Competition and Inflation Differentials in EMU[*]

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Abstract

In a monetary union, inflation rate differentials may be substantial over the business cycle. This paper parameterizes a two-country monetary union in which different economic structures in the two countries generate temporary inflation differentials. Cross-country differences are introduced in (i) the elasticity of demand in the goods markets, which cause producers to discriminate prices, (ii) the degree of price inertia and (iii) the degree of openness or preference for foreign goods in consumption. The model is calibrated to reproduce two average large EMU countries and it is able to generate such inflation differentials. We find the mechanism of price discrimination quantitatively more important than the differences in price inertia. Moreover, under asymmetric shocks, differences in the degree of openness such as those observed within the EMU can have sizeable effects on the dispersion of inflation rates.

Keywords: Price discrimination, inflation differentials, monetary union, nominal and real rigidities
JEL Classification: E31, E52, F41

1. Introduction

Changes in relative prices in a monetary union, i.e. inflation differentials, may not disappear despite the fixed exchange rate. In March 2006, the difference between the maximum and minimum HICP annual inflation rate between the euro area countries was about 2.8 percentage points. Indeed, the dispersion measured as the standard deviation of the inflation rates across euro area countries is around 1 per cent and has remained very persistent since the beginning of the EMU in spite of the changes in the level of inflation. Figure 1

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shows how this affects all sectors of the economy. Inflation dispersion in the non-energy industrial sector is as persistent and about as high as for the whole economy.

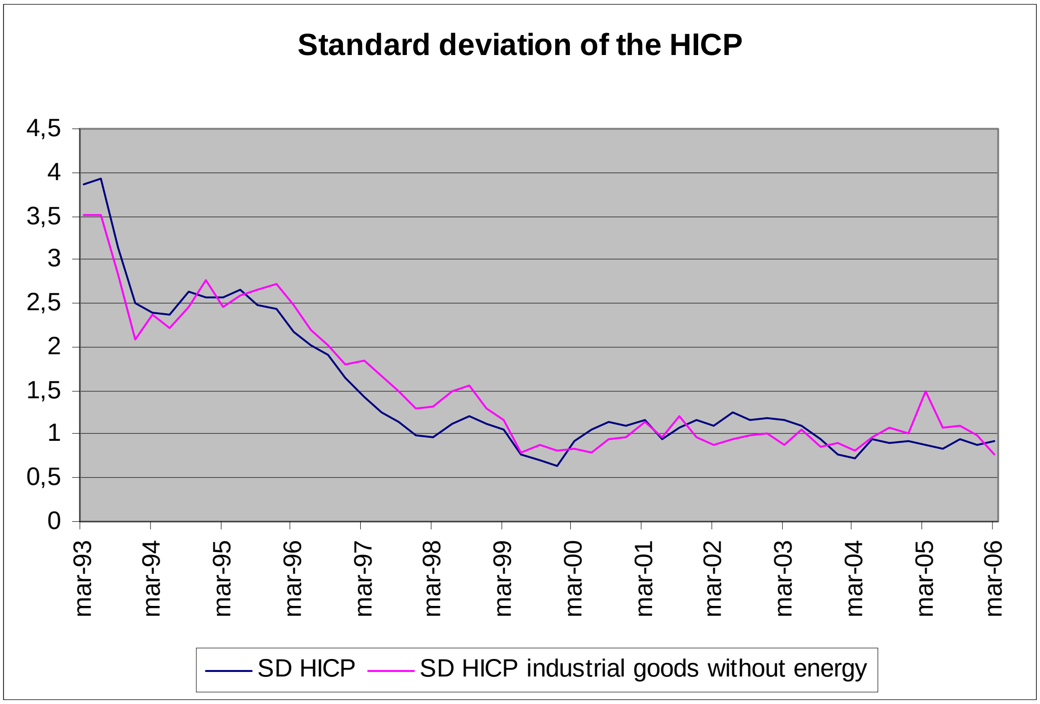

Fig. 1: *Figure 1. Standard deviation of HICP annual inflation rates across euro area countries.*

Observed inflation differentials can be due to the convergence processes enhanced by economic integration that vanish in the long run, such as convergence in price levels associated with productivity catching-up –the Balassa-Samuelson effect (Balassa, 1964, Samuelson, 1964)– and income levels convergence. Nevertheless, empirical evidence (see Rogers, 2002) shows that factors other than price convergence explain most of the cross-country inflation differences in Europe during the nineties.[1]

In the present paper, we analyze potential sources of inflation differentials among members of a monetary union beyond those associated with income and price conver-

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[1] Country case studies (see Estrada and Lopez Salido, 2002, for Spain) and Euro area comparisons for the largest economies (Ortega, 2003) also show that during the years prior to EMU convergence processes such as the Balassa-Samuelson hypothesis have not necessarily been the major factor behind the changes in relative prices across countries.

gence. Differences in economic structures, such as the degree of competition, openness or the intensity of nominal inertia, may also generate cross-country inflation differentials even in response to common shocks. We explore this alternative explanation to account for the EMU evidence. Our aim is to explain inflation differentials that are relevant at business cycle frequencies and, therefore, we focus on the differential of the short run response of inflation to shocks across countries.

It is well known that in the case of the EMU the different behaviour of the sectors closed to foreign competition, i.e. non-traded goods, is largely responsible for both the persistent and the short run inflation differentials. Evidence such as Figure 1 shows that the traded sector also displays persistent inflation differentials, while it is often assumed to have only negligible ones in a monetary union. We study which differences in the economic structure of the countries they depend upon. The fact that differences in economic structure play a role in the unequal response of inflation rates to shocks across European economies is widely acknowledged and there are serious legal efforts aimed to reducing them. However, few studies have examined the business cycle implications of such differences. Since we focus on just a limited set of causes behind inflation differentials, our paper can be viewed as aiming to explain a lower bound for these that would prevail even in economies in which other important factors in the emergence of inflation differentials within a monetary union, such as non-traded goods, distribution costs, asymmetric fiscal policies and others, are not present.

We set up a simple general equilibrium model of a two-country monetary union with no capital and where all goods are traded.[2] The model is calibrated to reproduce some of the features of representative European economies. We perform simulation exercises to analyze the effects of common and asymmetric shocks, for alternative values of some crucial parameters of the model. Our work is akin to Chari, Kehoe and McGrattan's (2002), who look at the persistence and volatility of deviations from the law of one price among traded goods between the US and Europe and Bergin (2001), who studies the deviations from purchasing power parity in a monetary union.[3]

The economics of inflation differentials in this model is simple: inflation reacts faster in countries with more competitive markets and with lower price adjustment costs. This simple structure is able to generate substantial inflation differentials for reasonable parameter values. Small deviations in the degree of competition that account for a 5 per cent long run price level difference across countries may be responsible for temporary infla-

[2] We have performed similar simulation exercises to those in the paper in a model that includes capital accumulation.The quantitative results are somewhat different but the main conclusions regarding the determinants of inflation differentials among traded goods hold.

[3] Unlike Bergin (2001), who uses translog preferences, we stick to a CES specification of consumption goods in which firms face different elasticities of demand across countries.

tion differentials up to 13 quarterly basis points when the economy is subject to a common monetary policy shock that rises the nominal interest rate by 34 quarterly basis points (136 basis points per annum). That may represent up to one fifth of the actual inflation dispersion in euro area countries. Moreover, realistic cross-country differences in the degree of nominal inertia and/or in openness also contribute to generating inflation differentials in the presence of regional shocks. For example, if the domestic country is very open, its inflation rate may respond even more than the foreign inflation rate to shocks originating abroad, depending on the type of disturbance.

The paper is organized as follows. Section 2 outlines the model. The calibration, in section 3, reproduces some of the long-term features in the European economy. Section 4 contains the main results of the paper that are presented in terms of impulse responses and of alternative price dispersion statistics. These are calculated for common and asymmetric shocks as well as under alternative values for the relevant parameters. Section 5 concludes.

2. The model

The model is a fixed exchange rate version of Obstfeld and Rogoff's (1995) in which the world is composed of two countries with a common monetary authority. The model incorporates two special features.

First, all goods are traded. Recent studies on inflation differentials in the EMU stress the fact that inflation dispersion is higher in the non-traded sector (see Altissimo et al, 2005). However, as shown in Figure 1, the actual inflation dispersion of industrial (non-energetic) goods is somewhat lower but still substantial and as persistent as those observed with the overall HICP. As explained before, the paper focuses on the traded inflation differential which is often assumed to be zero in a monetary union.

Second, the model allows for heterogeneity of market power across countries in order to capture institutional and regulatory differences as well as different preferences for the variety of goods within the monetary union. This generates optimal price discrimination by firms and will cause permanent deviations from the law of one price.[4]

The empirical motivation for this key property of the model is the observation that although there has been a significant price convergence process across European countries, deviations from the law of one price remain large and persistent among EMU countries both for specific goods (Goldberg and Verboven, 2005, for the car industry) and for a basket of goods (Rogers, 2002); this also occurs among cities and regions in well established monetary unions (see, for example, Cecchetti, Mark and Sonora, 2000, for the US).

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[4] An alternative to price discrimination discussed recently by the literature is that the traded sector contains a large share of non-traded intermediate inputs, such as transport, storage and communication (e.g. Burstein, Neves and Rebelo (2003), Corsetti and Dedola (2005)).

2.1. *Market Structure*

Let us consider a world of two countries: Home (H) and Foreign (F). Agents populating country H are indexed by j ($j \in [0,1]$), each of whom produces a variety of one type of intermediate good ($y_t(j)$) in which the country is specialized. All agents sell their production in the domestic market ($y_{H,t}(j)$) and the rest in the foreign market ($y^*_{H,t}(j) = y_t(j) - y_{H,t}(j)$); they enjoy some monopolistic power both at home and abroad.

