Bragoli, Daniela; Rigon, Massimiliano; Zanetti, Francesco

**Working Paper**

# Optimal Inflation Weights in the Euro Area

BCAM Working Paper, No. 1503

**Provided in Cooperation with:**
Birkbeck Centre for Applied Macroeconomics (BCAM), Birkbeck, University of London

*Suggested Citation:* Bragoli, Daniela; Rigon, Massimiliano; Zanetti, Francesco (2015) : Optimal Inflation Weights in the Euro Area, BCAM Working Paper, No. 1503, Birkbeck, University of London, Birkbeck Centre for Applied Macroeconomics (BCAM), London, https://eprints.bbk.ac.uk/id/eprint/26636

This Version is available at:
https://hdl.handle.net/10419/318139

ISSN 1745-8587


BCAM 1503

# Optimal Inflation Weights in the Euro Area

***Daniela Bragoli***
Università Cattolica

***Massimiliano Rigon***
Bank of Italy

***Francesco Zanetti***
*University of Oxford*

July 2015


Birkbeck Centre for Applied Macroeconomics

# Optimal Inflation Weights in the Euro Area

Daniela Bragoli[1] Massimiliano Rigon[2] Francesco Zanetti[3]

**Abstract**

This study investigates the appropriate measure for stabilizing inflation in the Euro Area. We use a model that accounts for both the heterogeneity observed in the degree of price rigidities across regions and sectors, and asymmetry of real disturbances in relative prices. Our work shows that the optimal weights to assign to each region or sector result from complex interactions between the degree of price stickiness, economic size and the distribution of shocks within regions.

*Keywords*: Optimal monetary policy, Euro Area regions, asymmetric shocks, asymmetric price stickiness.

*JEL*: E52, F41.

[1]Università Cattolica, via Necchi 9, 29100 Milano (Italy), e-mail:daniela.bragoli@unicatt.it

[2]Bank of Italy, Via Cordusio 1, 20123 Milano (Italy), e-mail: massimiliano.rigon@bancaditalia.it;

[3]University of Oxford, Department of Economics, Manor Road,OX13UQ Oxford (UK), e-mail: francesco.zanetti@economics.ox.ac.uk.

**Aknowledgements:** We would like to thank Anna Agliari, Carlo Altavilla, Gianni Amisano, Adib Bagh, Pierpaolo Benigno, Tim Cogley, Domenico Giannone, Michele Lenza, Giovanni Lombardo, Marco Mazzoli, Andrea Tambalotti, John Williams and two anonymous referees for extremely useful comments and suggestions. Some of this work was completed while Francesco Zanetti was visiting the De Nederlandsche Bank; he would like to thank the Bank and its staff for their hospitality and support. All remaining errors are our own.

# 1 Introduction

The importance given to stabilizing inflation is not only in line with the ECBs primary objective as imposed by the Maastricht Treaty, but also with opinion in the academic literature, where, complete price stability within the class of sticky price models, constitutes a robust optimal monetary policy.[4] However, heterogeneity in the degree of price stickiness across regions and sectors, and asymmetry in the shocks is characteristic of the Euro Area. Therefore the practical implementation of targeted inflation policy crucially depends on which measure of inflation the ECB needs to establish to offset the distortions caused by price volatility. This paper investigates optimal inflation targeting for the Euro Area using a multi-region and sector model with asymmetric demand shocks.

At present, the ECB stabilizes the Monetary Union Index of Consumer Prices (MUICP), which is a sum of the single regions HICP indexes, weighted by the economic size of each region. This practice is in stark contrast with recent academic results that conclude that in a two-region model, optimal monetary policy must target inflation in the region with the highest degree of nominal rigidities instead of using an aggregate measure of inflation across regions.[5] This naturally raises the question of whether monetary policy should take into account the dispersion of inflation across regions and sectors in the Euro Area, which is characterized by different degrees of nominal price rigidities and asymmetric shocks across regions and sectors.

The idea of stabilizing a core price index is in the Keynesian tradition of focusing on a core rather than an overall cost of living index. This is also in line with the monetarist recommendation to stabilize a long-run index and ignore relative price movement such as oil price shocks (Goodfriend and King, 1997). In the empirical literature, Bryan and Cecchetti (1994) and Cogley (2002) identify core inflation as a more persistent component of inflation and consider it, from a policy point of view to be a more important indicator than broader inflation measurement, since fluctuations in food and energy prices are regarded as transitory components of overall movements in inflation.

[4] See Woodford (2003) and references therein.

[5] See Benigno (2004). A similar result holds in a two-sector model, as shown in Aoki (2001). We discuss these studies in the rest of the introduction.

Aoki (2001) and Benigno (2004) use a theoretical model to formalize these main empirical results. Aoki (2001) develops a two-sector dynamic general equilibrium model with a flexible-price sector along with a sticky-price sector and shows that the optimal monetary policy (characterized as an inflation targeting regime) stabilizes core inflation rather than a broader measure of inflation. Benigno (2004) focuses on the optimal policy in a currency area and develops a two region model. Benigno's main conclusion is that the optimal plan can be approximated by what he calls a second best solution. This allows for a context of asymmetric shocks and a different level of price rigidities between regions, and minimizes a welfare criterion that accounts for the exact magnitude of all the distortions in the economy. This is an inflation targeting policy in which greater weight is given to inflation in those regions characterized by a higher degree of nominal rigidity.

Our paper extends this line of research. We use the microeconomic evidence on the frequency of price adjustments in the Euro Area to verify whether the 'stickiness principle' underlined by the baseline models (Benigno, 2004 and Aoki, 2001) still holds in a more realistic multi-region setting. Moreover, given that differences in the frequency of price adjustment are significant not only across regions but also across sectors, we also investigate the difference between sectoral inflation targeting and region inflation targeting. This aspect is of crucial importance for the ECB which faces the challenge of aggregating Euro Area inflation across sectors and regions.

We develop a multi-region/sector model by focusing on $10$ regions and $10$ sectors, and go on derive a microfounded welfare function. We then use this criterion to determine the unconditional optimal monetary policy as described in Woodford (2003) and we compare it with two alternative policy regimes. First, a pure inflation-targeting regime, in which aggregate inflation is based on weighting inflation for each region/sector according to its economic size. Second, an optimal inflation-targeting regime, in which the weights for each region/sectors inflation are chosen optimally. We calculate the welfare deadweight loss of these two alternative regimes against the optimal policy that minimizes the microfounded welfare function.

