 1.3\%, \rho_p = 0.99$

Domestic Inflation-CPI Inflation

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	-0.2165	-0.2166	-0.2146	-0.0067	-0.1801
0.75	-0.0222	-0.0102	0.0052	-0.0024	0.1153
1	0.0068	0.0232	0.043	-0.0023	0.1729
2	0.061	0.0859	0.114	-0.0026	0.2784
4	0.0955	0.1256	0.1585	-0.0032	0.3422

CPI Inflation -PEG

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	0.0407	0.057	0.0691	-0.1062	0.0846
0.75	0.005	0.0008	-0.0072	0.0077	-0.084
1	-0.0083	-0.0173	-0.03	0.0221	-0.1277
2	-0.0405	-0.0585	-0.08	0.0439	-0.2176
4	-0.065	-0.0887	-0.1158	0.0548	-0.2784

Domestic Inflation-PEG

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	-0.1757	-0.1596	-0.1455	-0.1128	-0.0955
0.75	-0.0172	-0.0094	-0.0021	0.0053	0.0314
1	-0.0016	0.0059	0.013	0.0198	0.0452
2	0.0205	0.0274	0.0339	0.0413	0.0609
4	0.0305	0.0369	0.0427	0.0517	0.0638

Dominance relative to SS

$\sigma \backslash \eta$	0.25	0.5	0.75	1	2
0.5	1	1	1	1	1
0.75	1	1	3	3	2
1	2	2	2	3	2
2	2	2	2	3	2
4	2	2	2	3	2

Table 19: Welfare Comparisons with Higher Food Import Share

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.85, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.4, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.6$

$\sigma_p = 1.3\%, \rho_p = 0.99$

Domestic Inflation-CPI Inflation

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	-0.491	-0.4813	-0.4647	-0.0107	-0.3137
0.75	0.0389	0.0959	0.1568	0.0002	0.4834
1	0.1428	0.2087	0.2775	0.0009	0.6297
2	0.3333	0.4129	0.4934	0.0014	0.8806
4	0.4481	0.5344	0.6206	0.0013	1.0222

CPI Inflation -PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.4931	0.4908	0.4799	0.0423	0.3394
0.75	-0.0427	-0.0994	-0.1605	-0.0039	-0.4954
1	-0.1496	-0.2155	-0.285	-0.0098	-0.6508
2	-0.3456	-0.4266	-0.5097	-0.0188	-0.9251
4	-0.4647	-0.5539	-0.6443	-0.0234	-1.0857

Domestic Inflation-PEG

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	0.0022	0.0095	0.0152	0.0316	0.0257
0.75	-0.0038	-0.0035	-0.0037	-0.0037	-0.0119
1	-0.0068	-0.0068	-0.0075	-0.0089	-0.021
2	-0.0124	-0.0138	-0.0163	-0.0173	-0.0443
4	-0.0166	-0.0194	-0.0237	-0.0221	-0.0634

Dominance relative to SS

$\sigma \setminus \eta$	0.25	0.5	0.75	1	2
0.5	3	3	3	3	3
0.75	2	2	2	2	2
1	2	2	2	2	2
2	2	2	2	2	2
4	2	2	2	2	2

Table 20: Welfare Comparisons with Lower Food Import Share

$\phi_\pi = 1.5, \rho_\nu = 0.6, \sigma_v = 0.6\%, \rho_a = 0.85, \sigma_a = 1.2\%$

$\phi_y = 0.0, \rho_z = 0.85, \phi = 0.1, \gamma = 1, \varphi = 1, \sigma_z = 5\%, \omega = 0.9$

$\sigma_p = 1.3\%, \rho_p = 0.99$

Domestic Inflation-CPI Inflation

$\sigma \backslash \eta$	0.25	0.5	1	0.75	2
0.5	-0.0394	-0.0392	-0.039	-0.002	-0.0363
0.75	-0.0063	-0.0063	-0.0058	-0.0013	0.0025
1	-0.0034	-0.003	-0.0021	-0.0012	0.0091
2	0.0011	0.0024	0.0044	-0.0011	0.0219
4	0.0037	0.0057	0.0084	-0.0011	0.0301

