# HETEROGENEITY IN A MONETARY UNION AND ITS IMPACT ON WELFARE\*

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# 1. INTRODUCTION

Since 1999, 15 European countries have abandoned their national currency and autonomous monetary policy, and have joined the euro area. According to the Optimal Currency Areas (OCA) theory, it is more advantageous for regions to share the same currency area when there is a minimum level of synchronisation of economic cycles and integration of trade and labour markets. Despite the increased economic integration among euro area countries, these have shown persistent differentials. Benalal et al. (2006) show that since the beginning of the euro area the dispersion of economic growth across countries has not changed significantly, and remains at relatively low levels. Given that the level of synchronisation of economic cycles has also increased, these differences suggest the existence of structural differences among countries. A paper by the European Central Bank (ECB, 2003) on inflation differentials has concluded that these are partly caused by convergence processes, but also by other structural factors. Other papers point out of the existence of differences across countries in priceand wage-setting mechanisms (Dhyne et al., 2005; Dickens et al., 2006).<sup>1</sup> Even in the case of common shocks, these structural differences across countries may have implications on monetary policy transmission mechanisms. Since monetary policy in the euro area is defined for the union as a whole, irrespective of country specificities or idiosyncratic shocks, what is the importance of heterogeneity at union level? In particular, what is the impact on welfare of individual economies and of the union as a whole?

This article addresses this matter from a broadly based and theoretical perspective, analysing the impact on welfare when monetary policy responds to the union aggregated variables, given that there is heterogeneity across countries, namely as regards price and wage rigidities. For that purpose, the article develops a simple stochastic economy model with two countries forming a monetary union, where the central bank defines the monetary policy according to a rule that reacts to the union aggregated variables.<sup>2</sup> The model does not include government, given that its objective is related to the evaluation of the impact of different heterogeneity sources on a monetary union, not the interaction between monetary and fiscal policy. However, fiscal policy is acknowledged to alleviate or even eliminate the negative impact of asymmetric shocks or asymmetries across regions in the context of a monetary union (Adão *et al.*, 2006).

The article is in line with recent literature on dynamic general equilibrium stochastic models, applied within a multi-country monetary union operating as a closed economy. In this context, it is worth mentioning the papers by Benigno (2004), Jondeau and Sahuc (2008) and Gomes (2004). Benigno (2004) addresses optimal monetary policy in a monetary union subject to asymmetric shocks, and concludes that an inflation targeting policy in which a higher weight is attached to inflation in the region with higher

<sup>\*</sup> The opinions expressed in this paper represent the views of the author and not necessarily those of Banco de Portugal.

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<sup>(1)</sup> In this respect, it is also worth mentioning the working papers developed in the context of the Inflation Persistence Network of the Eurosystem (http://www.ecb.int/home/html/researcher\_ipn.en.html).

<sup>(2)</sup> This article is based on Soares (2008).

nominal rigidity is nearly optimal. In turn, Jondeau and Sahuc (2008) compare two models estimated for the euro area: one for the area as a whole and a multi-country model (Germany, France and Italy). These authors conclude that there are significant welfare losses if the monetary authority does not take into account region specificities when defining monetary policy. In turn, Gomes (2004) investigates, based on an calibrated model, the implications of different price rigidity levels in a monetary union, in the presence of specific and common shocks. She concludes that idiosyncratic shocks and, to a lesser extent, common shocks generate significant growth and inflation differentials across countries. From the comparison of different monetary policy rules, she also concludes that the rules resulting in the best outcome for the union are not equivalent to the best result in individual terms. Rules with interest rate smoothing actually stabilise inflation and output and narrow differentials across countries, but reduce the inflation correlation among countries. Rules seeking to stabilise output actually reduce output volatility to the detriment of inflation volatility and reduce the output correlation among countries.

This article is structured as follows: Section 2 introduces a summarised description of the model. Section 3 presents the calibration for the reference case, which replicates a homogeneous union. In the following sub-sections heterogeneity across countries is introduced, in order to analyse the impact on welfare. The heterogeneity sources analysed are the home bias on consumption goods, and wage and price rigidities. In this regard, it is worth stressing the significant impact of introducing heterogeneity in wage and price nominal rigidities, wherefore this should be analysed in further detail through the assessment of the interaction between both types of rigidities. Section 4 presents the main conclusions.

# 2. DESCRIPTION OF THE MODEL<sup>3</sup>

The monetary union is formed by two countries: the domestic economy (referred to as D) and the foreign economy (referred to as F). Total population in the area comprises a continuum of identical and infinitely lived agents and is normalised to 1. The relative size of the domestic economy is given by n, wherefore (1-n) is the size of the foreign economy. The economy includes three agents: households, firms and the central bank. Each country's economy operates in a similar manner. Hence, this section describes the model of the economy in one of the countries, considering that the other one would be similar.