Either due to different regulations or preferences, the elasticity of substitution among brands is different across countries. The elasticity of substitution is country specific, but not product specific and takes the value of θ for those varieties sold in H, and θ^* for those sold in F. Thus, producers can discriminate prices across countries, and they optimally do so. Neither are consumers allowed to arbitrage across markets nor are firms' permitted to enter or exit in domestic or foreign markets.

In each country there is a sector of final goods selling products at home and abroad (exports). This sector is represented by two CES aggregators. Aggregator H buys varieties produced in the domestic country ($y_{H,t}(j)$) and sells a composite product to home consumers. These varieties are imperfect substitutes in consumer preferences:

$$y_{Ht} = \int_0^1 \left(y_{H,t}(j)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}}$$

The demand function for each variety derived from the aggregator problem is the following

$$y_{H,t}(j) = y_{H,t} \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\theta} \tag{1}$$

and, imposing the zero profit condition, the utility-based price index is given by $P_{H,t} = \int_0^1 \left(P_{H,t}(j)^{1-\theta} dj \right)^{\frac{1}{1-\theta}}$. Similar relationships are obtained for the home aggregator of $y^*_{H,t}$ (exports) and for the aggregators for country $F : y^*_{F,t}$ for foreign domestic consumption and $y_{F,t}$ for foreign exports (to the H country).

2.2. *Preferences and price formation*

Agent j sells one variety of intermediate goods produced at home and abroad, and uses the revenues to consume both domestic and foreign goods, seeking to maximize the utility of consumption and minimize the disutility of production.[5]

The consumption basket is represented by the CES aggregator,

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[5] Since we focus on price dynamics we abstract from the labor market and choose to feature the representative agents as yeoman farmers, simultaneously engaged in consumption and production. Woodford (2002) shows that the equilibrium in this economy is the same as one in which the representative agent decides the labor supply and where the labor market is competitive.

$$c_t(j) = \left[\omega_{H,t}\left(c_{H,t}(j)\right)^{\rho} + \omega_{F,t}\left(c_{F,t}(j)\right)^{\rho}\right]^{\frac{1}{\rho}}$$

where $c_{H,t}(j)$ is the consumption by H residents of H produced goods, $c_{F,t}(j)$ is the consumption by H residents of F produced goods, ω_H and ω_F are their respective trade-based weights in the consumption bundle and $\varepsilon = \frac{1}{1-\rho}$ is the elasticity of substitution between both goods. The more open the economy the larger the share of foreign goods in the consumption basket, i.e. higher $\frac{\omega_F}{\omega_H}$, and the higher the elasticity of substitution between home and foreign goods.

Agent j sells output in monopolistically competitive markets, setting the nominal price, $P_{H,t}(j)$ and $P^*_{H,t}(j)$, subject to the requirement that it satisfies the demand for final goods. Moreover, the agent faces a quadratic cost of adjusting prices (as in Rotemberg, 1982).

The constrained maximization program of the home producer-consumer agent j consists therefore of maximizing the lifetime utility given by,

$$U_t(j) = E_t \sum_{t=0}^{\infty} \beta^t s_t \left[\frac{c_t(j)^{1-\sigma}}{1-\sigma} - \frac{\left[y_t(j)v_t\right]^{\alpha}}{\alpha}\right] \tag{2}$$

subject to

$$\begin{aligned} & A_t(j) + P_{H,t}c_{H,t}(j) + P_{F,t}c_{F,t}(j) + P_{H,t}AC_{H,t}(j) + P^*_{H,t}AC^*_{H,t}(j) \\ \leq \quad & (r_{t-1} - \psi\left(e^{a_{t-1}} - 1\right))A_{t-1}(j) + P_{H,t}(j)y_{H,t}(j) + P^*_{H,t}(j)y^*_{H,t}(j) \end{aligned}$$

and the demand functions (1) (along with the corresponding demands for $y^*_{H,t}(j^*)$), where s_t is a preference shock, v_t is an innovation to the disutility of production that stands by a negative supply shock, and

$$AC_{H,t}(j) = \frac{\phi y_{H,t}}{2}\left(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - \bar{\pi}\right)^2 \tag{3}$$

$$AC^*_{H,t}(j) = \frac{\phi y^*_{H,t}}{2}\left(\frac{P^*_{H,t}(j)}{P^*_{H,t-1}(j)} - \bar{\pi}\right)^2 \tag{4}$$

represent the costs of adjusting prices in each market expressed in units of the aggregate bundle, scaled by a country specific factor ϕ. This convex cost function is just an abstraction and aims at representing the variety of reasons why a firm decides not to change its price instantaneously each period. The cost function generates similar dynamic implications to the alternative specification of staggered prices but has no long-run implications for inflation.

A_t is the nominal amount held by residents in H of an uncontingent international bond that yields a nominal gross return r_t in the world financial market. We include the function $\psi_t = \psi\left(e^{a_t} - 1\right)$ to represent a transaction cost of holding assets. The cost function depends on the ratio of asset holdings to consumption (i.e. $a_t = \frac{A_t}{P_t c_t}$) such that if the household is a lender, the returns are reduced by the amount of the cost $(-\psi\left(e^{a_t} - 1\right) < 0)$, conversely, if the household is a net borrower, then interest payments are increased by $(-\psi\left(e^{a_t} - 1\right) > 0)$. This transaction costs function guarantees that the model is stationary in presence of transitory shocks.[6]

A similar problem holds for the foreign representative household, j^*, where $c^*_{F,t}(j^*)$ is the consumption by F residents of F produced goods and $c^*_{H,t}(j^*)$ is the consumption by F residents of H produced goods. The scale factor for the costs of adjusting prices in the foreign country is ϕ^*, which allows the implications of different degrees of price stickiness in different countries to be explored as long as ϕ^* differs from ϕ. Foreign agents also face a similar transaction cost function.

The following aggregate goods market clearing condition is imposed for y_{Ht}

$$\int_0^1 c_{H,t}(j)dj + \int_0^1 AC_{H,t}(j)dj = c_{H,t} + AC_{H,t} = y_{H,t} \tag{5}$$

and similar ones for the exports market, y^*_{Ht}, the foreign domestic goods market, y^*_{Ft}, and foreign exports market, y_{Ft}.

The model closes with the specification of the balance of payments and the common monetary policy. The balance of payments constraints in both countries are expressed as:[7]

$$P^*_{H,t}c^*_{H,t} + \left(r_{t-1} - \psi\left(e^{a_{t-1}} - 1\right)\right) A_{t-1} - P_{F,t}c_{F,t} = A_t \tag{6}$$

$$A_t = -A^*_t \tag{7}$$

The common monetary policy is modeled as a standard Taylor interest rate rule where the central bank's sole concern is inflation. The monetary authority sets the nominal interest rate to prevent aggregate inflation from deviating from its steady state value, and

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[6] See Benigno (2001). Schmitt-Grohé and Uribe (2001) explore alternative ways to remove non-stationarity in open economy models with incomplete markets stemming from the accumulation of foreign assets. They find that all alternatives produce similar conditional and unconditional correlations.

[7] To rationalise the existence of transaction costs we assume that there is a financial intermediary that receives those payments as revenues in exchange for the services of financial intermediation. Furthermore, we assume that this financial firm is owned by residents of the foreign country so that total revenues for the foreign consumer budget constraint are augmented by $\left[\psi^*_t A^*_{t-1} + \psi_t A_{t-1}\right]$.

to ensure that the nominal interest rate moves smoothly. Both countries are assumed to be of equal size and therefore the weight of each country's variable is $\frac{1}{2}$.[8] In log-linear form, the rule is represented by the following expression, in which $z_{r,t}$ represents unexpected monetary policy changes,

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r)\rho_\pi \frac{1}{2}\left(\widehat{\pi}_t + \widehat{\pi}_t^*\right) + z_{r,t}. \tag{8}$$

2.3. *Equilibrium inflation dynamics*

The equilibrium of the model is obtained upon aggregation of the first order conditions of the representative consumer-producer agents at home and abroad, the market clearing conditions, the monetary policy rule and the balance of payments constraints in both countries. The log-linear model equilibrium is presented fully in the Appendix.[9]

The domestic aggregate consumption price index depends on both the home-bias, measured by the weight of domestic goods consumption (ω_H) relative to the weight of imported goods (ω_F), and also on the elasticity of substitution parameter (ρ),

$$\widehat{P}_t = (\omega_H)^{\frac{1}{1-\rho}} \left(\frac{\overline{P_H}}{\overline{P}}\right)^{\frac{\rho}{\rho-1}} \left(\widehat{P}_{H,t}\right) + (\omega_F)^{\frac{1}{1-\rho}} \left(\frac{\overline{P_F}}{\overline{P}}\right)^{\frac{\rho}{\rho-1}} \left(\widehat{P}_{F,t}\right) \tag{9}$$

and an equivalent expression holds for the foreign country price index P_t^*.

Since our aim is to explain the inflation differentials at business cycle frequencies, we need to pay special attention to the two aggregate inflation equations:

$$\widehat{\pi}_t = \beta E \widehat{\pi}_{t+1} + \frac{\tau(\theta-1)}{\phi\bar{\pi}^2}\left[\widehat{d}_t + \frac{(1-\tau)\phi}{\tau\phi^*}\left(\widehat{d}_t^* + \left(\widehat{P}_{Ft}^* - \widehat{P}_{Ft}\right)\right)\right] \tag{10}$$

$$\widehat{\pi}_t^* = \beta E \widehat{\pi}_{t+1}^* + \frac{(1-\tau^*)(\theta^*-1)}{\phi^*\bar{\pi}^2}\left[\widehat{d}_t^* + \frac{\tau^*\phi^*}{(1-\tau^*)\phi}\left(\widehat{d}_t + \left(\widehat{P}_{Ht} - \widehat{P}_{Ht}^*\right)\right)\right] \tag{11}$$

where $\frac{(1-\tau)}{\tau} = \left(\frac{\omega_F}{\omega_H}\right)^{\frac{1}{1-\rho}}$, $\frac{\tau^*}{(1-\tau^*)} = \left(\frac{\omega_H^*}{\omega_F^*}\right)^{\frac{1}{1-\rho}}$ and

$$\widehat{d}_t = \sigma\widehat{c}_t + (\alpha-1)\widehat{y}_t + \frac{\omega_F}{(1-\rho)}\left(\frac{\bar{c}_F}{\bar{c}}\right)^\rho \left(\widehat{P}_{F,t} - \widehat{P}_{H,t}\right) + \alpha\widehat{v}_t$$

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[8] This kind of monetary policy rule may not come close to the optimal policy, especially when the degree of price rigidity differs across countries (see Benigno and López-Salido (2002)).