CPI Inflation -PEG

$\sigma \backslash \eta$	0.25	0.5	1	0.75	2
0.5	-0.0982	-0.0933	-0.089	-0.1158	-0.0734
0.75	-0.0199	-0.0165	-0.0138	-0.0151	-0.006
1	-0.0111	-0.0082	-0.006	-0.0037	-0.0007
2	0.0006	0.0024	0.0036	0.0125	0.0032
4	0.0052	0.0063	0.0067	0.02	0.002

Domestic Inflation-PEG

$\sigma \backslash \eta$	0.25	0.5	1	0.75	2
0.5	-0.1376	-0.1326	-0.128	-0.1178	-0.1097
0.75	-0.0262	-0.0228	-0.0196	-0.0164	-0.0035
1	-0.0145	-0.0112	-0.0081	-0.0049	0.0085
2	0.0017	0.0049	0.008	0.0114	0.0251
4	0.009	0.012	0.0152	0.0189	0.0321

Dominance relative to SS

$\sigma \backslash \eta$	0.25	0.5	1	0.75	2
0.5	1	1	1	1	1
0.75	1	1	1	1	2
1	1	1	1	1	2
2	3	3	3	3	3
4	3	3	3	3	3

Figure 1: World WPI and World Relative Food Prices

(in deviations from HP-trend)