Households consume goods produced in both countries, save by investing in financial assets and provide differentiated labour to the firms producing in the country they live in. Households' objective is to maximise the expected utility discounted over time. The representative household's instantaneous utility is separable into consumption and labour, and depends positively on consumption less external habit in consumption,<sup>4</sup> and negatively on working hours. Households are subject to two random shocks: one preference shock that influences preference between households' current and future consumption, and a labour supply shock that affects the availability of households to supply labour to firms.

Consumption of the representative household consists in a basket of goods produced in both economies, according to their preference for domestically or externally produced goods (home bias). It is assumed that  $C_{D,t}$  (*j*) is the consumption by the representative household *j*, resident in the home economy, of domestically produced goods,  $C_{F,t}$  (*j*) is the consumption by the same household of

<sup>(3)</sup> For further details on the model, see Soares (2008).

<sup>(4)</sup> This paper assumes the hypothesis of external habit, i.e. households take into account deviations of their consumption level from the per capita consumption in the country in the previous period. Thus, consumption behaviour in the model seems to be more persistent and to respond gradually to shocks, in line with empirical evidence (Abel, 1990, Fuhrer, 2000, Smets and Wouters, 2003).

goods produced in the foreign economy<sup>5</sup> and  $\varpi$  (denominated the home bias parameter) is the share of domestically produced goods in total consumption. Therefore, the basket of goods consumed by household j, resident in the home economy, may be represented by the following expression:

$$C_{t}^{D}(j) = \frac{(C_{D,t}(j))^{\varpi} (C_{F,t}(j))^{1-\varpi}}{\varpi^{\varpi} (1-\varpi)^{1-\varpi}}$$
(2.1)

When  $\varpi$  is equal to 0.5 there is no home bias, i.e. households do not show different preferences about consuming domestic or imported goods. When  $\varpi$  is lower than 0.5, households prefer to consume externally produced goods; when it is higher than 0.5 they prefer domestically produced goods.

Households must observe the budget constraint to which they are subject. On the one hand, they receive income from labour and dividends from firms in the home country, given that the latter operate in a monopolist competitive market. On the other hand, they may use their income for consumption and saving. Households may thus trade in area wide riskless bonds and country-specific state-contingent securities. Both financial markets shall be balanced at each moment.

Each household in the model supplies labour services to firms in the home country. Households can only work in firms of their own country, since there is no labour mobility at the union level. Labour is differentiated among households, which operate as labour suppliers under monopolistic competition and set wages on the basis of their market power. In order to introduce friction in the wage-setting mechanism, it is assumed that households cannot set in each period the wage enabling them to reach maximum utility level, taking into account labour demand by firms. Households can only optimise wages occasionally, but do not know in advance when they can do it. In each period, every household will optimise wages with probability  $(1-\xi_w^D)^6$ . Thus, the parameter  $\xi_w^D \in [0,1]$ , which is the same for every household and is constant over time, indicates the degree of wage rigidity of the economy: the closer it is to 1, the greater the wage rigidity, given that the probability of optimising wages in each period is lower. When households cannot optimise wages, they will adjust them partly in line with consumer price inflation in the home country in the previous period. In those periods when households cannot determine their wages, they will take into account the expected time span (given by  $1/(1-\xi_w^D)$ ) quarters, considering quarterly model frequency) up to the subsequent optimisation. Therefore, the optimal wage of the representative household will be defined as a mark-up over the marginal rate of substitution between consumption and labour expected over time. Aggregate wage in every quarter is proxied by an average of optimum wage and adjusted wage, according to the indexing mechanism, weighed by the share of households that have adjusted their wages in that quarter.

Using labour as the single productive factor, firms will produce differentiated goods, and will also be subject to a random productivity shock. They are subject to fixed costs in production, which are common to all firms. Marginal costs are given by nominal wage weighed by the productivity factor. Similarly to wages, the price-setting mechanism also exhibits rigidity. Firms can only optimise prices at moment t when they receive a random "signal" to do so, which occurs with probability  $(1 - \xi_p^D)$ . Therefore, with probability  $\xi_p^D$ , they cannot optimise prices at moment *t*, adjusting prices to a share of the producer price index of the respective country in the previous period. Hence, parameter  $\xi_p^D$  denotes price rigidity, which will be the greatest, the closer to 1 the parameter is.<sup>7</sup> When firms may optimise prices, they set the optimal price with a mark-up over marginal costs expected over time. Given that at each mo-

<sup>(5)</sup> C<sub>D,t</sub> and C<sub>F,t</sub> represent aggregation in a homogeneous good, due to the existence of product differentiation both among domestically produced goods and among goods produced by the other economy. Households are willing to exchange between differentiated goods of the same country, according to the elasticity of substitution.

<sup>(6)</sup> The upper D index in the parameter means that this refers to the home economy. The F index is used for the foreign economy.