The analysis establishes the following results. First, a pure inflation-targeting regime, in

which aggregate inflation is based on inflation weighting for each region/sector according to its economy size, is always suboptimal. The only exception is the case in which all regions/sectors have the same price stickiness. In all the other cases there is an optimal set of weights that do not coincide with the relative size of the regions/sectors. In addition, the optimal inflation target turns out to be a close proxy of optimal monetary policy since the welfare loss implied by these two monetary regimes is very similar.

Differing from a two region model, the presence of multiple regions and asymmetric demand shocks that impact on the natural level of relative prices, produces optimal weights from complex interactions between the degree of price stickiness, economic size and the distribution of the shocks within regions. In this case the 'stickiness principle' is less evident. Our results show that implementing the optimal inflation target is a difficult task for the ECB and there is not a simple rule-of-thumb rule that can be used to choose weights optimally.

Numerous related studies investigate optimal monetary policy under a variety of imperfections. Erceg *et al.* (2000) consider the case of distortions in goods and labor markets, Huang and Liu (2005) study the effect of nominal rigidities in the production of intermediate goods, and Bodenstein *et al.* (2008) focus on optimal policy when shocks originate in an energy sector. The common policy prescription across these studies is that inflation stabilization should attach more weights to the sectors in which nominal rigidities are more pronounced as they create larger real distortions. More recently, some studies have extended the design of monetary policy for a currency area in different directions making such 'stickiness principles' less clear cut. Lombardo (2006) considers a second source of heterogeneity across regions (i.e. a different degree of competition) together with the different degrees of nominal rigidity and shows that the weights attached to the region-specific inflation rates should increase with the degree of competition, implying an ambiguous outcome on the inflation weights if the model requires a positive correlation between price flexibility and degree of competition.

Benigno and Lopez-Salido (2006) deepen Benigno (2004) framework by assuming that a fraction of firms set prices in a backward looking fashion. They find that the optimal inflation targeting policy model, which re-weighs countries according to degrees of rigidity and their

component of backward looking firms and their output gap stabilization policy, performs better than the HICP inflation targeting only for some calibrations of the model in terms of welfare, thus suggesting that it may not be desirable for the ECB to abandon HICP targeting. Finally, Eusepi *et al.* (2011) develop a multi-sector New Keynesian model, calibrated to match U.S. data on price stickiness, labor shares and inflation across sectors, to show that optimal inflation targeting can be closely approximated by a core inflation target which does not include the more volatile components of the PCE-based price index.

The remainder of the paper is structured as follows. Section 2 provides evidence on heterogeneity in the Euro Area across regions and sectors. Section 3 lays out the theoretical model. Section 4 derives the welfare function and outlines the optimal monetary policy and inflation targeting plans. Section 5 describes the calibration of the model. Section 6 reports the results of the simulations. Section 7 contains the conclusions.

## 2 Heterogeneity in Euro Area regions and sectors

In this section, we compare the size and frequency of price adjustment for regions and sectors within the Euro Area, using the micro evidence of price setting for Euro Area countries in Dhyne *et al.* (2006). We focus on $10$ regions within this area and on $10$ macro sectors. The number of regions and sectors considered is primarily related to data availability on the frequency of price changes. We will use this information to calibrate the theoretical model described in the next section.

Consumer price inflation in the Euro Area is measured by the Harmonized Index of Consumer Prices (HICP), compiled by Eurostat and the national statistical institutes using harmonized statistical methods. Each Member State measures the month to month movements in sector prices as an average of price indexes, using expenditure weights ($n_s$), which are an appropriate reflection of consumption patterns . The HICP is classified according to the four-digit categories and sub-categories of the Classification Of Individual Consumption by Purpose (COICOP). HICPs provide the basis for compiling the Monetary Union Index of Consumer

Prices (MUICP), which provides the official measure of inflation in the Euro Area. The MUICP is calculated as a weighted average of the HICPs of the participating regions of the EMU, where the weights $(n_r)$ are represented by the economic size of each region.[6]

The ECB remit is to maintain annual MUICP inflation rates below, but close to $2\%$ over the medium term. According to the theoretical academic results highlighted in the introduction, the ECB choice to target aggregate inflation should consider not only the economic size of regions/sectors, but also the distribution of price stickiness. The second column in Table 1 reports the economic size of each region (top table) and the economic size of each sector in the economy (bottom table), calculated according to consumer expenditure in each region or sector. Most of the larger regions measured in terms of consumption expenditure (e.g., Germany, Italy and Spain), with the exception however of France, show a higher degree of price stickiness. Looking at sectors, Restaurants and Hotels (which account for about thirty per cent of total expenditure) show the lowest frequency of price adjustment while the Energy sector is the most flexible sector in terms of price changes. The importance of the frequency of price adjustment is evaluated in the fourth column by the duration of price contracts which can be approximated by the reciprocity of price change frequency.[7]

The frequency of price changes, calculated within the Euro System Inflation Persistence Network as an average over the period $1996$-$2001$, represents the average share of prices that are revised in a given month (see Dhyne *et al.*, 2006 for its calculation). The monthly frequency of price changes for the Euro Area is equal on average to $15.0\%$, while this works out at $24.8\%$ for the US, according to Bils and Klenow (2004) calculations on a sub-sample of $50$ products. According to Dhyne *et al.* (2006), the source of cross-region variation is likely to be both structural (consumption structure, outlet composition) and methodological (the treatment of sales and quality adjustment by each National Statistical Institute), or reflects differences in the relative importance of regulated prices across regions. Nevertheless, Table 1 shows that there is a

[6]Up to $2000$ the weight of a Member State is calculated as the share of private domestic consumption expenditure in the EMU, from $2001$ the region weight of a member state is calculated as the share of household final monetary consumption expenditure of the Euro Area.

[7]The duration of price contracts should be read with caution given that according to Dhyne *et al.* (2006), the inverse frequency calculated as a proxy of average duration turns out to be systematically much lower than the average duration.

high degree of heterogeneity in price adjustments across both regions and sectors in the Euro Area, which may represent an effective challenge for the conduct of monetary policy.