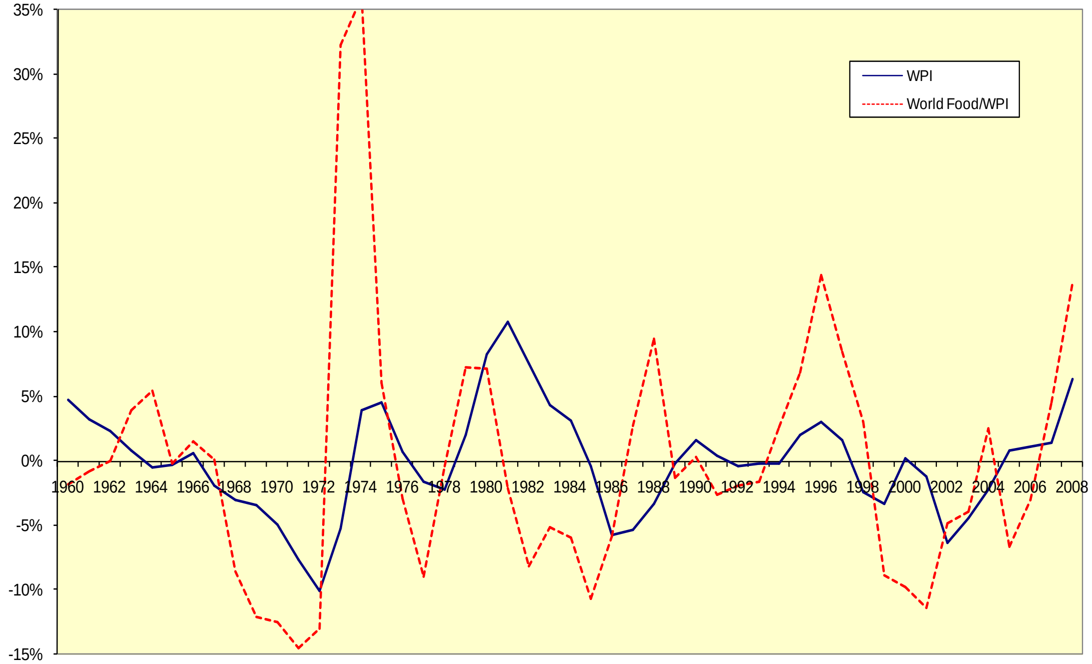

Figure 2: Effects of Food Price Shocks on Natural Output and the Terms of Trade

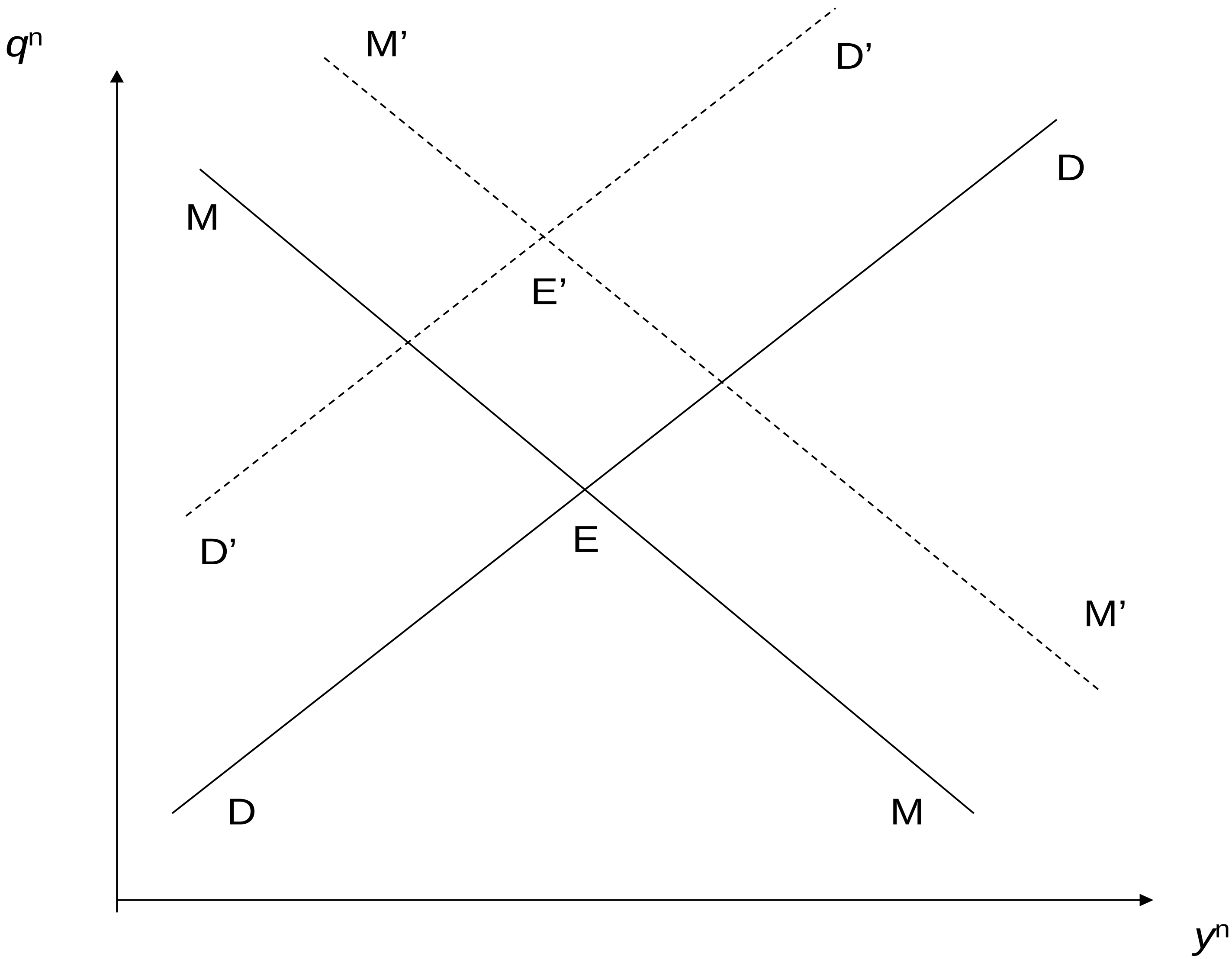

Figure 3: Impulse Responses of one unit world food's relative price shock with $sigma = 2$ and $eta = [0.25, 0.5, 0.5, 2]$ and $gamma = 1$ with PPI rule
]