<sup>(7)</sup> Similarly to the degree of wage rigidity,  $\xi_{a}^{D}$  ranges between zero and one, is equal for all firms and is constant over time.

ment some firms do optimise prices while other firms cannot do it, the price index of goods produced in either economy is proxied by an average of the optimal price level and prices adjusted according to the indexing mechanism, weighed by the degree of price rigidity.

Since households consume goods produced in either country, the consumer price index is given by the average of producer price indices in the home and foreign economies, weighed by the share of domestic goods consumption ( $\varpi$ ) and imported goods consumption ( $1-\varpi$ ). The index for the union will be the average of the national indices weighed by the respective size of the country.

Considering that this is a monetary union model, the nominal exchange rate will always be equal to one. As consumption goods are freely traded across countries, prices of the same goods are equal in the home economy and in the foreign economy. The pricing-to-market hypothesis (Obstfeld and Rogoff, 1996; Betts and Devereux, 2000) is therefore not viable in this model.

Given that the model shows a significant degree of nonlinearities, a straightforward solution is not available. Therefore, this paper follows literature and presents an analysis in terms of log-deviations from the steady state.<sup>8</sup> The monetary policy rule is introduced ad-hoc and is not a result of the optimisation programme. Following the extended use of Taylor rules in the literature, the central bank will respond to inflation and output deviations from the steady state, assuming that the central bank target for inflation is the steady state level. The monetary authority also shows a preference for smoothing the interest-rate path. Moreover, the rule is widened so that the central bank may respond to short-term changes in inflation and output (Smets and Wouters, 2003). Finally, the central bank is also subject to a monetary shock that may lead to surprises in the interest rate. Therefore, the monetary policy rule may be expressed as follows:

$$\hat{R} = \gamma_R \hat{R}_{t-1} + (1 - \gamma_R) (\gamma_\pi \hat{\pi}_t + \gamma_y \hat{Y}_t) + \gamma_{\Delta\pi} (\hat{\pi}_t - \hat{\pi}_{t-1}) + \gamma_{\Delta y} (\hat{Y}_t - \hat{Y}_{t-1}) + \hat{m}_t$$
(2.2)

where  $\hat{R}_t$ ,  $\hat{\pi}_t$  and  $\hat{Y}_t$  are, respectively, the interest rate, inflation and output deviations from the steady state in the area, and  $\hat{m}_t$  is the monetary policy random shock.

The welfare function in either country is defined from the utility function of the representative household, corresponding to the aggregation of the utility of all households in each country (Benigno and Woodford, 2004).<sup>9</sup>

# 3. WELFARE ANALYSIS

#### 3.1. Calibration of the model for the reference case of a homogeneous union

At a first stage, the model is calibrated so as to replicate the case of a homogeneous union, i.e. countries have the same size, there is no home bias and the remaining parameters are equal for both countries. Calibration is close to the results of estimated DSGE models for the euro area, e.g. the Smets and Wouters (2003) model.<sup>10</sup>

The intertemporal discount rate of households is calibrated so that the annual steady-state real interest rate is close to 4%. Since it is assumed that there is no home bias in the reference case of a homo-

<sup>(8)</sup> The log-linearised model equations are presented in appendix, where variables in terms of log-deviations from the steady state are given by ^.

<sup>(9)</sup> The welfare function is proxied by a second-order Taylor expansion of the household utility aggregation of each country. Welfare depends on the steady-state welfare levels, namely of consumption, and on the dynamics of the economy when responding to shocks. Worthy of mention as factors with a bearing on welfare are price and wage inflation volatility, consumption and output volatility, and the interaction between output dynamics and the shocks affecting the economy (except the monetary policy shock).

<sup>(10)</sup> Appendix 5.2 presents the values of the calibrated parameters.

geneous union, the parameter m is calibrated to 0.5. The persistence of consumption is calibrated to 0.6, in line with the estimation by Smets and Wouters (2003), but slightly below the value estimated for a smaller euro area model such as in Jondeau and Sahuc (2008).<sup>11</sup> The intertemporal elasticity of substitution of consumption is calibrated to around 0.7, in line with the hypothesis widely spread in real business cycles literature of an elasticity ranging from 0.5 to 1. In turn, labour supply elasticity is calibrated to around 0.4. The degree of wage rigidity is calibrated to 0.7, meaning that, on average, households take 3 to 4 guarters to optimise wages. In those guarters when wages cannot be optimised, these are adjusted by 75% of consumer price inflation in the previous period. In turn, the degree of price rigidity is calibrated to 0.9, hence firms optimise their prices every 10 quarters, on average. Galí et al. (2001) have also reached a high value close to 0.9 for price rigidity in the euro area when estimating a Phillips curve with constant returns to scale in the production function.<sup>12</sup> During those guarters when firms do not optimise prices, these are adjusted by 50% of producer price inflation in the previous period. Therefore, according to Smets and Wouters' results (2003), the model presents greater nominal rigidity in prices than in wages. The elasticity of labour demand is calibrated to 3, meaning that wage markup is 1.5. A calibrated value of 6 for price-elasticity of demand implies a price markup of 1.2, which is in line with the 1.1-1.4 range usually acknowledged in literature (Galí et al., 2001, Christiano et al., 2005). The calibration used in the monetary policy rule is also in line with most literature. The interest rate exhibits relatively high persistence, with an autocorrelation coefficient of 0.8. The central bank gives more weight to inflation deviations from target than to output deviations, which is in line with the literature (1.7 weight on the rule for inflation and 0.1 for output). The weights of the differential components of output and inflation on the monetary policy rule are also relatively low (0.15). The monetary policy shock is not assumed to show persistence, given that the interest rate already has a high persistence level. Preference, labour supply and productivity shocks show high persistence, according to literature.