[9] Variables with $\widehat{}$ represent log-deviations with respect to their steady state value, whereas a_t and a_t^* are expressed as absolute deviations from the steady state.

$$\widehat{d}_t^* = \sigma\widehat{c}_t^* + (\alpha-1)\widehat{y}_t^* + \frac{\omega_H^*}{(1-\rho)}\left(\frac{\bar{c}_H}{\bar{c}}\right)^{\rho}\left(\widehat{P}_{H,t}^* - \widehat{P}_{F,t}^*\right) + \alpha\widehat{v}_t^*$$

These expressions are straightforward extensions of the standard closed economy new Keynesian Phillips curve.[10] Thus, $\widehat{d}_t$ represents the open economy equivalent to the domestic real marginal cost of production in the yeoman farmer economy as defined by Woodford (2003), i.e. the marginal disutility of production in units of an equivalent quantity of the consumption aggregate. Similarly, $\widehat{d}_t^*$ represents the real marginal cost in the foreign economy. Domestic and foreign real marginal costs affect domestic inflation through their effect upon $\widehat{\pi}_{H,t}$ and $\widehat{\pi}_{F,t}$ respectively.

Since the disutility of production is measured in terms of a consumption aggregate that includes imported goods, the marginal cost depends on relative prices. Improvements in the terms of trade, $(\widehat{P}_{F,t} - \widehat{P}_{H,t})$, increase the domestic marginal cost by inducing a substitution of foreign to home produced goods. Similarly, $\widehat{\pi}_{F,t}$ responds to $(\widehat{P}_{H,t}^* - \widehat{P}_{F,t}^*)$.

An additional term in our model, $(\widehat{P}_{Ft}^* - \widehat{P}_{Ft})$, captures the effect of price discrimination. An increase in $\widehat{P}_{Ft}^*$ relative to $\widehat{P}_{Ft}$ generates a wealth transfer from the foreign to the home country that also raises the implicit wage and the marginal cost at home.

In a two-country world, this simple structure makes also possible to represent the incidence of the price setting mechanism in the dynamics of inflation differentials through demand elasticities (θ, θ^*) as well as through price inertia parameters (ϕ, ϕ^*). Moreover, the parameters that govern the degree of openness (ω_H, ω_F, ω_H^*, ω_F^*, ρ) will also affect relative price dynamics.[11]

Inflation rates respond differently to shocks originating at home and abroad. A shock originated at home translates into inflation more quickly the higher the elasticity of substitution faced by the producer (θ), the lower the cost of adjusting prices at home (ϕ) and the higher the home consumption bias, i.e. the lower the openness $(\frac{\omega_F}{\omega_H})$ and the cross-country substitutability of consumption goods. If the shock is originated abroad its effect is greater the higher the degree of openness, the higher the elasticity of substitution $(\frac{1}{1-\rho})$ and the lower the price inertia abroad (ϕ^*).

Even shocks that are common to domestic and foreign real marginal costs, in particular innovations to the common monetary policy, may cause disparities in the inflation rates if the degree of market competition, price inertia or openness differ across coun-

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[10] The closed economy case can be easily recovered (for the domestic country) making $\tau = 1$ $(\omega_F = 0)$,

$$\widehat{\pi}_t = \beta E\widehat{\pi}_{t+1} + \frac{(\theta-1)}{\phi\bar{\pi}^2}[\sigma\widehat{c}_t + (\alpha-1)\widehat{y}_t + \alpha\widehat{v}_t]$$

where $\sigma\widehat{c}_t + (\alpha-1)\widehat{y}_t + \alpha\widehat{v}_t$ represents the real marginal cost.

[11] It is assumed that the steady state inflation rate $\bar{\pi}$ is the same in both economies.

tries. Inflation differentials will be larger (in absolute value $|\widehat{\pi}_t - \widehat{\pi}_t^*|$) the wider the gap between θ and θ^* and between ϕ and ϕ^*.

2.4. *Discussion of alternative price setting mechanisms*

Since the different inflation response across markets to common or idiosyncratic shocks is a key feature of our approach, the choice of the price setting mechanism is not only a matter of analytical convenience. Although the above dynamic specification of inflation is common to the new Keynesian Phillips curve in an open economy setting (e.g., Galí and Monacelli, 2005), the fact that the slope of the Phillips curve is an increasing function of the elasticity of demand (θ) is not. This feature comes out naturally in the model of convex adjustment costs. Firms compare the opportunity cost of not adjusting the price to its optimum level after a shock, with an increasing marginal cost of changing the level of prices. This produces an optimal rate of adjustment that will be faster for those firms whose profits are more sensitive to deviations from the optimal policy. This sensitivity depends on the curvature of the profit function which is a function of the elasticity of demand. Thus, firms operating in a highly competitive environment will experiment a substantial opportunity cost if the price deviates from its profit maximizing level, whereas this cost will be of second order for firms with high monopoly power (Akerloff and Yellen, 1984; Martin, 1993).

Staggered price models, in which firms revise their prices at exogenously given intervals, yield a rather different implication. For example, Gali, Gertler and López-Salido (2001) and Sbordone (2002) show, under the stochastic Calvo (1983) setup and some technology assumptions, that the response of inflation to exogenous shocks depends negatively on the elasticity of demand. When firms change prices at exogenously given points in time, the logic of the comparison between the cost of changing and that of not changing prices no longer applies. When the opportunity of changing prices arises, the firm does not care about the losses made during the period of no action; rational firms will look to the future in order to avoid large deviations of the marginal revenue from the expected path of the marginal cost. Thus, firms facing highly elastic demand curves will require smaller price adjustments to bring the marginal revenue back on line with the marginal cost, i.e. the optimal price of these firms barely changes with expected movements in the marginal cost. Conversely, other things being equal, less competitive firms will find it optimal to proceed to a larger change in price.

In fact, these conflicting results in alternative price setting models can be made compatible. We must bear in mind that it is the exogeneity of the spell of price stability by firms that drives the implication of faster adjustment by more competitive firms. This assumption is very helpful in order to generate a tractable dynamic equation for aggregate inflation, but is also the least satisfactory feature of this type of models. If we remove the assumption of exogenously fixed intervals, less competitive firms might proceed to change prices less often than more competitive firms, thus generating more price inertia (Blanchard and Fischer, 1989).[12]

Thus, a negative correlation between market competition and price stickiness is a fairly general implication of the literature of price inertia. The empirical evidence is not unequivocal, but several papers find that price stickiness is lower for firms operating in more competitive markets (see, e.g., Carlton, 1986, Geroski, 1995, Hall, Walsh and Yates, 2000 and Bils and Klenow, 2004).

3. Calibration

This section discusses the calibration of the parameters and the steady state relationships that affect the coefficients of the log-linear model presented in the Appendix. The benchmark calibration represents two average large Euro area countries that are moderately open. However, one economy is more competitive than the other. We are also interested in analyzing how changes in the degree of price inertia and in the degree of openness in one of the countries affect the results. Finally, we parameterize the sources of fluctuations needed for the alternative conditional exercises performed in the next section.

3.1. Price discrimination.

To calibrate the parameters related to the price discrimination mechanism we rely on recent evidence that reports deviations from the law of one price in the long run despite the significant price level convergence occurred across EMU countries, especially in the traded sector.

Goldberg and Verboven (2005) find convergence towards the law of one price in the European car market, although significant fixed effects in the convergence equation indicate systematic price differentials across countries. Their measured long-term price differences take values between 5 and 17 per cent and are highly significant. Rogers (2002) also reports differences in individual items and in a composite price level for 18 cities in all Euro area countries and compares them to the dispersion of the same prices across 13 US cities. These results are summarized in Table 1 where the standard deviation across cities in the US and the Euro area for 1990 and 2001 are reported. Even in a long lasting monetary union, such as the US, price level differences persist in the long run; their evolution indicates that there is a limit to price convergence of about 5 per cent differences in the price levels in the traded sector. There has been highly significant price convergence

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[12] Using a simple *Ss* model these authors show that the threshold for the exogenous shock beyond which the firm will adjust prices is negatively related to the elasticity of demand. Thus, more competitive firms will tend to change prices more often.

Table 1

Price level dispersion across locations

CPI-weighted indexes

	Composite price	1990	2001
Euro Area	Non-traded	0.15	0.12
	Traded	0.18	0.06
US	Non-traded	0.31	0.40
	Traded	0.04	0.05

Source: Rogers (2002), Figures 1 and 2.

during the nineties for traded goods in the Euro area and the 6 per cent price differences across locations in 2001 is similar to that observed for US. Non-traded prices are much more dispersed in both economies but especially in the US.

In our model, the elasticities of substitution across varieties sold in each country (θ, θ^*) determine the steady state markups ($\frac{\theta}{\theta-1}$ and $\frac{\theta^*}{\theta^*-1}$, respectively), and hence the size of price level differences in the long run. If these elasticities are different, home producers will mark up those products sold at home differently to those sold abroad

$$\left(\frac{\overline{P_H^*}}{\overline{P_H}}\right) = \frac{\frac{\theta^*}{\theta^*-1}}{\frac{\theta}{\theta-1}} \neq 1 \tag{12}$$

and the same will hold for $\left(\frac{\overline{P_F^*}}{\overline{P_F}}\right)$. We consider the domestic country as the most competitive one, with a markup of 1.1 (i.e. a net markup of 10 per cent), lower than that in the foreign country which is calibrated to be 15 per cent, in line with Basu and Fernald's (1997) evidence. These values imply a conservative estimation of the importance of markup differences across European markets.