Table 1: *Economic Size and Frequency of Price Adjustment in Europe*

| | economic size ($n_r$) | frequency of price adjustment | average duration in quarters |
|---|---|---|---|
| Italy | 19.9 | 10.0 | 3.3 |
| Spain | 12.5 | 13.3 | 2.5 |
| Germany | 30.0 | 13.5 | 2.5 |
| Austria | 3.3 | 15.4 | 2.1 |
| Netherlands | 5.4 | 16.2 | 1.9 |
| Belgium | 3.5 | 17.6 | 1.6 |
| Finland | 1.6 | 20.3 | 1.6 |
| France | 21.2 | 20.9 | 1.6 |
| Portugal | 2.3 | 21.1 | 1.6 |
| Luxembourg | 0.3 | 23.0 | 1.4 |
| EURO AREA | | 15.1 | 2.2 |
| US | | 24.8 | 1.3 |
| | economic size ($n_s$) | frequency of price adjustment | average duration in quarters |
| Restaurants and Hotels | 30.3 | 4.2 | 7.9 |
| Housing | 2.7 | 6.5 | 5.1 |
| Recreation and Culture | 6.5 | 6.6 | 5.1 |
| Furnishing, Household Equipment | 5.0 | 7.2 | 4.6 |
| Transport and Communications | 8.5 | 7.2 | 4.6 |
| Miscellaneous goods and services | 4.8 | 7.3 | 4.5 |
| Clothing | 16.2 | 8.4 | 4.0 |
| Processed food | 7.4 | 12.5 | 2.7 |
| Unprocessed food | 7.8 | 37.2 | 0.9 |
| Energy | 10.8 | 78.8 | 0.4 |

**Table Notes**

$n_r$: region share of household monetary consumption expenditure

$n_s$: expenditure weights which reflect the consumption patterns of households

**frequency of price adjustment:** represents the average share of prices revised in a given month

**average duration in quarters:** inverse of the frequency of price adjustment

**Source:** Dhyne et al (2006) for Euro Area data; Bils and Klenow (2004) for the US

## 3 The model

We develop a multi-region model similar to Benigno (2004) and Aoki (2001) to accommodate the microeconomic evidence on price stickiness across regions and sectors described in the previous section. This addresses the question of what is the optimal inflation targeting policy in a currency area such as the Euro Area.[8] Ideally one would have to consider regions and sectors in a joint model with two degrees of heterogeneity within regions and between regions. In this paper, we are going to consider this model but with two different calibrations, focusing respectively on different frequencies of price adjustment across both regions and sectors.[9]

The economy is made up of a continuum of agents defined over the unit interval $[0, 1]$. Each agent manufactures a single differentiated product, $u$, and consumes a fraction of all the goods produced in the economy. In each region, a measure $n_i$ of goods is produced, with $i = 1, 2, ..., K$, and the total sum of produced goods is normalized equal to one, such that $\sum_{i=1}^{K} n_i = 1$. All produced goods are traded across regions and there is no migration across regions. Goods are differentiated and prices are set on a staggered basis. In the economy there is a single central bank and $K$ fiscal authorities, each of which has sovereignty over one region only.

The demand side of the model comprises household's $j$ preferences defined by

$$U_t^j = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[ U(C_s^j) + L\left( \frac{M_s^j}{P_s}, \xi^i \right) - V(y_s^j, z_s^j) \right],$$

where the upper index $j$ denotes a variable that pertains to agent $j$, while the upper index $i$ denotes a variable specific to region $i$. The term $E_t$ denotes the expectation conditional on the information set at date $t$, and the parameter $\beta$ is the intertemporal discount factor $0 \leq \beta \leq 1$. During each period $s$, each agent $j$ gains utility from a consumer basket, $C_s^j$, of goods produced

[8] The theoretical framework is also close and extends the works by Galí and Monacelli (2005) and Soffritti and Zanetti (2008).

[9] We thank an anonymous referee for this suggestion.

in region $i$, defined as

$$C_i^j \equiv \left[ \left( \frac{1}{n^i} \right)^{\frac{1}{\sigma}} \int_{u \in i} c^j(u)^{\frac{\sigma-1}{\sigma}} du \right]^{\frac{\sigma}{\sigma-1}},$$

and this applies to the liquidity services of holding money ($M_s^j/P_s$), while he/she receives disutility from producing goods, $V(y_s^j, z_s^j)$.

The terms $\xi^i$ and $z_s^j$ denote exogenous shocks to (region-specific) money holdings and (agent-specific) disutility from production respectively. The consumption index, $C^j$, is defined as $C^j \equiv \left[\prod_{i=1}^K (C_i^j)^{n_i}\right] \left[\prod_{i=1}^K n_i\right]^{-1}$, for $i = 1, 2, ..., K$. The parameter $\sigma > 1$ is the elasticity of substitution across goods produced within a region[10], whereas the elasticity of substitution between the bundles $C_i$ is set equal to 1. The total demand for each good $u$ produced in region $i$ is

$$y_i^d(u) = \left( \frac{p(u)}{P_i} \right)^{-\sigma} \left( \frac{C^W}{P_i^R} + G_i \right),$$

where $p(u)$ is the price of the product $u$, $C^W$ is union aggregate consumption, (defined as $C^W \equiv \int_0^1 C^j dj$), $P_i^R$ is the relative price in region $i$, defined as $P_i^R \equiv P_i/P$, where $P_i = \int_0^1 p(u)du$ and $P = \left[\prod_{i=1}^K (P_i)^{n_i}\right] \left[\prod_{i=1}^K n_i\right]^{-1}$, $G_i$ is public expenditure in region $i$.

Aggregate demand is represented by standard Euler equations derived by maximizing the utility function subject to budget constraints for each household $j$ in each region $i$.

The supply side of the model comprises imperfectly competitive firms that set prices as in Calvo (1983). In each period, a seller faces a fixed probability $1 - \alpha$ of adjusting its price, and receives a subsidy $\tau^i$ that offsets the distortions generated by monopolistic competition in the steady state. Producers in the same region set similar prices since they face the same discounted future demands and future marginal costs under the hypothesis that the new price is maintained. The optimal price, $\tilde{p}_t(u)$, is given by:

$$\tilde{p}_t(u) = \frac{\sigma}{(\sigma-1)(1-\tau^i)} \frac{E_t \sum_{k=0}^{\infty} (\alpha^i \beta)^k V_y(\tilde{y}_{t,t+k}^d(u), z_{t+k}^i) \tilde{y}_{t,t+k}^d(u)}{E_t \sum_{k=0}^{\infty} (\alpha^i \beta)^k \lambda_{t+k} \tilde{y}_{t,t+k}^d(u)}, \quad (1)$$

[10] In this model $\sigma$ is common to all regions. For an heterogeneous degree of competition see Lombardo (2006).

where $\tilde{y}^d_{t,t+k}(u)$ is the total demand for good $u$ at time $t+k$, $\lambda_{t+k} = U_C(C_{t+k})/P_{t+k}$ with $U_C(C_{t+k})$ denoting the marginal utility of consumption, and $V_y(\tilde{y}^d_{t,t+k}(u), z^i_{t+k})$ is the derivative of the disutility function $V(\cdot)$ with respect to total demand. The state equation for aggregate prices in each region is:

$$P^{1-\sigma}_{i,t} = \alpha^i P^{1-\sigma}_{i,t-1} + (1-\alpha^i)\tilde{p}_t(u)^{1-\sigma}, \tag{2}$$

for $i = 1, 2, ..., K$. Aggregate supply is represented by standard New Keynesian Phillips curves derived by combining equations (1) and (2) for each region $i$.