#### 3.2. Monetary policy rules

This section examines the impact on welfare of the different rules that may be followed by the central bank. For this purpose, the following string of rules was considered:

- 1. Original rule  $\hat{R}_t = 0.8\hat{R}_{t-1} + 0.2(1.7\hat{\pi}_t + 0.1\hat{Y}_t) + 0.15(\hat{\pi}_t \hat{\pi}_{t-1}) + 0.15(\hat{Y}_t \hat{Y}_{t-1}) + \hat{m}_t$
- 2. Rule without differential components (  $\gamma_{\Delta\pi} = \gamma_{\Delta\nu} = 0$  )
- 3. Rule without interest rate smoothing ( $\gamma_R = 0$ )
- 4. Simple Taylor rule (  $\gamma_{\Delta\pi} = \gamma_{\Delta\nu} = 0 e \gamma_R = 0$  )
- 5. Low weight on inflation (  $\gamma_{\pi} = 1$ )
- 6. High weight on inflation ( $\gamma_{\pi} = 2$ )
- 7. No weight on the output gap ( $\gamma_v = 0$ )
- 8. High weight on the output gap ( $\gamma_v = 1$ )

The rule originally defined in the model (rule 1) is similar to that estimated in the model for the euro area by Smets and Wouters (2003). In rule 2, the central bank does not react to short-term developments in inflation and output. Rule 3 evaluates the impact of the preference for smoothing the interest rate path. If there is no interest rate persistence, the inflation and output targets may be reached faster. Most liter-

(12) However, when compared to other estimations, namely for the USA, the assumption implies great price rigidity (Christiano et al., 2005).

<sup>(11)</sup> The calibrated value is also close to the value estimated for the USA in Christiano et al. (2005)

ature considers as quite valid the hypothesis of interest rate smoothing, since less interest rate volatility may be deemed important for the welfare of the economies. Moreover, the uncertainty regarding the true model of the economy and the impact of shocks warrant a more cautious approach by central banks (Martins, 2000). A simple Taylor rule is also examined, which only reacts to inflation and output deviations (rule 4).

A second string of rules evaluates the relative importance assigned by the central bank to inflation and output stabilisation around the target (rules 5 to 8). The existence of a short-term trade-off between output and inflation stabilisation justifies the analysis of the impact of this option of the central bank on welfare. If the central bank responds to inflation and as a result the interest rate changes less than inflation, monetary policy may then contribute to generate more volatility in the economy (Clarida *et al.*, 2000). Therefore, 1 is the lowest value that the monetary authority is deemed to place on the inflation weight on the rule. As higher values are placed on the inflation weight, the rule gradually allows for sharper shock adjustment (Clarida *et al.*, 2000). If the monetary authority places more relevance on output stabilisation, then its relative weight on the rule is expected to increase.

The results for the different heterogeneity sources (see Charts 1, 2 and 3) show that the comparison of the different rules is not affected by the rigidity source considered. In any case, rules with a higher relative weight on inflation, compared to their weight on the output gap generate better results in terms of welfare in either country and at the union level. In turn, rules with relative higher weight on the output gap lead to higher losses in terms of welfare, when compared to the other rules. In this model, rules with a relatively higher weight on inflation are those that better stabilise this variable. This suggests that, given the effects of the rules on welfare, inflation volatility is relevant for welfare levels. In effect, the agents are deemed to assign high importance to inflation volatility in the welfare function. Inflation volatility is also expected to affect consumption and production decisions by households and firms.

The comparison of the different rules is in line with most literature. Indeed, it seems to be consensual that the central bank should react more strongly to inflation. Clarida *et al.* (1999) mention that, under commitment, the optimal policy leads the central bank to respond more aggressively to inflation than to output. Gomes (2004) indicates that the policies allowing for greater stabilisation of inflation are not the same inducing greater stabilisation of output around the steady-state level.

In turn, the group of policy rules that compare different rule structures (rules 1 to 4) leads to rather close welfare levels, suggesting that the choice of the central bank among the different formulations is not very relevant. If the central bank opts for smoothing the interest-rate path, welfare declines slightly. However, this result may depend on the type and size of the main shocks in the economy.