The markup ratio of 15 to 10 per cent we use in our benchmark calibration implies a permanent price level differential of around 4.5 per cent, slightly lower than the estimations in Rogers (2002) for European traded goods and close to the lower bound of car price differences in Europe reported by Goldberg and Verboven (2005).

3.2. *Preferences*

Preference parameters are taken from the business cycle literature. The frequency is quarterly and the discount factor β is 0.99. The ratio $\psi/\bar{r}$ is set to 10^{-3} to approximate the cost of intermediation in financial markets, as in Benigno (2001).

The risk aversion parameter, σ, is 2. The output elasticity parameter α corresponds to the parameters in a decentralized setup with separable consumption-labor preferences and a decreasing returns to labor production function. If α_L is the labor share and χ is the inverse of labor supply elasticity then $\alpha = \frac{(1+\chi)}{\alpha_L}$. The average labor share in the Euro area is about 0.75.[13] Measurement of the labor supply elasticity is not unique in the literature. Micro evidence and estimations by labor economists point to a value of $1/\chi = 0.2$, while macro calibrations use higher values (up to $1/\chi = 4$ in some RBC applications), the most common being $1/\chi = 1$. The implications of this parameter are quantitatively relevant for the mechanisms that generate inflation differentials in this model. Lower labor supply elasticity values generate higher rises in real wages when employment rises, which in turn causes larger increases in the marginal cost and inflation.[14] Hence, lower labour supply elasticity would increase the likelihood of finding larger inflation differentials.

We have thus opted for a high labor supply elasticity, $1/\chi = 1$, so as to ensure the calibration is not biased in favor of sizeable inflation differentials. Again, we would then be generating a lower bound for the possible inflation differentials.

3.3. *Openness*

The following steady state equations are derived from the equations describing the equilibrium:

$$1 = \frac{\bar{c}_H}{\bar{y}} + \frac{\bar{c}^*_H}{\bar{y}} \tag{13}$$

$$\left[\left(\frac{\overline{P_F}}{\overline{P_H}}\right)\frac{\omega_H}{\omega_F}\right]^{1/(1-\rho)} = \frac{\bar{c}_H}{\bar{c}_F} \tag{14}$$

Table 2 shows the most relevant ratios for each EMU country on average for the period 1991-2001 that are used to calibrate the above expressions.[15] $\frac{\bar{c}_H}{\bar{c}_F}$ represents the steady state weight in total consumption of home produced goods relative to imports. $1 - \frac{\bar{c}_H}{\bar{y}}$ is the steady state imports share of GDP.

We have calibrated our economies to represent an average large Euro area country such as Germany, France, Italy or Spain. Thus, we take $\frac{\bar{c}_H}{\bar{c}_F} = 3$ and $\frac{\bar{c}_H}{\bar{y}} = 0.75$ as benchmark calibration representing a moderately open economy. Notice that this calibra-

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[13] The average labor shares in the 1991-2000 period are 0.79 for Germany, 0.70 for France and Italy and 0.76 for Spain.

[14] Indeed, with the common monetary policy shock size of the benchmark calibration, the quarterly standard deviation of output drops from 0.8 per cent to 0.6 per cent if a labor supply elasticity of 0.2 is chosen instead of the benchmark of 1. Instead, as predicted, such decrease in the labor supply elasticity raises the quarterly standard deviation of the two countries' inflation rates: from 0.6 per cent to 0.9 per cent in the domestic country and from 0.5 to 0.7 per cent in the foreign economy.

[15] The source is Eurostat annual national accounts. Data availability has forced us to take a shorter sample size starting in 1995 for Greece. The consumption of home produced goods, $\bar{c}_H$, is approximated by the sum of private and government final consumption expenditure plus gross fixed capital formation and changes in inventories minus imports of goods and services. The ratio $\frac{\bar{c}_H}{\bar{c}_F}$ is measured by the average share over the period of consumption of domestic goods to imports.

Table 2

Average ratios of openness in consumption

	$\frac{\bar{c}_H}{\bar{c}_F}$	$\frac{\bar{c}_H}{\bar{y}}$
Belgium	0.47	0.32
Germany	2.84	0.74
Greece	2.81	0.73
Spain	3.30	0.76
France	3.54	0.78
Ireland	0.35	0.26
Italy	3.17	0.76
Netherlands	0.85	0.46
Austria	1.50	0.60
Portugal	1.86	0.65
Finland	2.12	0.68

tion would hold not only for large Euro area countries, but also for some small ones (i.e. Greece). The parameters that measure the share of home produced goods and imports in total consumption, ω_H and ω_F, respectively and the relative prices, are calibrated by using the remaining steady state expressions.

The elasticity of substitution $\varepsilon = \frac{1}{1-\rho}$ is fixed to 1.5, the value used by Backus, Kehoe and Kydland (1994). We shall also consider different values of ρ, ranging from a unit elasticity ($\rho \simeq 0$) to an elasticity of $\varepsilon = 4$ ($\rho = 0.75$).

We assume that the steady state nominal net asset position for each country, A, is zero and that both countries are of the same size ($\frac{\overline{P}}{\overline{P}^*}\frac{\bar{c}}{\bar{c}^*} = 1$). Thus, net exports are zero at the steady state,

$$\left(\frac{\overline{P_H^*}}{\overline{P_F}}\right) = \frac{\bar{c}_F}{\bar{c}_H^*} \tag{15}$$

Sensitivity exercises are carried out in Section 4 in order to explore the incidence of allowing for different degrees of openness and size across countries.

3.4. *Nominal stickiness and the monetary policy rule*

The price inertia parameters ϕ and ϕ^* have been set to 100 to generate a slope of the Phillips curve, $\frac{\tau(\theta-1)}{\phi\bar{\pi}^2}$, equal to 0.10. A 10 per cent response of inflation to a unit change in the real marginal cost corresponds to the estimations in Benigno and López-Salido (2002) for France and Germany. We also perform sensitivity analysis on this parameter in line with the estimates of the Phillips curve for other European countries.

The monetary policy rule displays interest rate smoothing ($\rho_r = 0.8$), no output response and the inflation response coefficient is $\rho_{\pi} = 1.5$. Such parameterization of the Taylor rule is consistent with recent Euro area estimates (e.g. Andrés, López-Salido and Vallés, 2006).

3.5. Shocks

We will analyze the magnitude of inflation differentials and the volatility of relative prices under a common (monetary policy) shock and two asymmetric shocks: a positive foreign preference or demand shock and a negative foreign supply shock.

We assume that the asymmetric shocks follow AR(1) processes with persistence parameter 0.9. The sizes of the three shocks have been calibrated to reproduce the volatility of output observed on average in each case for the large Euro area countries, Germany, France, Italy and Spain, i.e. $std(y) = 0.8$ per cent per quarter (see Table 4 in the next section). A quarterly standard deviation of 0.5 per cent in the monetary policy shock generates a volatility of 0.8 per cent per quarter in domestic output, while the standard deviation of the foreign demand and supply shocks have been calibrated to 4.7 and 0.65 per cent per quarter, respectively, to generate the same standard deviation of foreign output.

The size of the calibrated shocks are not meant to be realistic since no single shock generates the kind of output fluctuations observed in market economies. The strategy we have followed in calibrating the shocks is a common convention in the literature- It helps us to investigate, given a benchmark calibration, what deviations from the benchmark would make inflation differentials larger or smaller within a monetary union.[16]

4. Simulation Results

In this section we carry out a quantitative assessment of the changes in relative prices predicted by the model under different shocks, as well as the sensitivity of those predictions to the key parameters that govern the dynamics of inflation. We compute the responses of output and prices to a given shock, either symmetric or asymmetric, and we focus on the short run response of the inflation differential between the two countries. We compute an additional measure of price dispersion: the business cycle volatility of the relative consumption-based national price indexes, measured with the ratio of the standard deviation of relative prices to the standard deviation of one country's output.

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[16] An alternative strategy would have been to work with calibrated shocks that reproduce the business cycle features for a number of dimensions of average EMU countries. This, nonetheless, would demand the consideration of the non-traded sector which is beyond the aim and scope of this paper, as discussed above.

4.1. *Monetary policy shocks*

Figure 2 depicts the pattern of responses of the main variables to a common monetary policy shock. The calibrated shock generates an unexpected rise in the nominal interest rate of 34 basis points, which is similar to the results obtained in recent VAR literature for the Euro area (see Peersman and Smets, 2001). The two lines represent the impulse responses for the case of symmetric economies with equal demand elasticities consistent with a 10 per cent steady state markup (solid line) and for the asymmetric case (dashed line) in which the domestic economy has higher market competition than the foreign one. The latter is the benchmark calibration: monopoly markup of 10 per cent in the domestic economy and 15 per cent in the foreign economy.