The model is closed by requiring that the government of each region $i$ maintain a balanced budget, and assuming that the instrument of monetary policy is set in terms of the one period risk-free interest rate on the nominal bonds denominated in the common currency.

## 3.1 Equilibrium under flexible and sticky prices

We first focus on fluctuations around the steady state in the flexible-price model since it is the relevant equilibrium for welfare evaluation. We then describe the model with sticky prices.

Before proceeding with the analysis some of the notation we use should be clarified. We denote the log-deviation of $X_t$ from its steady state in the flexible-price model with $\tilde{X}_t$, while $\hat{X}_t$ denotes the deviation of the same variable in the sticky-price model. A world variable $X^W$ is defined as $X^W \equiv \sum_{i=1}^K n_i X_i$. In addition, $X^R_i$ denotes a relative variable with respect to the world, defined as $X^R_i \equiv X_i - X^W$.

The solution of the model with flexible prices is described by the equations:

$$\tilde{C}^W_t = \frac{\eta}{\rho+\eta}(\bar{Y}^W_t - g^W_t), \tag{3}$$

$$\tilde{Y}^W_t = \frac{\eta}{\rho+\eta}\bar{Y}^W_t + \frac{\rho}{\rho+\eta}g^W_t, \tag{4}$$

$$\tilde{P}^R_{i,t} = \frac{\eta}{1+\eta}(g^R_{i,t} - \bar{Y}^R_{i,t}), \tag{5}$$

where $\bar{Y}^R_{i,t}$ ($\bar{Y}^W_t$) and $g^R_{i,t}$ ($g^W_t$) are region-specific (world) shocks to supply and government

purchase respectively, and $\eta$ and $\rho$ respectively are the inverse elasticity of goods production and the inter-temporal elasticity of consumption substitution. The natural interest rate, $\tilde{R}_t$, in equilibrium, under zero inflation rate, is

$$\tilde{R}_t = \frac{\rho\eta}{\rho+\eta} E_t[(\bar{Y}^W_{t+1} - \bar{Y}^W_t) - (g^W_{t+1} - g^W_t)]. \tag{6}$$

The solution of the model with sticky prices is described by the standards Euler and aggregate output equations:

$$E_t\hat{C}^W_{t+1} = \hat{C}^W_t + \rho^{-1}(\hat{R}_t - E_t\pi^W_{t+1}), \tag{7}$$

$$\hat{Y}_{i,t} = -\hat{P}^R_{i,t} + \hat{C}^W_t + g^i_t, \tag{8}$$

defined for each region $i = 1, 2, ..., K$. Similarly, the aggregate supply equation for each region $i = 1, 2, ..., K$, is equal to:

$$\pi^i_t = \beta E_t\pi^i_{t+1} - k^i_P(\hat{P}^R_{i,t} - \tilde{P}^R_{i,t}) + k^i_C(\hat{C}^W_t - \tilde{C}^W_t), \tag{9}$$

which shows that region-specific inflation rates depend on the expectations of future price setting behavior[11] as well as on both the deviations of the union output gap from zero and relative prices from their natural rates. In addition, the definition of relative price for each region $i = 1, 2, ..., K$ implies

$$\hat{P}^R_{i,t} = \hat{P}^R_{i,t-1} + \pi^i_t - \pi^W_t. \tag{10}$$

The equilibrium dynamics of the variables $\{\tilde{C}^W_t, \tilde{Y}^W_t, \tilde{P}^R_{i,t}, \tilde{R}_t, \hat{C}^W_t, \hat{Y}_{i,t}, \hat{P}^R_{i,t}, \hat{P}^R_{i,t}, \pi^i_t, \pi^W_t, \hat{R}_t\}$ is described by equations (3) - (10) together with the equation for the monetary policy rule and the definitions of world variables $\hat{C}^W_t$ and $\pi^W_t$.

[11] Benigno and Lopez-Salido (2006) allow for an hybrid model in which past inflation plays a role in the inflation dynamics that we do not consider.

[2] Note that $k^i_C \equiv [(1-\alpha^i\beta)(1-\alpha^i)/\alpha^i][(\rho+\eta)/(1+\rho\eta)]$, and $k^i_P = k^i_C[(1+\eta)/(\rho+\eta)]$.

## 3.2 Shocks structure

Following Benigno (2004) we impose an asymmetric demand shock. We implement this shock by assuming that the natural level of relative prices $\tilde{P}^R_{i,t}$ moves proportionally to the exogenous process $\zeta_t$ defined as follows:

$$\tilde{P}^R_{i,t} = p_i \zeta_t$$

with

$$\zeta_t = \phi \zeta_{t-1} + \varepsilon_t,$$

where $\varepsilon_t$ is a white noise shock with zero mean and variance equal to $\sigma^2_\epsilon$. We assume that all regions show the same persistence of the shock affecting the flexible relative prices whose variance is $\sigma^2_{\tilde{P}^R_{i,t}} = p_i^2 \sigma^2_\epsilon$.

In order for the shock structure to be consistent, given that the shocks refer to relative prices, we need to impose the following constraint:

$$\sum_{i=1}^{K} n_i p_i = 0. \tag{11}$$

Equation (11) describes how the shock is distributed across regions. In a two-region model only the shock to one region needs to be imposed for the shock to the other region to be automatically calculated. In a multi-region case we can assume different distributions of the shock across regions that are consistent with equation (11).

In Section 6 we investigate how both optimal inflation weights and welfare losses are affected by such alternative distributions.

## 4 Welfare comparison

The main goal of the ECB is to stabilize the Monetary Union Index of Consumer Prices (MUICP), which is a weighted average of the single regions HICP index, and the weights are the economic size of each region. However, Benigno (2004) shows that in a two-region model with asymmetries in price rigidity, the optimal policy involves giving higher weights to the inflation in regions with a higher degree of nominal rigidity. In order to investigate to what extent the two region results hold in a multi-region setting, we derive the optimal monetary policy and then evaluate it against two alternative policy regimes. Firstly, a pure inflation targeting regime, in which aggregate inflation weights the inflation of each region according to its economy size. Secondly, an optimal inflation targeting regime, in which the weights to each region inflation are chosen optimally.