#### 3.3. Heterogeneity as regards the home bias

This sub-section introduces heterogeneity in the monetary union, by changing only one parameter separately in the home economy vis-à-vis the reference calibration (section ). The first heterogeneity source to be analysed is the home bias, where the foreign economy remains with no home bias ( $\varpi^* = 0.5$ ). The impact on welfare from changing the home bias in the home economy is analysed, i.e. the scenario when domestic households prefer to consume imported goods ( $\varpi < 0.5$ ) and when they prefer domestically produced goods ( $\varpi > 0.5$ ). Chart 1 presents the main results.

Different levels of home bias across countries has impacts mainly on the steady-state welfare, since the dynamics of the economies remain relatively unchanged. When the home bias is lower in the home economy ( $\varpi < 0.5$ ), preference for domestic goods and, therefore, demand for these goods are lower, as well as their production. Labour utilisation is thus lower in domestic firms. In turn, firms in the foreign



economy increase production in response to higher demand for their goods and, as a result, the amount of labour used increases. Given that labour elasticity is lower than consumption elasticity in households, sharper changes are observed in consumption than in labour in each country. As a result of the combined effect of the decline (increase) in labour and of the increase (decline) in consumption in the home (foreign) economy in view of these lower levels in home bias in the home country, welfare is slightly higher in the home economy and, in contrast, it is lower in the foreign economy. However, the best result in terms of welfare for the union and for either country is reached when the countries are complementary as regards the home bias, i.e. when the overall preference of the union is similar for goods of either country. This does not mean that the countries must be equal, but if the preference of the home economy for domestic goods is high, then the preference for domestic goods by households in the other country should be low (i.e.  $\varpi + \varpi^* = 1$ ).

#### 3.4. Heterogeneity as regards nominal rigidity

It can be assumed that the economies may differ as regards the degrees of price and wage rigidity. The analysis of the effect of this heterogeneity source requires the parameters reflecting the rigidity degree

Note: A home bias in the home economy below 0.5 means that households in this country prefer to consume external goods; a value above 0.5 means that households prefer to consume domestic goods.

on wages  $\xi_w^D$  and prices  $\xi_p^D$  in the home economy to be changed separately. This type of differences across countries in the union does not change the steady-state welfare, but has significant effects on the dynamics of the economies. Charts 2 and 3 present the results of the impact on welfare of changes in the wage and price stickiness parameters, respectively, of the home economy.

In general, when rigidity is reduced in the home economy while it is high in the foreign economy, this leads to a decline in welfare in either economy. This is chiefly due to the fact that more flexibility generates more volatility, particularly of inflation, which deteriorates welfare. The more flexible country, namely as regards price setting, tends to present a lower welfare level. It is also interesting to stress some results in terms of heterogeneity as regards wage rigidity. On the one hand, whereas wages are more flexible in one of the countries, the impact in terms of welfare is virtually nil. However, when the parameter of wage rigidity is raised in one of the countries, especially above the level of price stickiness, welfare drops significantly. This means that, in addition to heterogeneity at the union level, the interaction between price and wage rigidity also seems to be relevant for welfare. Therefore, this paper also presents a more detailed analysis of these effects.

#### Chart 2



Note: The degree of rigidity increases in tandem with its parameter value. In the foreign economy, the wage rigidity parameter stands at 0.7.





#### 3.4.1. Interaction between price and wage rigidity

The analysis in this section is presented in two stages: first, considering that countries remain equal at all times, the effects of changing nominal rigidity degrees is evaluated (Chart 4); at the second stage, only the home economy parameters are changed, in order to evaluate the interaction between price and wage rigidity (Chart 5). In either case, the monetary policy rule is maintained (following rule 1 and the central bank keeps on responding to the aggregated variables, and the other countries' parameters are kept unchanged. In addition, this analysis refers only to the effects on short-run dynamics of the economies in response to shocks, given that, as previously mentioned, changes in the nominal rigidity parameters would not change the steady state.

Chart 4 shows that flexible wages and prices actually generate the best situation in terms of welfare (point A in the Chart). When countries start from the scenario of the most flexible prices and wages as possible (panel (b) of Chart 4), increasing stickiness leads to a decline in welfare (moving from the left-to the right-hand side of the Chart), which is all the more significant when only wage rigidity increases while prices remain flexible. In turn, when countries start from the baseline scenario of a high degree of nominal rigidity (panel (a) of Chart 4), raising the overall degree of flexibility of the economies improves welfare, but decreasing only price rigidity while maintaining wages sticky deteriorates welfare. In this



Note: Each line corresponds to the union's welfare according to the nominal rigidity parameter being changed in both economies at the same time. Chart (a) illustrates the case where, when only one rigidity source changes, the other source maintains the baseline calibration according to which economies are sticky. Chart (b) illustrates the case where, when only one rigidity source changes, the other source maintains the calibration closer to the flexible price/wage scenario.

case, prices accommodate more the effect of shocks, and therefore inflation becomes more volatile, given that adjustments via wages, which remain sticky, are more time-consuming. This is the worst situation for households and firms. Hence, the main conclusions to be drawn from the interaction among rigidity types with similar countries are the following: (i) more flexibility allows for higher welfare, (ii) price flexibility has an impact on welfare more significant, but (iii) a very high degree of price and wage rigidity also translates into one of the best results in terms of welfare. In this case, prices and wages react little to shocks and, as a result, they show very low volatility, which largely explains this result.