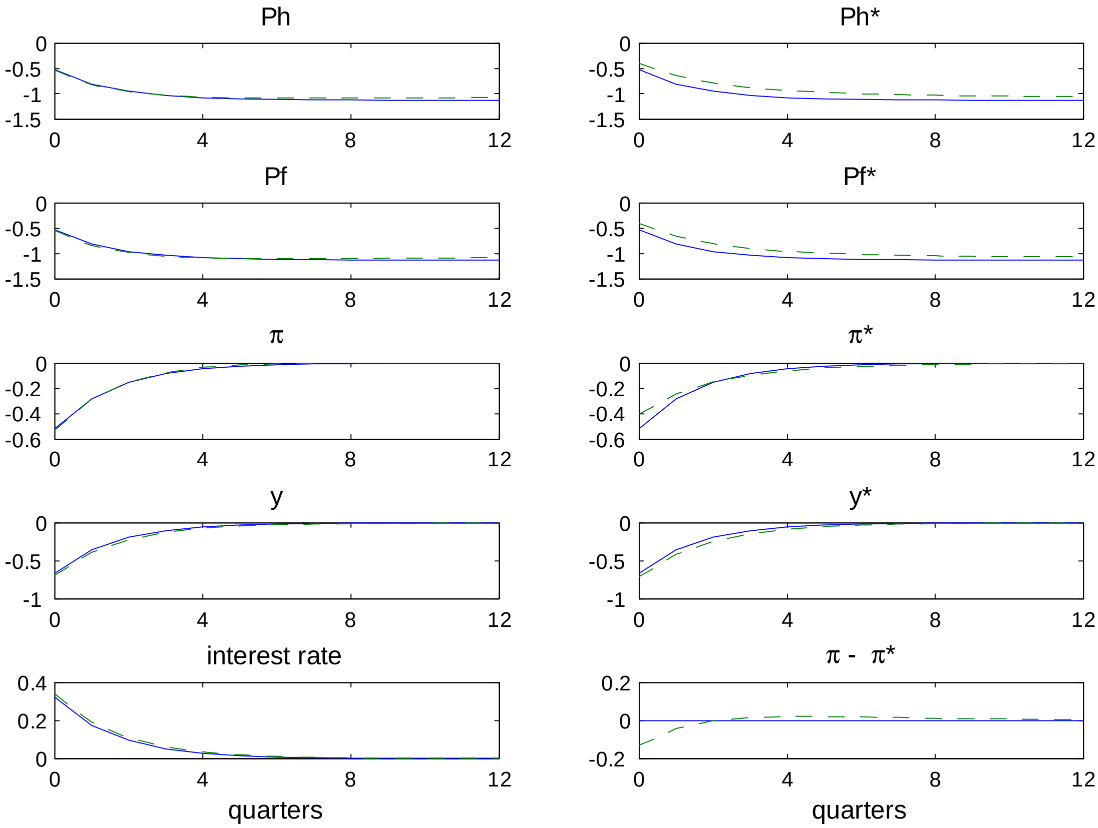

Figure 2. Responses to a contractionary monetary policy shock

In all cases, the presence of price stickiness leads to a temporary fall in output followed by a gradual recovery to the baseline level that takes about a year and a half. The response of output in both countries is similar. The response of prices is different, though,

Table 3

Impact π Differential Under Alternative Shocks

	Monetary	Asym. Demand	Asym. Supply
Benchmark [(1)]	-0.13	-0.15	-0.06
Symmetric [(2)]	0	-0.28	-0.09
Sensitivity			
Competition:			
$\theta < \theta^*$ [(3)]	1.39	-1.38	-0.33
$\theta > \theta^*$ [(4)]	-0.31	0.04	-0.02
Price Inertia:			
$\phi^* = 70.5$	-0.10	-0.19	-0.07
$\phi^* = 167$	-0.16	-0.11	-0.05
Substitution:			
Lower ($\varepsilon \simeq 1$)	-0.128	-0.20	-0.08
Higher ($\varepsilon = 4$)	-0.13	-0.05	-0.02
Openness:			
High $\frac{\omega_F}{\omega_H}$=1	-0.132	0.03	-0.01

(1) $\frac{\theta}{\theta-1}$=10% $<$ $\frac{\theta^*}{\theta^*-1}$=15% , ϕ, ϕ^*=100, ε=1.5, $\frac{\omega_F}{\omega_H} = \frac{\omega_H^*}{\omega_F^*}$=0.48, $\overline{\frac{P^*}{P}}\,\frac{\bar{c}^*}{\bar{c}}$=1

(2) As in benchmark except for $\frac{\theta}{\theta-1} = \frac{\theta^*}{\theta^*-1}$=10%

(3) As in benchmark except for $\frac{\theta}{\theta-1}$=10% $>$ $\frac{\theta^*}{\theta^*-1}$=1.1%

(4) As in benchmark except for $\frac{\theta}{\theta-1}$=10% $<$ $\frac{\theta^*}{\theta^*-1}$=30.3%

in the case of different demand elasticities: because of lower price elasticity in the less competitive (foreign) economy, the price set by producers of both domestic goods (P_H^*) and of foreign goods (P_F^*) sold in that economy responds less to marginal costs. Hence, foreign inflation falls less than domestic inflation. The negative inflation differential ($\pi - \pi^*$) of 13 basis points is substantial but it diminishes rather quickly.[17] When the simulation of the monetary policy shock is conducted using a Taylor rule that responds to the output gap as well as to inflation (i.e. we add a response to the output gap in both countries of 0.5 in equation (8)) we generate a slightly lower fall in output and inflation in both countries, but the inflation differential is very similar. Obviously, no inflation differential is generated in the symmetric case. Table 3 reports the inflation differential generated on impact under alternative shocks and parameter configurations.

Figure 3 shows the size of this impact inflation differential for alternative values of foreign demand elasticity (while keeping domestic markup at the 10 per cent benchmark value). The starting point is the symmetric case, where relative demand elasticity is 1. As expected, the difference between the responses of the two national inflation rates to the common shock becomes larger as the foreign country becomes less competitive (with smaller demand elasticity θ^*) since this leads to a milder response of the foreign inflation

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[17] Note that there is no attempt in the model to account for realistic inflation inertia. The persistence of such a differential could be increased by e.g. explicitly introducing a lagged inflation term in the Phillips curve in the spirit of the hybrid new Keynesian Phillips curves.

to the shock. As relative elasticity $\frac{\theta}{\theta^*}$ increases, due to an increase in the foreign country markup from 10 to 30 per cent, the steady-state price level differential rises from 4.5 to 18 per cent. As the heterogeneity across economies increases, so does the impact inflation differential, that climbs to 31 basis points, in response to the aggregate shock.

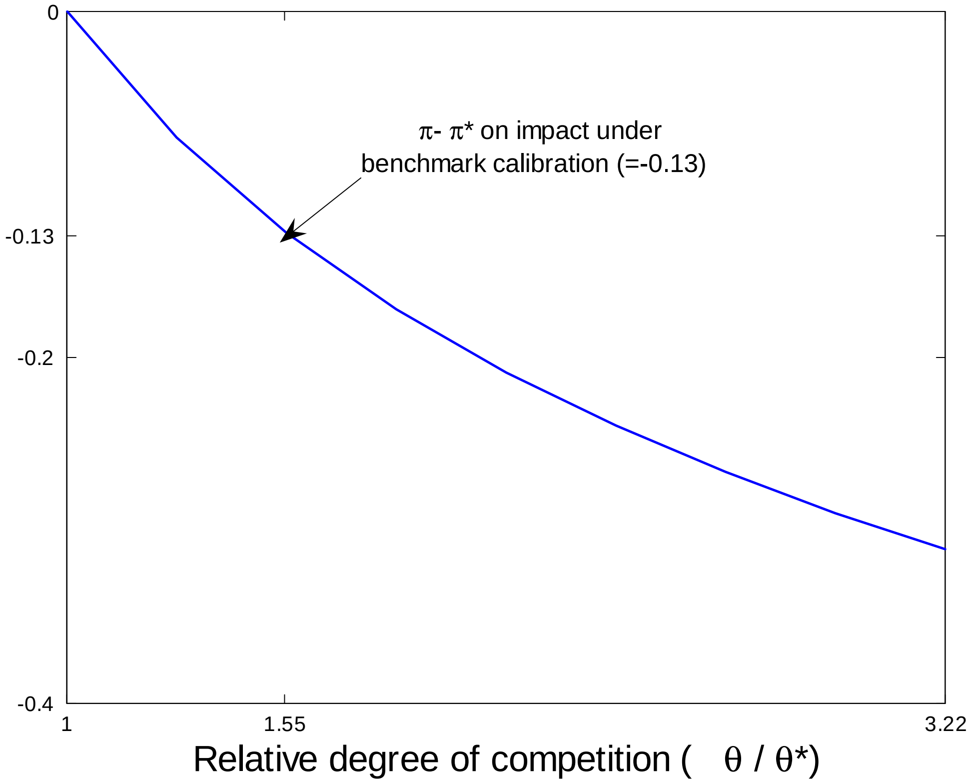

Figure 3. Impact inflation differential under a contractionary monetary policy shock

Differential inflation responses are also affected by the degree of price rigidity faced by each producer. To quantify this effect we have kept domestic price inertia at the benchmark value, i.e. $\phi = 100$, while allowing the less competitive foreign economy to vary from very low to fairly high price inertia (ϕ^* from 50 to 200) as shown in Figure 4. Higher price inertia in the more competitive domestic economy reduces the impact response of prices relative to that in the other country, thus generating smaller negative inflation differentials, while the opposite is true to the right of the benchmark value of $\frac{\phi^*}{\phi} = 1$, where the less competitive foreign economy is also the stickier of the two.