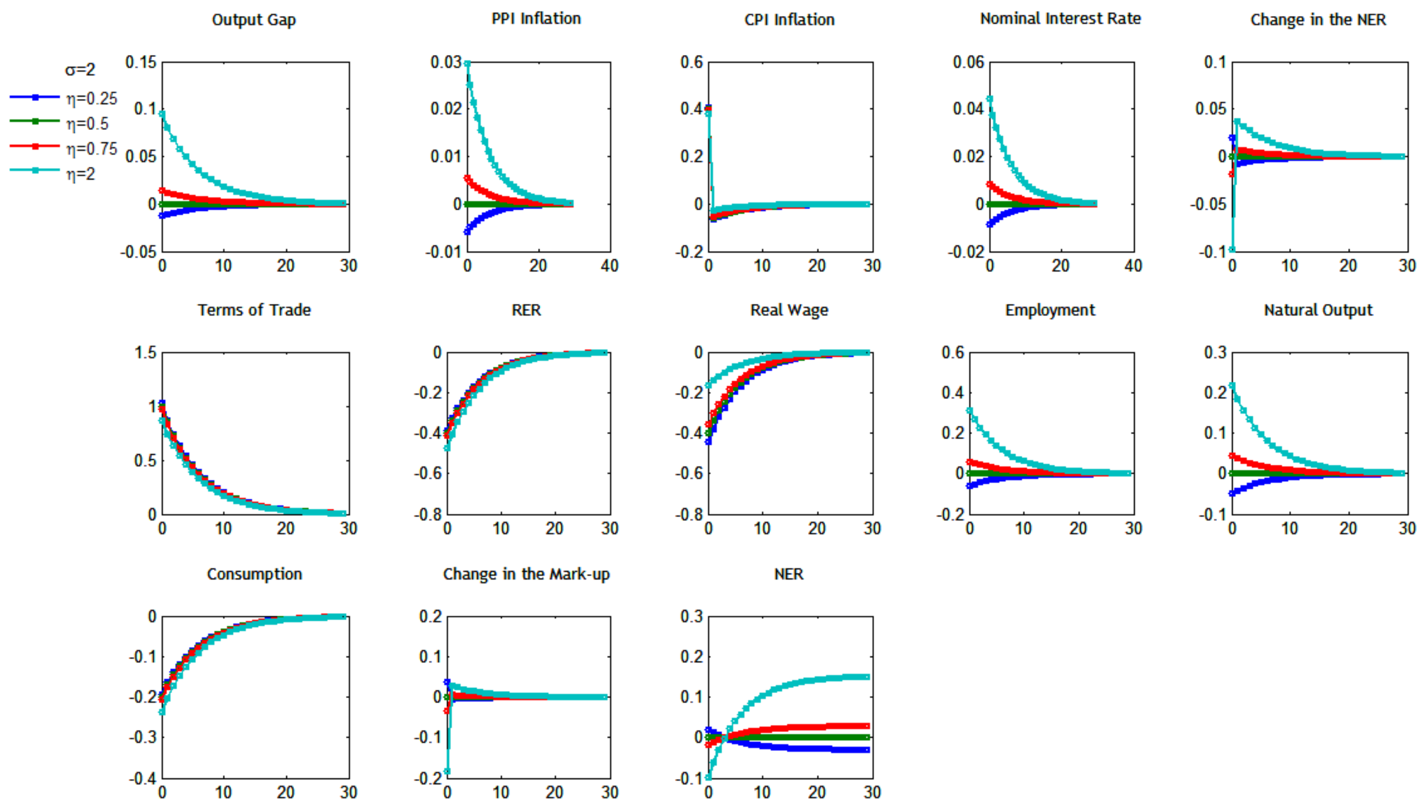

Figure 4: Impulse Responses of one unit world food's relative price shock with $sigma = 2$ and $eta = [0.25, 0.5, 0.5, 2]$ and $gamma = 5$ with PPI rule