In an economy with sticky wages and flexible prices, firms may easily adjust prices to marginal costs. However, households cannot optimise wages, but may update it to a quite high share (75%) of consumer price inflation in the previous period. Ultimately, price developments are being determined by past inflation, which is also the main determining factor of the central bank response. In turn, wages take much longer to resume their optimal level, and monetary policy does not take into account their development. Therefore, inflation volatility is rather high and, as a result, the welfare level is considerably lower.

When heterogeneity is introduced across countries as regards the parameters reflecting nominal rigidity, conclusions change slightly. Whereas in Chart 4 countries remain equal at all times, Chart 5 presents the results when nominal rigidity parameters in the home economy are changed, while in the foreign economy the degree of nominal rigidity remains high (panel (a)) or very low (panel (b)). More flexible economies continue to be the preferable situation in terms of welfare, but only when countries are similar. If countries start from a situation of great flexibility and the rigidity degree increases in the home economy (panel (b) of Chart 5), it can be seen that welfare in the foreign economy remains virtually unchanged, but welfare in the home economy drops considerably, more so when only wage stickiness is raised. In turn, if the starting situation is the baseline scenario (section ), in which both countries show high nominal rigidity, and if nominal rigidity parameters are changed in the home economy (panel (a) of Chart 5), then there are welfare losses for the union, although this does not imply that the situation deteriorates in both countries. In effect, if the home economy reduces overall rigidity, it may im-



Note: Each line corresponds to the welfare according to the nominal rigidity parameter being changed in the home economy. The charts in column (a) illustrate the case where, when only one rigidity source in the home economy is changed, the other source maintains the baseline calibration according to which economies are sticky, as well as the foreign economy calibration. That charts in column (b) illustrate the case where, when only one rigidity source in the home economy is changed, the other source maintains the table price/wage scenario, as well as the foreign economy calibration.

prove welfare, but the situation deteriorates considerably in the foreign economy. The home economy is able to adjust more quickly to shocks and the policy response will be more contained than if both countries were very rigid. This situation would have a negative impact in the most rigid country. In turn, when only one source of nominal rigidity is flexible, there are welfare losses, given that the economy adjustment to shocks occurs via prices or wages, depending on which is more flexible, and via its impact on activity. When the home economy only raises wage flexibility, the decline in the welfare level is relatively low and similar across countries. However, when the home economy only reduces price stickiness while wages remain rigid, then the welfare level drops in both countries, although more markedly in the home economy. In this case, inflation volatility of the home economy is higher because prices adjust more quickly to shocks, thus contributing to a substantial fall in welfare in this country. The abovementioned strong impact on welfare elapsing from the existence of price flexibility with wage rigidity is again confirmed.

From the model analysis, it is possible to conclude that there is an incentive for coordinated policies among the union member regions, which would foster price and wage flexibilisation.

## 3.5. Countries' weight on the monetary policy rule

There is in literature some papers that seek to evaluate central bank optimal policy in a monetary union with heterogeneity across regions. Benigno (2004) suggests that the central bank should respond more aggressively to inflation in the country with greater rigidity. Jondeau and Sahuc (2008) advance arguments suggesting that central banks should take into account the specificities of the member countries when defining monetary policy.

In this context, and evaluating only the impact of simple rules,<sup>13</sup> one can inquire whether, in the context of this model, the central bank should consider the economic behaviour of each country instead of examining only the aggregate. It is assumed that the central bank follows the above rule 2 (Taylor rule with interest rate smoothing), but instead of responding to the aggregated variables calculated from the average of the individual variables weighed by country size, it may weigh inflation and output of each country based on a different share, other than size. In this way, it would be interesting to know which weight the central bank shall assign to each country, considering that these may be different in terms of their nominal rigidity degrees.