The optimal monetary policy is obtained as the minimization of a deadweight loss from the discounted sum of a weighted average of the average utility flows of all households across all regions $K$, assuming that the liquidity services provided from holding real money balances are small. The welfare criterion is therefore defined as:

$$\mathbf{W}_t = E_0 \sum_{j=0}^{\infty} \sum_{i=1}^{K} \beta^j n_i \left[ U(C^j_{t+j}) - \int_0^1 V(y_{t+j^j}, z^j_{t+j}) dj \right], \tag{12}$$

To evaluate welfare we use a second-order Taylor expansion of $\mathbf{W}_t$ around the steady state, as in Woodford (2003) and Benigno (2004), which leads to re-write equation (12) as: $\mathbf{W}_t = -\Omega E_t \sum_{j=0}^{\infty} \beta^j L_{t+j}$,with

$$L_{t+j} = \Lambda[c^W_{t+j} - \bar{c}^W]^2 + \Gamma[\sum_{i=1}^{K} n_i(\hat{P}^R_{i,t} - \tilde{P}^R_{i,t})^2] + \sum_{i=1}^{K} \varsigma_i(\pi^i_{t+j})^2 + t.i.p. + o(\|\xi\|^3), \tag{13}$$

where $t.i.p.$ denotes parameters independent from policy, $o(\|\xi\|^3)$ includes terms of third or

higher order and the coefficients $\Omega$, $\Lambda$, $\Gamma$, $\varsigma_i$ and $d^i$ are defined as:

$$\begin{aligned}
\Omega &\equiv \frac{1}{2}U_C\bar{C}(\sum_{i=1}^{K} n_i d^i)\sigma(1+\sigma\eta), \\
\Lambda &\equiv \frac{1}{\sigma}(\sum_{i=1}^{K} n_i (k_C^i)^{-1})^{-1}, \\
\Gamma &\equiv \frac{1}{\sigma}(\sum_{i=1}^{K} n_i (k_P^i)^{-1})^{-1}, \\
\varsigma_i &\equiv \frac{n_i d^i}{(\sum_{i=1}^{K} n_i d^i)}, \\
d^i &\equiv \frac{\alpha^i}{(1-\alpha^i)(1-\alpha^i\beta)}.
\end{aligned}$$

The loss function (13) shows that a currency union has three sources of inefficiency. First, an inefficient output level, second, inefficient price dispersion and, third, inefficient response of relative prices to asymmetric shocks due to price stickiness. Equation (13) shows that the first best option is one in which the central bank offsets the three inefficiencies. However this outcome is not feasible if the degree of price stickiness differs across regions because of the mismatch between objectives and instruments.

As described in the next section we use $\mathbf{W}_t$ to derive the optimal monetary policy. However, we use the unconditional expectation of the welfare function (as in Woodford, 1999), to compare the welfare loss in alternative monetary policies:

$$W = 100 \cdot \Omega \cdot E(E_0 \mathbf{W}_{t+j})$$

$$W = -100 \cdot \Omega \cdot \left[ \Lambda var\left(\hat{y}_t^w\right) + \Gamma \sum_{i=0}^{K} n_i var\left(\hat{P}_{i,t}^R - \tilde{P}_{i,t}^R\right) + \sum_{i=0}^{K} \varsigma_i var\left(\hat{\pi}_{i,t}\right) \right], \qquad (14)$$

where $U_C\bar{C}$ has been normalized to 1. The expectation $E_0$ is calculated at time zero based on all the information available at that date. Its conditionality is based on the initial conditions of the two state variables $\hat{P}_{i,t-1}^R = 0$ and $\tilde{P}_{i,t-1}^R = 0$. The expectation $E$ is obtained by integrating over the stationary distributions of $\tilde{P}_{i,t,-1}^R$.

## 4.1 The optimal plan

The central bank chooses $\left\{\hat{y}_t^w, \hat{\pi}_{i,t}, \hat{P}_{i,t}^R\right\}$ to minimize the welfare function (12) subject to the New Keynesian Phillips curves (9) and the definition of relative prices (10). In this work we let $\varphi_{i,t}$ be the Lagrange multiplier associated with equation (9) and $\psi_{i,t}$ the Lagrange multiplier associated with equation (10), and assume the initial conditions $\varphi_{i,-1} = \psi_{i,-1} = \hat{p}_{i,-1} = 0$.

Having solved the optimization problem, we write the equilibrium conditions as a system of first order stochastic difference equations:

$$A \cdot \hat{x}_{t+1} = B \cdot \hat{x}_t + C \cdot \varepsilon_t.$$

where the column vector $\hat{x}_{t+1}$ contains all the endogenous and exogenous variables of the model $\left\{\hat{y}_{t+1}^w, \hat{P}_{i,t+1}^R - \tilde{P}_{i,t+1}^R, \hat{\pi}_{i,t+1}, \psi_{i,t}, \tilde{P}_{i,t+1}^R, \hat{P}_{i,t}^R, \varphi_{i,t}\right\}$, while $\varepsilon_t$ is the column vector of regional specific shocks. The square matrices $A$ and $B$ are functions of the structural parameters of the model. The system is reduced to the following state space form representation:

$$\hat{x}_t = D \cdot \hat{s}_t$$

$$\hat{s}_t = G \cdot \hat{s}_{t-1} + H \cdot \varepsilon_t,$$

where the column vector $\hat{s}_t$ contains the state variables of the system $\left\{\tilde{P}_{i,t}^R, \hat{P}_{i,t-1}^R, \varphi_{i,t-1}\right\}$.

## 4.2 Inflation targeting

As mentioned in the previous section, we use the optimal plan as a benchmark to evaluate the performance of alternative inflation targeting rules. Following Benigno (2004), we focus on two different rules. The first one is a pure inflation targeting rule where the measure of inflation that the central bank aims to stabilize is the average inflation rate of the $K$ regions, which means

$$\sum_{i=0}^{K} n_i \hat{\pi}_{i,t} = \hat{\pi}_t^w = 0 \tag{15}$$

This measure of inflation resembles the actual goal of the ECB. Equation (15) can be interpreted as the MUICP (Monetary Union Index of Consumer Prices), which is a weighted sum of the single regions HICP index weighted by the economic size of each region. We compare the welfare loss entailed by this rule with the one obtained under the optimal inflation targeting defined as

$$\sum_{i=0}^{K} \gamma_i^{opt} \hat{\pi}_{i,t} = 0,$$

where the weights $\gamma_i^{opt}$ are not given by the economic size of the regions, but chosen optimally in order to minimize the welfare loss (12) with the following constraints:

$$\gamma_i^{opt} \in [0,1] \ , \ for \ i = 1....K$$

and

$$\sum_{i=0}^{K} \gamma_i^{opt} = 1.$$

It can be easily shown that if the central bank follows an inflation targeting rule, the variables $\left\{ \hat{y}_t^w, \hat{\pi}_{i,t}, \hat{P}_{i,t}^R \right\}$ can be written as linear combinations of two groups of state variables: the relative prices $\hat{P}_{i,t-1}^R$ and the natural level of relative prices $\tilde{P}_{i,t}^R$. Hence the system of equations under inflation targeting assumption becomes:

$$\hat{z}_t = D \cdot \hat{z}_{t-1} + H \cdot \varepsilon_t,$$

where $\hat{z}_t$ is the column vector of variables $\left\{ \tilde{P}_{i,t+1}^R, \hat{y}_{t+1}^w, \hat{P}_{i,t+1}^R - \tilde{P}_{i,t+1}^R, \hat{\pi}_{i,t+1}, \hat{P}_{i,t}^R \right\}$. All the entries of the square matrix D are zeros with the exception of the first and the last K columns corresponding to the state variables.