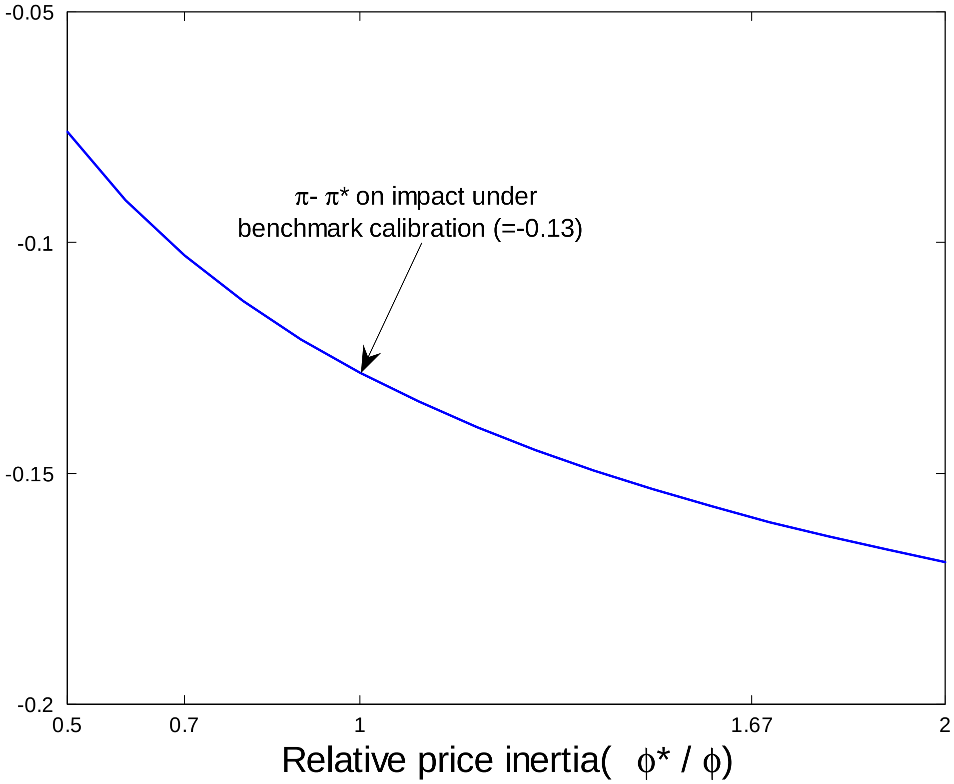

Figure 4. Impact inflation differential under a contractionary monetary policy shock.

An important result emerges when comparing Figures 3 and 4: inflation differentials induced by common shocks are much less sensitive to variations in relative price inertia than they are to variations in the relative degree of competition.

Once we consider a monetary union and fix the nominal exchange rate, the volatility of relative prices becomes a relevant business cycle statistic. Table 4 shows the volatility of the cyclical component of relative prices observed for different EMU countries with respect to Germany for the period 1991-2001.[18] We find that relative price volatility is lower than output volatility (except in Italy). The average value of the ratio between these two magnitudes for the reported EMU countries is 0.62, but reaches 0.75 for the average of the main EMU economies (Spain, Germany, Italy and France). In a similar study, Chari, Ke-

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[18] Cyclical components have been obtained by applying the Baxter-King filter to the logs of the original series. Output is measured by real GDP and prices by the GDP deflator, both obtained from Eurostat Quarterly National Accounts. All variables are converted into Euro equivalents. Data for Germany, and hence for the comparisons with that country starts in 1991q1. Ireland has been excluded due to a lack of data.

Table 4

	$std(y)$	$std(P/P^{GE})$	$\frac{std(P/P^{GE})}{std(y)}$
Belgium	1.07%	0.39%	0.36
Germany	0.69%	0	0
Greece	0.93%	0.66%	0.56
Spain	1.04%	0.60%	0.57
France	0.76%	0.45%	0.43
Italy	0.79%	0.99%	1.26
Netherlands	0.84%	0.57%	0.67
Austria	0.77%	0.48%	0.63
Finland	1.96%	1.08%	0.55

hoe and McGrattan (2002) report more pronounced real exchange rate volatility in the US with respect to Europe (4.5 times the volatility of US GDP for the period 1973-2000), which is mostly caused by nominal exchange rate fluctuations in the period. We acknowledge that during the nineties, although the Euro area countries belonged to the EMS, exchange rate policies and the independent monetary policies may have affected these figures and therefore, they are not fully comparable to those predicted by the model.

The value of $\frac{std(P/P^{*})}{std(y^{*})}$ generated by the model for the benchmark parameterization when common monetary policy shocks are the only source of fluctuations, is 0.39. As expected, this figure is lower than that observed in most euro area countries despite the fact that we have calibrated the size of the shock to reproduce observed output volatility, since the model abstracts from the non-traded sectors of the economy whose prices are stickier. Figure 5 shows how the volatility of relative prices after a common shock changes as we change the degree of competition in the foreign economy. The solid line represents the case in which relative price inertia in both countries is the same, as in the benchmark. As expected, the more different the demand elasticities in the two countries the more volatile the relative prices are. As discussed earlier, lower competition makes foreign producer prices less sensitive to a contractionary monetary policy shock, thus increasing the difference between the price responses in the two countries. In fact, when both countries are equally competitive, relative prices do not change after the common shock (i.e. the solid line in Figure 5 starts at zero when the relative degree of competition is 1).

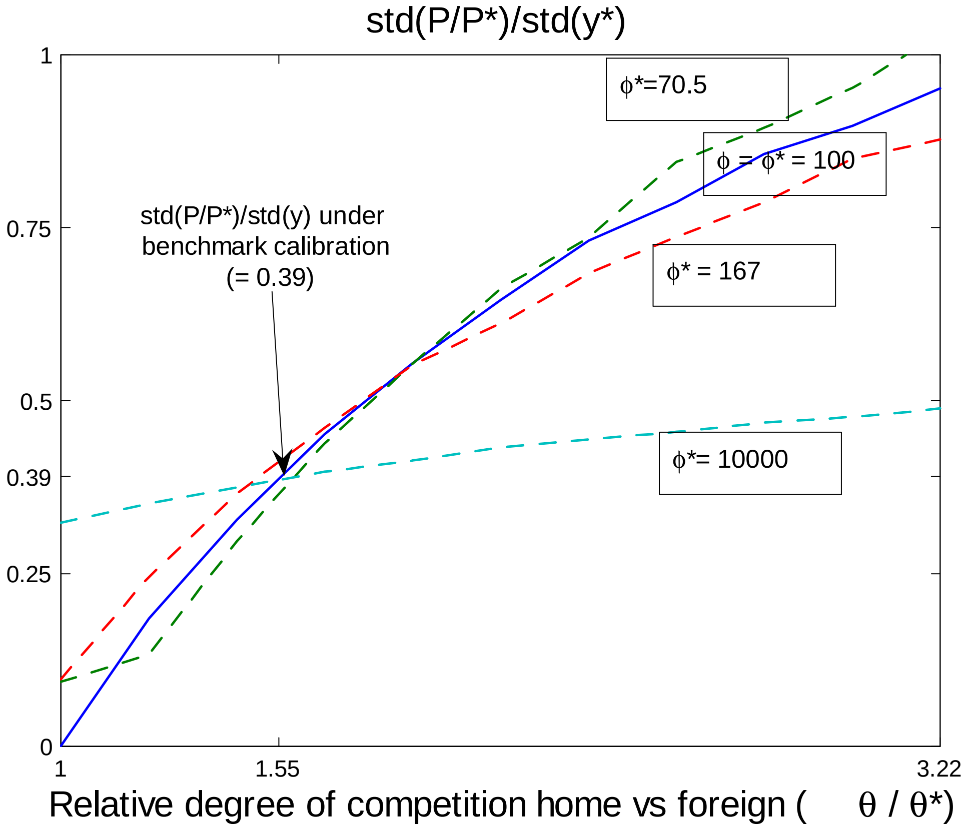

Figure 5. Volatility of relative prices under a contractionary monetary policy shock.

Figure 5 also shows that the sensitivity to variations in relative demand elasticity across countries is smaller the higher the level of price inertia. The solid line includes the benchmark parameterization of the degrees of price inertia for the two countries, which correspond to slopes of the Phillips curve estimated in Benigno and López-Salido (BL) (2001) for countries such as Germany or France. In this case, significant discrepancies only arise for very large differences in the degree of market competition. Allowing for more flexible prices in the foreign country (compatible with the BL (2001) estimate for The Netherlands, $\phi^* = 70.5$) increases the differences in price reactions and therefore the sensitivity of relative price volatility to the markup differential also rises, although this is barely noticeable for such a small difference in price inertia across countries. The opposite occurs when the foreign country has more price inertia as is the case of the price stickiness BL(2001) estimate for Spain ($\phi^* = 167$). In this case, the sensitivity of the relative price volatility to the markup differential is smaller. This is even more clearly seen when one of the countries has very high price inertia, such as Italy ($\phi^* = 10000$, in accordance with

BL(2001) estimations). The volatility of relative prices changes substantially becoming very insensitive to differences in the degree of competition.

However, as shown in the first column of Table 3, the sensitivity of relative price fluctuations to a reasonable range of different price stickiness across countries is smaller than to a moderate range of demand elasticity ratios.

We conclude from this section that small differences in the price elasticity of demand across countries are sufficient to generate sizeable cross-country relative price volatility even for shocks that are common to both countries.

4.2. Asymmetric real demand and supply shocks

Figure 6 depicts the impulse responses, under the benchmark calibration, to a positive demand shock originated in the less competitive (foreign) economy that generates a negative inflation differential of 15 basis points on impact. The shock to real demand in the foreign country positively affects domestic inflation: on the one hand imported goods prices are higher and on the other hand foreign demand rises as well. The monetary policy rule reacts to this rise in inflation by increasing nominal interest rates, making most of the effects of the positive shock disappear after two years.