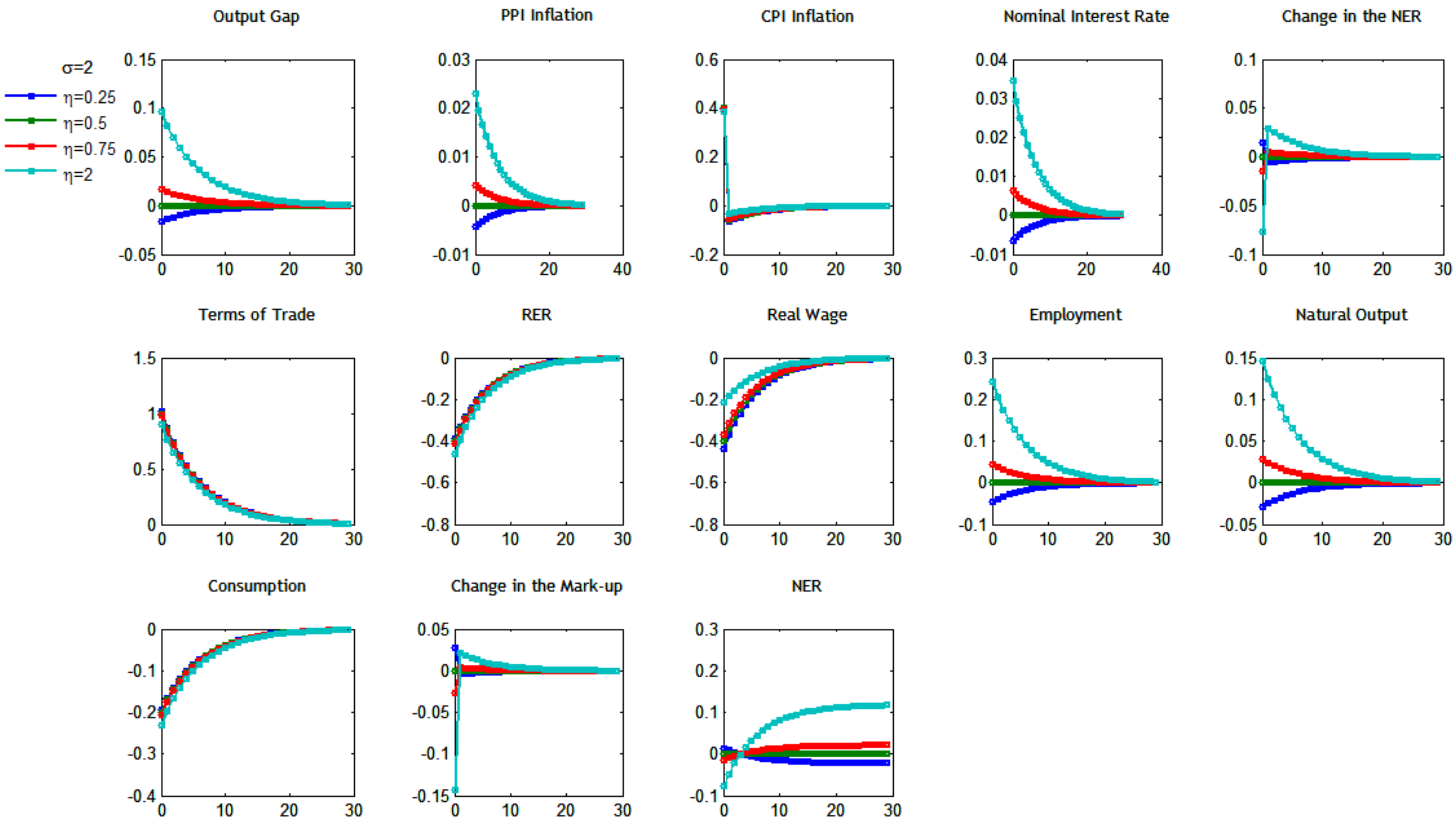

Figure 5: Impulse Responses of one unit world food's relative price shock with $sigma = 2$ and $eta = [0.25, 0.5, 0.5, 2]$ and $gamma = 1$ with CPI rule