## 5 Calibration

To simulate the model we calibrate the structural parameters. The level of price stickiness ($\alpha_c$ and $\alpha_s$) and the economic sizes of the regions/sectors ($n_c$ and $n_s$) are calibrated using microdata on price stickiness in Europe as well as the weights used by Eurostat to create the MUICP index for regions and the HICP index for sectors, as described in Section 2 (Table 1).

The structural parameters that are common across sectors and regions are calibrated following Benigno (2004) and Rotemberg and Woodford (1997). The intertemporal discount factor ($\beta$) is set equal to $0.99$, which approximately corresponds to a gross real rate of return ($\beta^{-1}$) of $1.01$ on average and on a quarterly basis. The degree of monopolistic competition ($\sigma$) is set equal to $7.66$, which corresponds to a mark up of prices over marginal cost of around $15\%$.[12] The risk aversion coefficient (or the inverse of the intertemporal elasticity of substitution of consumption ($\rho$)), is set equal to $0.16$ as in Benigno (2004).[13] Assuming that the average real wage with respect to variations in production is $0.5$ in the Euro Area[14], the value of $\rho$ is compatible with an elasticity of labor supply equal to $0.67$, which is in line with the micro and macro evidence, as described in Keane and Rogerson (2012). Assuming labor as the only input factor in the production function, such value implies that in the steady state workers allocate around $60\%$ of their time to working activity.

We set the parameter $\phi$, which measures the degree of persistence of the Markovian process for the relative price under flexible prices, equal to $0.95$ and the variance of the region specific white noise shocks $\sigma_\epsilon^2$ equal to $0.0086^2$. This is consistent with the international RBC literature on the calibration of asymmetric productivity shocks.

[12] We also experimented with values between $4$ and $11$, as in Nakamura and Steinsson (2008) and Carvalho (2006), and results remain robust.

[13] We also try a risk aversion coefficient equal to $1$ as a robustness check.

[14] Rotemberg and Woodford (1997) calibrate a value of $0.47$ for the US. We also try this value for a robustness check.

## 6 Results

In this section we present the results of the simulations. We start by considering whether our multi-region model is consistent with the two-region model developed in Benigno (2004). In order to replicate the same calibration exercise as in Benigno (2004), the $10$ regions are split into two macro regions of approximately equal size. For this purpose it is convenient to include Italy, Austria, Belgium, France and Portugal in the first macro region, whereas we include Spain, Germany, the Netherlands, Finland and Luxembourg in the second macro region. In this way the shares of aggregate consumption in these two macro regions work out at about $50.1\%$ and $49.9\%$ of the total. The size of each macro region is computed as the sum of the economic sizes of the regions belonging to it, and price stickiness as a weighted average of the stickiness of each country within each macro region, where the weights are given by the economic size of each country ($n_r$).

In a model with two equal size regions implementing an asymmetric shock to flexible relative prices, such as the one described in Section 3.2, turns out to be straightforward, since the shock impacting on the two macro regions has the same size and opposite sign. Although the two macro regions have different degrees of price stickiness, the changes in relative prices in the first region mimics exactly the changes in the second region. The same reasoning applies to inflation which has the same size and opposite sign in the two macro regions.

Table 2 reports the welfare reduction, expressed in terms of consumption units, for the three different policies derived in Section 4: inflation targeting $W_{IT}$, optimal targeting $W_{OT}$ and optimal plan $W_{OP}$. The deadweight loss reduction (DR) represents the percentage reduction in the deadweight loss that society can obtain by using the optimal inflation targeting instead of the pure inflation targeting. The percentage reduction is calculated as

$$DR \equiv \frac{E[W_{IT}] - E[W_{OT}]}{E[W_{IT}] - E[W_{OP}]} \times 100$$

Table 2 shows that optimal targeting outperforms inflation targeting. In fact, the implied welfare reduction measured by the unconditional loss function in equation (14) comes very close to that

of the optimal plan. As pointed out in Benigno (2004), when the central bank is allowed to optimally choose the weights, it turns out to be welfare improving to assign higher weights (with respect to its economic size) to the region with more sluggish prices. The bottom panel of Table 2 shows that the same applies if we consider sectors instead of regions. Given that price stickiness in the two macro sectors is very dispersed compared to the macro regions, the sector optimal weights turn out to be different from the ones imposed by pure inflation targeting.[15]

Table 2: **A two region/sector model**

| **Regions** | | | | |
|---|---|---|---|---|
| | economic size | shock proportion | price adjustment | optimal weights |
| | $(n_r)$ | $(p_r)$ | $(1-\alpha_r)$ | $(\gamma_r^{opt})$ |
| Macro Region1 | 50.13 | + | 15.99 | 45.03 |
| Macro Region2 | 49.87 | - | 14.02 | 54.97 |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.1035 | -0.1021 | -0.1021 | 97.84 |
| **Sectors** | | | | |
| | economic size | shock proportion | price adjustment | optimal weights |
| | $(n_s)$ | $(p_s)$ | $(1-\alpha_s)$ | $(\gamma_s^{opt})$ |
| Macro Sector1 | 50.20 | + | 6.14 | 91.73 |
| Macro Sector2 | 49.80 | - | 27.74 | 8.27 |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.1690 | -0.0843 | -0.0822 | 97.53 |

**Table Notes**

**Macro Region1**: Italy, Austria, Belgium, France, Portugal; **Macro Region2**: Spain, Germany, Netherlands, Finland, Luxembourg.
**Macro Sector1**: Restaurants and Hotels, Housing, Furnishing, Household Equipment, Miscellaneous Goods and Services, Processed food.
**Macro Sector2**: Recreation and Culture, Transport and Communications, Clothing, Unprocessed food, Energy.
**DR**: Deadweight Loss Reduction

The interaction among variables becomes more complex in a multi-region model. The central bank itself faces a minimization problem where the welfare loss depends on several variables (i.e. aggregate output gap, relative prices and inflation rates for each region). Moreover, we need to decide how the different regions are affected by asymmetric shock to flexible relative prices. In fact, it differs from a two region model because there are several alternative patterns of asymmetric shocks that satisfy the condition imposed by equation (11).