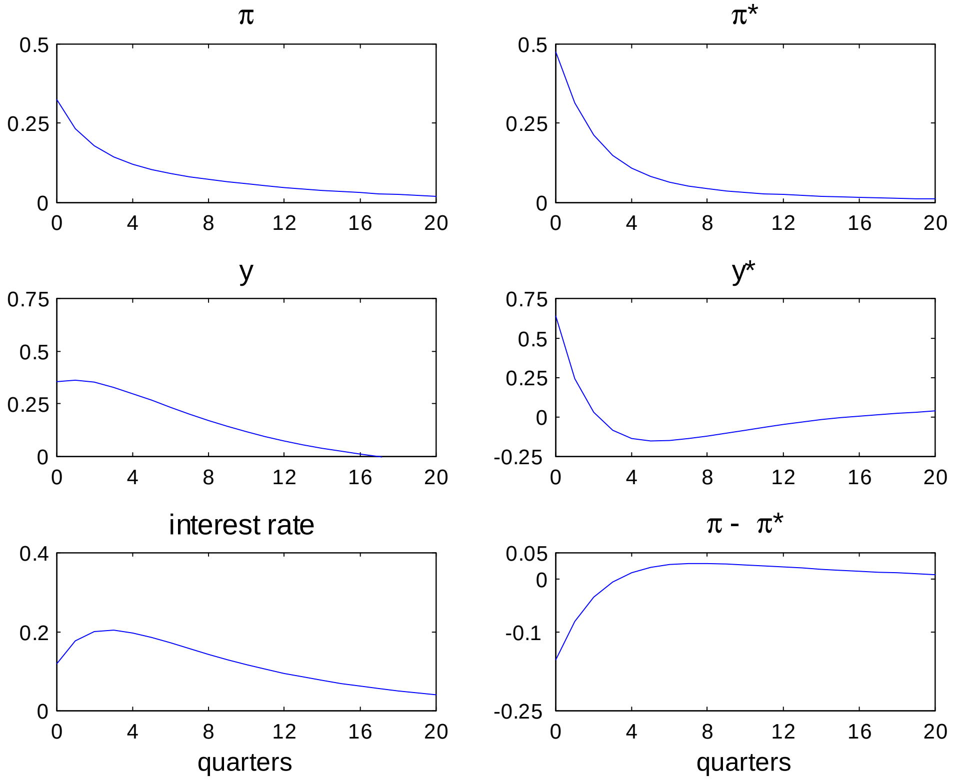

Figure 6. Responses to a positive demand shock in the foreign country (F)

The relative inflation response also varies with differences in market competition across countries, as shown in Table 3. As competition increases in the foreign economy, prices in that economy react more on impact after the demand shock and, therefore, the negative inflation differential increases (-1.38). On the contrary, as the markup in the foreign economy grows (up to 30 per cent) due to lower demand elasticity, its inflation response becomes smaller, thus reverting the inflation differential generated on impact (0.04). The table also shows the sensitivity of this impact response to changes in the degree of price stickiness. The variation in the inflation differential is now more pronounced than it was in the case of the symmetric shock. The higher the price inertia in the country suffering the shock the smaller the reaction of its prices and hence the smaller the inflation differential observed.

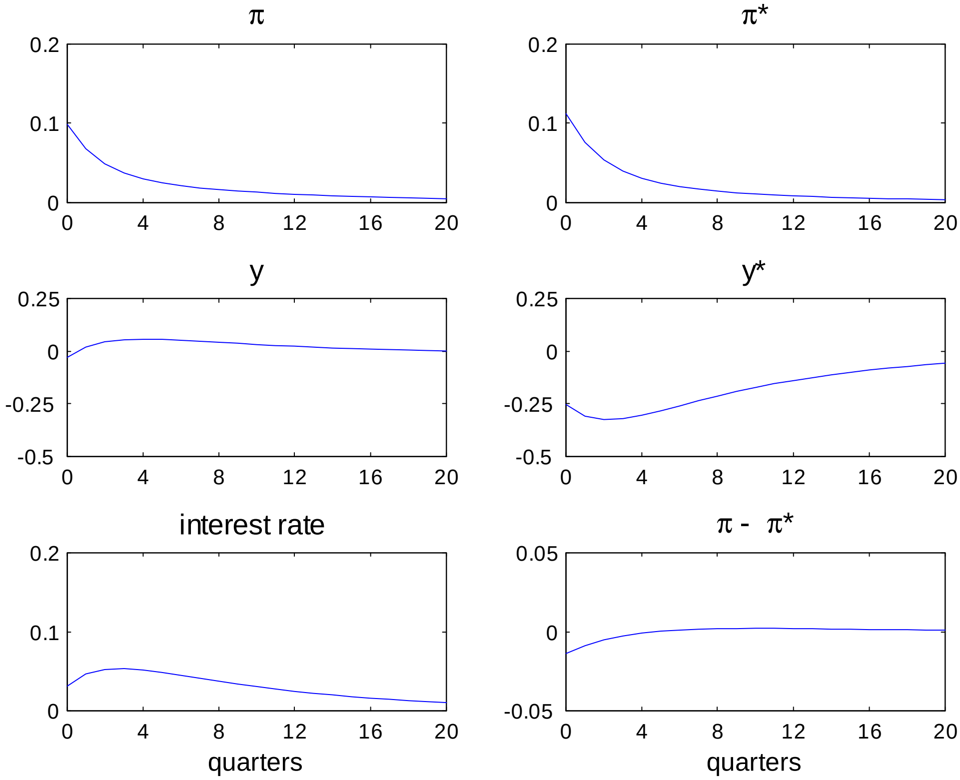

Figure 7. Responses to a negative supply shock in the foreign country (F)

Figure 7 depicts the impulse responses under the benchmark parameterization to an unanticipated negative technology shock in the less competitive foreign country. In this case the negative foreign supply shock positively affects domestic inflation through higher import prices, but lowers foreign demand for domestic goods which contributes negatively to home inflation $\hat{\pi}_t$. The overall effect is a small rise in domestic inflation. Domestic inflation increases less than foreign inflation thus yielding a negative inflation differential that is also sensitive to the relative degree of competition and to relative price inertia. Table 3 shows that the less competitive the country suffering the shock (lower price elasticity θ^*) and the higher its price inertia, the lower the inflation reaction in that country and thus the lower the inflation differential generated as a consequence of the shock.

4.3. *Sensitivity to the degree of substitution and openness*

Price dynamics are also affected by the elasticity of substitution between domestic and foreign goods ($\varepsilon = \frac{1}{1-\rho}$) as well as the degree of openness ($\frac{\omega_F}{\omega_H}$). The effect of changes in that elasticity depends on the nature of the shocks. In the case of the common monetary policy shock the effect of a change in the elasticity of substitution is insignificant. But in presence of a regional shock, the higher the elasticity of substitution, the lower the relative inflation differential.

Quantitatively, this is a very relevant parameter: as shown in Table 3, a change in the elasticity of substitution from 1 to 4 makes the inflation differential generated on impact almost vanish through an asymmetric demand or supply shock.

Our previous results correspond to a calibration representing two EMU countries that are equally open. In the benchmark model, the ratio of foreign to home goods in consumption $\frac{\omega_F}{\omega_H}$ is calibrated to 0.48 which represents 25 per cent of imports in the aggregate consumption bundle and corresponds to the average value observed during the nineties for the main Euro area countries. But there are a number of other countries with a significantly higher share of imports. Our model can be modified to analyze the implications of cross-country differences in the degree of openness (or home bias in consumption). To that end we also parametrize the more competitive domestic economy as the more open one with ratios similar to those of The Netherlands (see Table 2), $\frac{\omega_F}{\omega_H} = 1$ and $\frac{\bar{c}_H}{\bar{y}} = 0.50$, corresponding to 50 per cent of imported goods, whereas the less competitive foreign economy keeps the benchmark parameterization and becomes the least open.[19]

Table 3 summarizes the effect that changes in openness have on the impact inflation differential. This impact response is not significantly altered under an unexpected rise in nominal interest rates. This is not surprising since symmetric shocks affect both $\widehat{d}_t$ and $\widehat{d}_t^*$ in a similar way and hence their effect on the inflation rates is roughly independent on the value of $\frac{\omega_F}{\omega_H}$. Nevertheless, we do find significant changes in the presence of regional demand or supply shocks.

Under an asymmetric demand shock the inflation differential changes from -15 to 3 basis points. The explanation for this is that as the economy becomes more open output and inflation respond more to foreign shocks. A positive impact inflation differential is generated to the extent that domestic inflation may rise more than that in the country actually suffering the shock.

Similarly, in presence of a negative supply shock in the foreign economy the transmission to the domestic country is more significant the more open is that economy. Now the weight of import prices is higher than in the benchmark case, causing a bigger rise in domestic inflation. Domestic inflation responds almost twice as much and therefore produces a very low inflation differential.

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[19] The relative size of the two countries is modified accordingly, in order to satisfy balance of payments equilibrium. In particular, nominal consumption was of equal size in the benchmark calibration, $\overline{\frac{P*}{P}}\frac{\bar{c}^*}{\bar{c}}$=1, whereas now that of the foreign country is twice as large as the nominal consumption of the more competitive and now more open domestic economy.

5. Concluding remarks

What explains temporary inflation differentials in monetary unions? This paper goes half of the way towards answering this question. In particular we focus on the determinants of those inflation differentials that are not associated with long run processes of productivity catching-up and/or price level convergence. Even within long existing monetary unions there is a significant amount of price variability across countries at business cycle frequencies. Part of the explanation lies in asymmetric or regional shocks. But even shocks of this kind cannot reproduce the observed dispersion of inflation rates unless we assume that countries within the union differ in some crucial features that govern the way markets adjust. These differences may also account for inflation differentials in response to symmetric shocks, like innovations to the common monetary policy instrument.

This paper parameterizes a one-sector two-country monetary union in which different economic structures in the two countries generate permanent price level differences and temporary inflation differentials. We focus on the traded sector only. It is often assumed that inflation differentials in a monetary union stem mainly from the lack of competition in the non-traded sector but this contradicts the evidence showing substantial differences among traded goods inflation rates. In one sense we are looking at a lower bound of inflation differentials, to which that of the non-traded sector and that which is due to long-run convergence processes should be added up.

The structural asymmetries we investigate consist of cross-country heterogeneity in the degree of competition in goods markets –which cause producers to discriminate prices–, different price inertia and different degrees of openness or preference for foreign goods in consumption. Once we allow for moderate cross-country variations in the degree of nominal and real rigidities, we are able to observe inflation differentials emerge in a model calibrated to match the most salient long run features of the average large EMU economies.