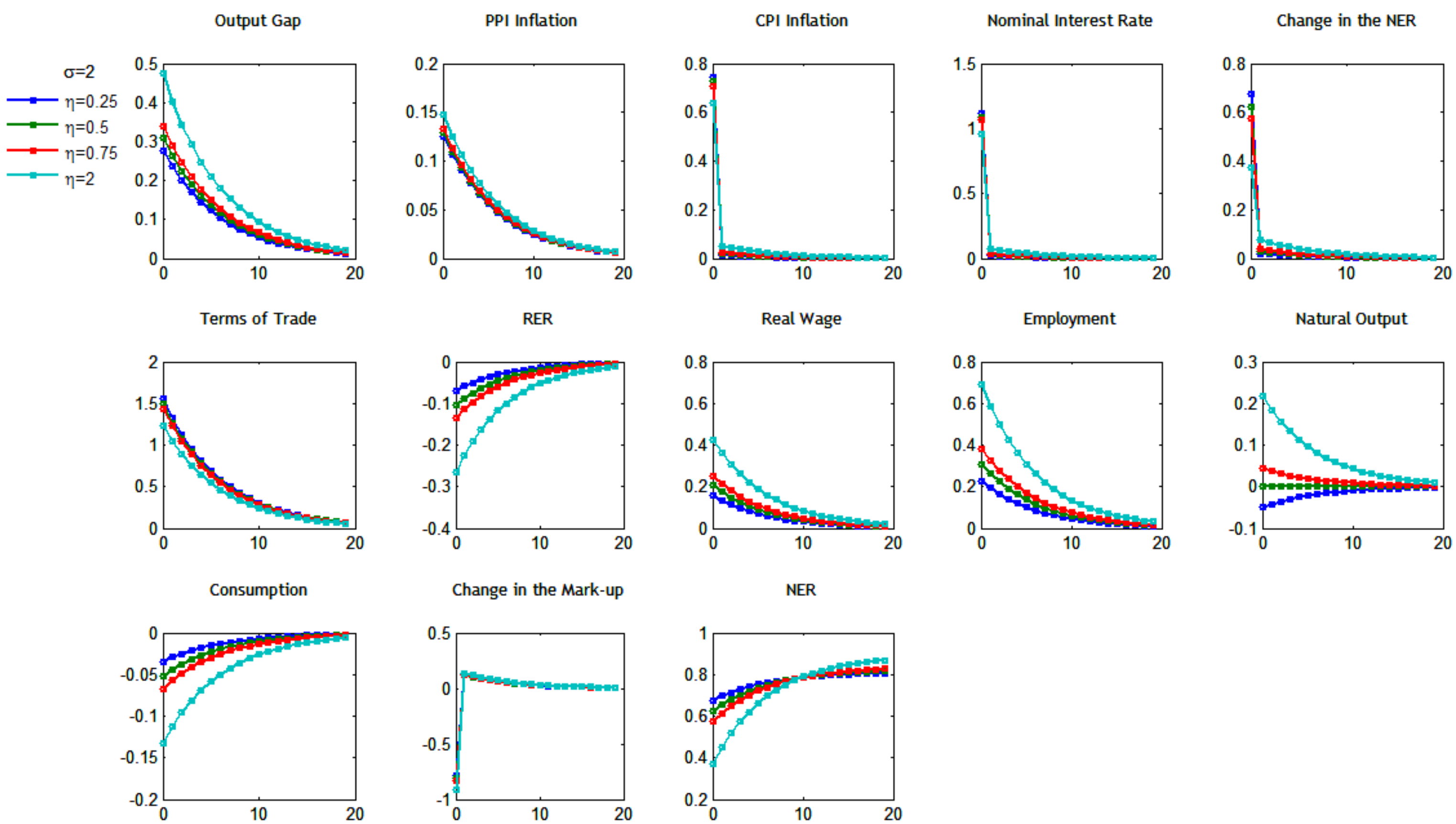

Figure 6: Impulse Responses of one unit world food's relative price shock with $sigma = 2$ and $eta = [0.25, 0.5, 0.5,\ 2]$ and $gamma = 5$ with CPI rule