The results of the model are in line with the main conclusions found in literature. When there is heterogeneity regarding the degree of nominal rigidity between the union members, and considering that the central bank can observe each country stickiness levels, then the central bank should respond more strongly, relatively to countries' size, to the macroeconomic variables of the more rigid country, since that leads to a higher welfare level. For instance, Chart 6 shows that, in the case of low overall degree of nominal rigidity in the home economy, the welfare of the union would be higher if the central bank would weigh inflation and output in this economy with a weight below the real size of the country. In this case, the adjustment to shocks in the home economy occurs more quickly, wherefore the central bank may seek to contribute more to the stabilisation of the other economy, where this process is slower. The central bank should follow this strategy when countries are different in just one of the two types of rigidity or in both simultaneously. In most cases, this strategy has better results in terms of welfare for the union and for individual countries. It should be mentioned that when countries are more similar, the weight of each country on the rule is closer to the country size and welfare gains due to a change in weight are minimal.

<sup>(13)</sup> This article does not present an analysis of optimal policy. Galí (2002) mentions that simple rules are a good proxy to optimal rules and, in addition, are better understood by economic agents.



# 4. CONCLUSION

This articles presents an analysis of the effects on welfare from considering heterogeneity across member countries in a monetary union, based on a two-country simple dynamic stochastic model. Heterogeneity sources considered are the home bias, i.e. the preference of households for consuming domestically produced goods, and the price and wage rigidity degrees.

Some findings on the importance of heterogeneity in a monetary union are presented. As regards the home bias, countries should preferably complement each other, since this would permit them to reach a higher welfare level. The analysis of heterogeneity as regards nominal rigidity degrees leads to the following main conclusions:<sup>14</sup>

- More flexible economies lead to higher welfare for the union, as long as countries are identical, especially as regards nominal rigidity levels;
- · Price flexibility with wage rigidity has a strong negative effect on welfare;
- Introducing heterogeneity in nominal rigidity degrees across countries in a monetary union may have negative effects on welfare, justifying coordination among countries;
- If the central bank can observe country specificities, it should respond more aggressively to deviations from target of the most rigid country.

<sup>(14)</sup> It should be recalled that these conclusions derive from the analysis of short-term dynamics of the economies in response to shocks considered in the model, since different nominal rigidity levels do not change the steady state in this model.

Nevertheless, it is important to recall that these findings are taken from simulations carried out in a simple model, not including capital or government. Therefore, with a view to enrich the study and understanding the robustness of the results, a future research line could incorporate capital and government in the model, since the interaction between monetary policy and fiscal policy may ease or even eliminate the negative effects of asymmetries or idiosyncratic shocks in a monetary union (Adão *et al.*, 2006).

Given the importance of wage rigidity when prices are sticky, there is a possibility that labour mobility at the union level could alleviate such negative effects, given that firms may better adjust production according to the specific shocks affecting the economies.

Finally, bringing the model closer to statistical data, another possible line of future research could be the estimation of the model. Following Pytlarczyk (2005),<sup>15</sup> one could assume that one of the countries would be Portugal and the other would be the rest of the euro area. This would make it possible to investigate the possible structural differences and the effects of monetary union in Portugal.

# 5. APPENDIX

#### 5.1. The model defined in terms of log-deviations from the steady state

Consumption:  $\hat{C}_{t}^{D} = \frac{h}{1+h}\hat{C}_{t-1}^{D} + \frac{1}{1+h}E_{t}\hat{C}_{t+1}^{D} + \frac{1-h}{\sigma_{c}(1+h)}(\hat{\varepsilon}_{t}^{b} - E_{t}\hat{\varepsilon}_{t+1}^{b}) - \frac{1-h}{\sigma_{c}(1+h)}(\hat{R}_{t} - E_{t}\hat{\pi}_{t+1}^{cD})$ 

Real wage:  $\hat{w}_{D,t} = \frac{\beta}{1+\beta} E_t \hat{w}_{D,t+1} + \frac{1}{1+\beta} \hat{w}_{D,t-1} + \frac{\beta}{1+\beta} E_t \hat{\pi}_{t+1}^{cD} - \frac{1+\beta\gamma_w}{1+\beta} \hat{\pi}_t^{cD} + \frac{\beta}{1+\beta} E_t \hat{\pi}_t^{cD} + \frac$ 

$$+\frac{\gamma_{w}}{1+\beta}\hat{\pi}_{t-1}^{cD} - \frac{1}{1+\beta}\frac{(1-\beta\xi_{w}^{D})(1-\xi_{w}^{D})}{(1+\varphi\sigma_{L})\xi_{w}^{D}}\left[\hat{w}_{D,t} - \sigma_{L}\hat{L}_{t}^{D} - \frac{\sigma_{c}}{1-h}(\hat{C}_{t}^{D} - h\hat{C}_{t-1}^{D}) - \hat{\varepsilon}_{t}^{LD}\right]$$

Producer price inflation:

$$\hat{\pi}_{D,t} = \frac{\beta}{1+\beta\gamma_{p}} E_{t} \hat{\pi}_{D,t+1} + \frac{\gamma_{p}}{1+\beta\gamma_{p}} \hat{\pi}_{D,t-1} + \frac{1}{1+\beta\gamma_{p}} \frac{(1-\beta\xi_{p}^{D})(1-\xi_{p}^{D})}{\xi_{p}^{D}} (\hat{w}_{D,t} - \hat{A}_{t}^{D})$$