[15]Note that when we group together different regions, averaging their price stickiness and economic size, we disregard the differences across regions. However, the analysis is focused on evaluating what happens within each macro region when we take explicitly into account that regions have a different economic size and a different degree of price stickiness. In particular, we are interested in testing whether the 'stickiness principle' holds within each macro region or only between the two macro regions.

In this analysis we assume that half the regions experience a positive shock to their flexible relative price, which means that their relative prices increase, whereas the other half incurs a negative shock, with an implied relative price decrease. We also assume that the shock is uniformly distributed within each macro region.

As pointed out by Benigno (2004), when all regions have the same degree of price stickiness the optimal weights coincide with the economic size of the regions and pure inflation targeting leads to the same welfare loss as the optimal plan[16]. When we relax this assumption we are able to evaluate how the optimal weights change with the degree of price rigidity and the welfare gain implied by an optimal inflation targeting.

In Table 3 and 4 we report the results of our multi-region model. In particular, we look, on the one hand, at different combinations of countries belonging to each of the two macro regions. In Panel A of both tables, regions are split into the same macro regions reported in Table 2 whereas in Panel B of both tables we group the first five more rigid regions together and then the first five more flexible ones . On the other hand, in order to gain more insight into the results, we compare the case in which all regions have the same economic size (Table 3), with that in which the observed size of each region is considered (Table 4). Observing regions with the same economic size is interesting because it implies that the two macro regions have the same size and consequently are hit by shocks characterized by the same intensity and opposite sign. In other words, the regions in Table 3 differ only in their price stickiness and the sign of the shock that impacts on their relative prices.

Tables 3 and 4 show that, although optimal inflation targeting clearly outperforms inflation targeting in terms of welfare reduction, results on the optimal weights tend to partially contrast with the 'stickiness principle', since the optimal weights are not strictly allocated according to the degree of rigidity in the frequency of price adjustment. In the specific examples that we put forward the region with the higher degree of price adjustment rigidity within macro regions receives the highest weight. Italy, the most rigid region in Table 3 (Panel A), holds the highest weight ($26.45\%$) and Spain, the most rigid region in the second macro group, holds the

[16]We confirm this result in a multi-region setting.

second highest weight ($13.92\%$) although its price adjustment frequency is higher with respect to other regions. The same pattern emerges in Panel B where the stickiest regions in the two macro regions are Italy ($57.89\%$) and Belgium ($31.70\%$). The optimal weights are not strictly allocated according to the sluggishness of their price adjustment, even though the less/more sticky macro region/sector receives a lower/higher weight with respect to its economic size, within each group.

The exercise shows that in a context of asymmetric shocks to relative prices, the optimal inflation weights are not exclusively related to price stickiness and economic size, but also to how the shocks are distributed across regions. The optimal weights are sensitive to the composition of the macro regions (Panel A versus Panel B) and to the economic size/shock intensity of the two macro regions (Table 3 versus Table 4), showing that there is no simple rule-of-thumb to establish the optimal weights.

Table 5 reports simulations on economic sectors and shows that the results are similar to the regional analysis. We still assume that half of the sectors receive a uniformly distributed positive shock to the flexible relative price and the other half a uniformly distributed negative shock. We include in the first group Restaurants and Hotels, Housing, Furnishing and Household Equipment, Miscellaneous Goods and Services and Processed Food while in the second group we include Recreation and Culture, Transport and Communications, Clothing, Unprocessed Food and Energy. Table 5 shows that the most sticky sector in each group receives the highest optimal weight. Interestingly, in line with the findings in the literature that proposes the stabilization of a core price index that excludes goods with a high frequency of price change (Bryan and Cecchetti, 1994; Aoki, 2001; Cogley, 2002; Eusepi *et al.*, 2011), we observe that food and energy also receive very low weights in this context. Finally, for sectors the welfare gain due to optimal inflation targeting is also high.

Table 3: **Optimal weights with equal Economic size (Regions)**

| | **PANEL A** | | | |
|---|---|---|---|---|
| | economic size ($n_r$) | shock proportion ($p_r$) | price adjustment ($1-\alpha_r$) | optimal weights ($\gamma_r^{opt}$) |
| Italy | 10.00 | + | 10.00 | 26.45 |
| Austria | 10.00 | + | 15.40 | 1.24 |
| Belgium | 10.00 | + | 17.60 | 3.09 |
| France | 10.00 | + | 20.90 | 12.23 |
| Portugal | 10.00 | + | 21.10 | 9.42 |
| Spain | 10.00 | - | 13.30 | 13.92 |
| Germany | 10.00 | - | 13.50 | 11.75 |
| Netherlands | 10.00 | - | 16.20 | 9.77 |
| Finland | 10.00 | - | 20.30 | 1.11 |
| Luxembourg | 10.00 | - | 23.00 | 11.03 |
| **Macro Region1a** | **50.00** | **+** | **17.00** | **50.60** |
| **Macro Region2a** | **50.00** | **-** | **17.26** | **49.40** |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.0999 | -0.0999 | -0.0999 | 97.67 |
| | **PANEL B** | | | |
| | economic size ($n_r$) | shock proportion ($p_r$) | price adjustment ($1-\alpha_r$) | optimal weights ($\gamma_r^{opt}$) |
| Italy | 10.00 | + | 10.00 | 57.89 |
| Spain | 10.00 | + | 13.30 | 0.02 |
| Germany | 10.00 | + | 13.50 | 0.02 |
| Austria | 10.00 | + | 15.40 | 0.03 |
| Netherlands | 10.00 | + | 16.20 | 10.34 |
| Belgium | 10.00 | - | 17.60 | 31.70 |
| Finland | 10.00 | - | 20.30 | 0.01 |
| France | 10.00 | - | 20.90 | 0.00 |
| Portugal | 10.00 | - | 21.10 | 0.00 |
| Luxembourg | 10.00 | - | 23.00 | 0.00 |
| **Macro Region1b** | **50.00** | **+** | **13.68** | **65.58** |
| **Macro Region2b** | **50.00** | **-** | **20.58** | **34.42** |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.1107 | -0.0987 | -0.0985 | 98.79 |

**Table Notes**

**Macro Region 1a**: Italy, Austria, Belgium, France, Portugal;
**Macro Region 2a**: Spain, Germany, Netherlands, Finland, Luxembourg.
**Macro Region 1b**: Italy, Spain, Germany, Austria, Netherlands;
**Macro Region 2b**: Belgium, Finland, France, Portugal, Luxembourg.
**DR**: Deadweight Loss Reduction.