In presence of common shocks, the relative degree of market competition turns out to be a crucial parameter governing relative price responses. Deviations in the degree of competition that account for a 5 per cent long run price level difference across countries may explain inflation differentials up to 13 quarterly basis points in response to a common monetary policy shock that rises the nominal interest rate by 34 quarterly basis points (136 basis points per annum). Small differences in the degree of nominal inertia also contribute to generating inflation differentials, although the relevance of this channel is quantitatively less important. Not surprisingly, in presence of regional (asymmetric) shocks, the elasticity of substitution between home produced and imported goods and the degree of openness also play a major role in producing sizeable inflation differentials.

We have focused on short-term measures of inflation like impact responses. But these inflation differentials could last longer. Higher persistence can be generated not only by ad-hoc persistent sources of fluctuations or ad-hoc inflation inertia, but also by endogenous mechanisms like the consideration of capital accumulation or the existence of real frictions (e.g. habit formation or investment adjustment costs). Moreover, the differences in countries' competitiveness and the degree of openness may be completed with other structural differences (e.g. taxation or labour costs) that are known to be relevant in the context of the EMU. We leave the interaction of these elements for further research.

Appendix

The equilibrium (in log-linear form) is represented by the following system of 23 equations and 23 endogenous variables: $\widehat{c}_t$, $\widehat{c}_{H,t}$, $\widehat{c}_{F,t}$, $\widehat{c}^*_t$, $\widehat{c}^*_{F,t}$, $\widehat{c}^*_{H,t}$, $\widehat{P}_t$, $\widehat{P}_{H,t}$, $\widehat{P}_{F,t}$, $\widehat{P}_t$, $\widehat{P}^*_{H,t}$, $\widehat{P}^*_{F,t}$, $\widehat{y}_t$, $\widehat{y}_{H,t}$, $\widehat{y}^*_{H,t}$, $\widehat{y}^*_t$, $\widehat{y}^*_{F,t}$, $\widehat{y}_{F,t}$, a_t, a^*_t, $\widehat{r}_t$, $\widehat{\pi}_t$, $\widehat{\pi}^*_t$.

$$\widehat{P}_{F,t} - \widehat{P}_{H,t} = (1-\rho)\left(\widehat{c}_{H,t} - \widehat{c}_{F,t}\right) \tag{A1}$$

$$\widehat{c}_t = E_t\widehat{c}_{t+1} - \frac{1}{\sigma}\left(\widehat{r}_t - E_t\widehat{\pi}_{t+1} - \left(\frac{\psi}{\overline{r}}\right)a_t\right) + \frac{1}{\sigma}\left(\widehat{s}_t - E_t\widehat{s}_{t+1}\right) \tag{A2}$$

$$\widehat{P}_{H,t} = \left[\begin{array}{c} \frac{1}{1+\beta}\widehat{P}_{H,t-1} + \frac{\beta}{1+\beta}E_t\widehat{P}_{H,t+1} + \\ \frac{\mu_H}{1+\beta}\left((\alpha-1)\widehat{y}_t - (1-\sigma)\widehat{c}_t + \widehat{c}_{H,t} + \alpha\widehat{v}_t\right) \end{array}\right] \tag{A3}$$

$$\widehat{P}^*_{H,t} = \left[\begin{array}{c} \frac{1}{1+\beta+\mu^*_H}\widehat{P}^*_{H,t-1} + \frac{\beta}{1+\beta+\mu^*_H}E_t\widehat{P}^*_{H,t+1} + \frac{\mu^*_H}{1+\beta+\mu^*_H}\widehat{P}_{H,t} \\ +\frac{\mu^*_H}{1+\beta+\mu^*_H}\Big((\alpha-1)\widehat{y}_t - (1-\sigma)\widehat{c}_t + \widehat{c}_{H,t} + \alpha\widehat{v}_t + (\widehat{P}_{Ht} - \widehat{P}^*_{Ht}\Big) \end{array}\right] \tag{A4}$$

$$\widehat{c}_t = \omega_H\left(\frac{\overline{c}_H}{\overline{c}}\right)^{\rho}\left(\widehat{c}_{H,t}\right) + \omega_F\left(\frac{\overline{c}_F}{\overline{c}}\right)^{\rho}\left(\widehat{c}_{F,t}\right) \tag{A5}$$

$$\widehat{y}_t = \left(\frac{\overline{y}_H}{\overline{y}}\right)\widehat{y}_{H,t} + \left(\frac{\overline{y}^*_H}{\overline{y}}\right)\widehat{y}^*_{H,t} \tag{A6}$$

$$\widehat{P}_t = (\omega_H)^{\left(\frac{1}{1-\rho}\right)}\left(\frac{\overline{P_H}}{P}\right)^{\left(\frac{\rho}{\rho-1}\right)}\left(\widehat{P}_{H,t}\right) + (\omega_F)^{\left(\frac{1}{1-\rho}\right)}\left(\frac{\overline{P_F}}{P}\right)^{\left(\frac{\rho}{\rho-1}\right)}\left(\widehat{P}_{F,t}\right) \tag{A7}$$

$$\widehat{\pi}_t = \widehat{P}_t - \widehat{P}_{t-1} \tag{A8}$$

$$\beta\left(\frac{\overline{P^*_H}}{P}\right)\frac{\overline{c}^*_H}{\overline{c}}(\widehat{P}^*_{H,t} + \widehat{c}^*_{H,t} - \widehat{P}_{F,t} - \widehat{c}_{F,t}) + a_{t-1} = \beta a_t \tag{A9}$$

$$\widehat{P}^*_{F,t} - \widehat{P}^*_{H,t} = (1-\rho)\left(\widehat{c}^*_{H,t} - \widehat{c}^*_{F,t}\right) \tag{A10}$$

$$\widehat{c}_t^* = E_t\widehat{c}_{t+1}^* - \frac{1}{\sigma}\left(\widehat{r}_t - \widehat{\pi}_{t+1}^* - \left(\frac{\psi}{\overline{r}}\right)a_t^*\right) + \frac{1}{\sigma}\left(\widehat{s}_t^* - E_t\widehat{s}_{t+1}^*\right) \tag{A11}$$

$$\widehat{P}_{F,t}^* = \left[\begin{array}{c} \frac{1}{1+\beta}\widehat{P}_{F,t-1}^* + \frac{\beta}{1+\beta}E_t\widehat{P}_{F,t+1}^* + \\ \frac{\mu_F^*}{1+\beta}\left((\alpha-1)\widehat{y}_t^* - (1-\sigma)\widehat{c}_t^* + \widehat{c}_{F,t}^* + \alpha\widehat{v}_t^*\right) \end{array}\right] \tag{A12}$$

$$\widehat{P}_{F,t} = \left[\begin{array}{c} \frac{1}{1+\beta+\mu_F}\widehat{P}_{F,t-1} + \frac{\beta}{1+\beta+\mu_F}E_t\widehat{P}_{F,t+1} + \frac{\mu_F}{1+\beta+\mu_F}\widehat{P}_{F,t}^* + \\ \frac{\mu_F}{1+\beta+\mu_F}\left((\alpha-1)\widehat{y}_t^* - (1-\sigma)\widehat{c}_t^* + \widehat{c}_{F,t}^* + \alpha\widehat{v}_t^* + \left(\widehat{P}_{Ft}^* - \widehat{P}_{Ft}\right)\right) \end{array}\right] \tag{A13}$$

$$\widehat{c}_t^* = \omega_H^*\left(\frac{\overline{c}_H^*}{\overline{c}^*}\right)^{\rho}\left(\widehat{c}_{H,t}^*\right) + \omega_F^*\left(\frac{\overline{c}_F^*}{\overline{c}^*}\right)^{\rho}\left(\widehat{c}_{F,t}^*\right) \tag{A14}$$

$$\widehat{y}_t^* = \left(\frac{\overline{y}_F}{\overline{y}^*}\right)\widehat{y}_{F,t} + \left(\frac{\overline{y}_F^*}{\overline{y}^*}\right)\widehat{y}_{F,t}^* \tag{A15}$$

$$\widehat{P}_t^* = \left(\omega_H^*\right)^{\left(\frac{1}{1-\rho}\right)}\left(\frac{\overline{P_H^*}}{P^*}\right)^{\left(\frac{\rho}{\rho-1}\right)}\left(\widehat{P}_{H,t}^*\right) + \left(\omega_F^*\right)^{\left(\frac{1}{1-\rho}\right)}\left(\frac{\overline{P_F^*}}{P^*}\right)^{\left(\frac{\rho}{\rho-1}\right)}\left(\widehat{P}_{F,t}^*\right) \tag{A16}$$

$$\widehat{\pi}_t^* = \widehat{P}_t^* - \widehat{P}_{t-1}^* \tag{A17}$$

$$a_t^*\left(\frac{\overline{P^*}}{P}\right)\frac{\overline{c}^*}{\overline{c}} + a_t = 0 \tag{A18}$$

$$\widehat{c}_{H,t} = \widehat{y}_{H,t} \tag{A19}$$

$$\widehat{c}_{H,t}^* = \widehat{y}_{H,t}^* \tag{A20}$$

$$\widehat{c}_{F,t} = \widehat{y}_{F,t} \tag{A21}$$

$$\widehat{c}^{*}_{F,t} = \widehat{y}^{*}_{F,t} \tag{A22}$$

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r)\rho_\pi \frac{1}{2}(\widehat{\pi}_t + \widehat{\pi}^{*}_t) + z_{r,t} \tag{A23}$$

where $\mu_H = \frac{(\theta-1)}{\phi\bar{\pi}^2}$; $\mu^{*}_H = \frac{(\theta^{*}-1)}{\phi\bar{\pi}^2}$; $\mu^{*}_F = \frac{(\theta^{*}-1)}{\phi^{*}\bar{\pi}^2}$; $\mu_F = \frac{(\theta-1)}{\phi^{*}\bar{\pi}^2}$.

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