Consumer price inflation:  $\hat{\pi}_{t}^{cD} = \varpi \hat{\pi}_{D,t} + (1 - \varpi) \hat{\pi}_{F,t}$ 

Production function:  $\hat{Y}_{t}^{D} = \phi^{D} (\hat{A}_{t}^{D} + \hat{L}_{t}^{D})$ 

Market equilibrium:  $\hat{Y}_t^D = \varpi T^{1-\varpi} \frac{C^D}{Y^D} \left[ (1-\varpi)\hat{T}_t + \hat{C}_t^D \right] + \varpi * \frac{1-n}{n} T^{1-\varpi} \frac{C^f}{Y^D} \left[ (1-\varpi^*)\hat{T}_t + \hat{C}_t^F \right]$ 

Aggregate variables for the area:  $\hat{\pi}_t = n \hat{\pi}_t^{cD} + (1-n) \hat{\pi}_t^{cF}$ 

$$Y_{t} = C_{t}$$
  
$$p\hat{Y}_{t}^{D} + (1-n)\hat{Y}_{t}^{F} = n\hat{C}_{t}^{D} + (1-n)\hat{C}$$

Monetary policy rule:  $\hat{R} = \gamma_R \hat{R}_{t-1} + (1 - \gamma_R)(\gamma_\pi \hat{\pi}_t + \gamma_y \hat{Y}_t) + \gamma_{\Delta\pi} (\hat{\pi}_t - \hat{\pi}_{t-1}) + \gamma_{\Delta y} (\hat{Y}_t - \hat{Y}_{t-1}) + \hat{m}_t$ Welfare function:

(15) Pytlarczyk (2005) presents an estimated model for Germany and the rest of the euro area.

$$W_{t}^{D} = \overline{U}^{D} (C^{D}) + \overline{U}_{C^{D}} (C^{D}) C^{D} \left[ \begin{pmatrix} \hat{C}_{t}^{D} - h\hat{C}_{t-1}^{D} \end{pmatrix} + \frac{1}{2} ((\hat{C}_{t}^{D})^{2} - h^{2} (\hat{C}_{t-1}^{D})^{2}) - \\ - \frac{\sigma_{c}}{2(1-h)} (\hat{C}_{t}^{D} - h^{2} \hat{C}_{t-1}^{D})^{2} + \frac{1-h}{2(1-\sigma_{c})} (\hat{\varepsilon}_{t}^{bD})^{2} + \\ + \hat{\varepsilon}_{t}^{b} (\hat{C}_{t}^{D} - h^{2} \hat{C}_{t-1}^{D}) - u_{1} (\hat{\pi}_{w,t}^{D} - \gamma_{w} \hat{\pi}_{D,t-1})^{2} - \\ - u_{2} (\hat{\pi}_{D,t} - \gamma_{P} \hat{\pi}_{D,t-1})^{2} - u_{3} (\hat{Y}_{t}^{D})^{2} + u_{4} \hat{Y}_{t}^{D} \hat{A}_{t}^{D} - \\ - u_{5} \hat{Y}_{t}^{D} (1 + \hat{\varepsilon}_{t}^{bD} + \hat{\varepsilon}_{t}^{LD}) \right]$$

#### 5.2. Model calibration

## Table 1

# PARAMETER VALUES USED IN THE CALIBRATION AND SIMULATION OF THE MODEL IN HOMOGENEOUS COUNTRIES (EQUAL PARAMETERS IN BOTH ECONOMIES)

Parameter	Description	Value
β	Intertemporal discount factor	0.99
h	Consumer persistence	0.6
σ <sub>c</sub>	Relative risk aversion coefficient on consumption	1.4
ω	Home bias	0.5
σι	Relative risk aversion coefficient on labour supply	2.4
γw	Wage indexation	0.75
ξw	Probability of not optimizing wages	0.7
φ	Labour demand elasticity	3
Ύ́́́́́	Price indexation	0.5
ξn	Probability of not optimizing prices	0.9
θ	Price elasticity	6
n	Size of the home economy	0.5
Ϋ́́́́́R	Interest rate smoothing	0.8
γ	Weight of inflation on the monetary policy rule	1.7
Ϋ́ν	Weight of the output gap	0.1
γ <sub>Δπ</sub>	Weight of the inflation differential	0.15
ΥΔκ ΥΔκ	Weight of the output differential	0.15
ρ <sub>b</sub>	Persistence of the preference shock	0.85
ρ,	Persistence of the labour supply shock	0.89
ρ	Persistence of the productivity shock	0.82
ρ <sub>m</sub>	Persistence of the monetary policy shock	0
	Size of the preference shock	0.4
	Size of the labour supply shock	3
	Size of the productivity shock	0.6
	Size of the monetary policy shock	0.1

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