Table 4: **Optimal weights with unequal Economic size (Regions)**

| | | | | |
|---|---|---|---|---|
| | **PANEL A** | | | |
| | economic size ($n_r$) | shock proportion ($p_r$) | price adjustment ($1-\alpha_r$) | optimal weights ($\gamma_r^{opt}$) |
| Italy | 19.89 | + | 10.0 | 24.97 |
| Austria | 3.25 | + | 15.40 | 0.09 |
| Belgium | 3.51 | + | 17.60 | 0.18 |
| France | 21.19 | + | 20.90 | 14.96 |
| Portugal | 2.29 | + | 21.10 | 8.13 |
| Spain | 12.49 | - | 13.30 | 13.96 |
| Germany | 30.00 | - | 13.50 | 29.07 |
| Netherlands | 5.44 | - | 16.20 | 0.21 |
| Finland | 1.65 | - | 20.30 | 0.09 |
| Luxembourg | 0.29 | - | 23.00 | 8.33 |
| **Macro Region 1a** | **50.13** | **+** | **16.00** | **45.01** |
| **Macro Region 2a** | **49.87** | **-** | **14.02** | **54.99** |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.1026 | -0.1007 | -0.1007 | 99.17 |
| | **PANEL B** | | | |
| | economic size ($n_r$) | shock proportion ($p_r$) | price adjustment ($1-\alpha_r$) | optimal weights ($\gamma_r^{opt}$) |
| Italy | 19.89 | + | 10.00 | 74.97 |
| Spain | 12.49 | + | 13.30 | 0.05 |
| Germany | 30.00 | + | 13.50 | 0.05 |
| Austria | 3.25 | + | 15.40 | 0.09 |
| Netherlands | 5.44 | + | 16.20 | 9.48 |
| Belgium | 3.51 | - | 17.60 | 15.34 |
| Finland | 1.65 | - | 20.30 | 0.01 |
| France | 21.19 | - | 20.90 | 0.01 |
| Portugal | 2.29 | - | 21.10 | 0.01 |
| Luxembourg | 0.29 | - | 23.00 | 0.00 |
| **Macro Region 1b** | **71.07** | **+** | **12.78** | **83.87** |
| **Macro Region 2b** | **28.93** | **-** | **20.50** | **16.13** |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.0469 | -0.0398 | -0.0397 | 99.03 |

**Table Notes**

**Macro Region 1a**: Italy, Austria, Belgium, France, Portugal;
**Macro Region 2a**: Spain, Germany, Netherlands, Finland, Luxembourg.
**Macro Region 1b**: Italy, Spain, Germany, Austria, Netherlands;
**Macro Region 2b**: Belgium, Finland, France, Portugal, Luxembourg.
**DR**: Deadweight Loss Reduction.

Table 5: **Optimal weights with unequal Economic size (Sectors)**

| | | | | |
|---|---|---|---|---|
| **PANEL A** | | | | |
| | economic size | shock proportion | price adjustment | optimal weights |
| | $(n_s)$ | $(p_s)$ | $(1-\alpha_s)$ | $(\gamma_s^{opt})$ |
| Restaurant and Hotels | 30.30 | + | 4.20 | 63.27 |
| Housing | 2.70 | + | 6.50 | 0.24 |
| Furnishing Household Equipment | 5.00 | + | 7.20 | 0.19 |
| Miscellaneous Goods and Services | 4.80 | + | 7.30 | 0.19 |
| Processed food | 7.40 | + | 12.50 | 9.40 |
| Recreation and Culture | 6.50 | - | 6.60 | 0.42 |
| Transport and Communications | 8.50 | - | 7.20 | 1.00 |
| Clothing | 16.20 | - | 8.40 | 24.70 |
| Unprocessed food | 7.80 | - | 37.20 | 0.58 |
| Energy | 10.80 | - | 78.80 | 0.01 |
| **Macro Sector 1a** | **50.20** | **+** | **6.14** | **91.74** |
| **Macro Sector 2a** | **49.80** | **-** | **27.74** | **8.26** |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.151 | -0.0834 | -0.0834 | 99.99 |
| **PANEL B** | | | | |
| | economic size | shock proportion | price adjustment | optimal weights |
| | $(n_r)$ | $(p_r)$ | $(1-\alpha_r)$ | $(\gamma_r^{opt})$ |
| Restaurant and Hotels | 30.30 | + | 4.20 | 79.89 |
| Housing | 2.70 | + | 6.50 | 0.17 |
| Recreation and Culture | 6.50 | + | 6.60 | 0.17 |
| Furnishing Household Equipment | 5.00 | + | 7.20 | 0.73 |
| Transport Communications | 8.50 | + | 7.20 | 0.44 |
| Miscellaneous Goods and Services | 4.80 | - | 7.30 | 3.50 |
| Clothing | 16.20 | - | 8.40 | 15.01 |
| Processed food | 7.40 | - | 12.50 | 0.01 |
| Unprocessed food | 7.80 | - | 37.20 | 0.07 |
| Energy | 10.80 | - | 78.80 | 0.01 |
| **Macro Sector 1b** | **53.00** | **+** | **5.38** | **94.72** |
| **Macro Sector 2b** | **47.00** | **-** | **29.89** | **5.28** |
| | inflation targeting | optimal targeting | optimal plan | DR |
| welfare reduction | -0.1523 | -0.0738 | -0.0738 | 99.99 |

**Table Notes**

**Macro Sector 1a**: Restaurant and Hotels, Housing, Furnishing Household Equipment, Miscellaneous Goods and Services, Processed Food; **Macro Sector 2a**: Recreation and Culture, Transport and Communications, Clothing, Unprocessed Food, Energy. **Macro Sector 1b**: Restaurant and Hotels, Housing, Recreation and Culture, Furnishing Household Equipment, Transport and Communications; **Macro Sector 2b**: Miscellaneous Goods and Services, Clothing, Processed Food Unprocessed Food, Energy. **DR**: Deadweight Loss Reduction.

# 7 Concluding Remarks

This paper investigates optimal inflation targeting for the Euro Area using a multi-region model with asymmetric demand shocks. The analysis shows that in a multi-region context the optimal weights result from complex interactions between the degree of price stickiness, economic size and the distribution of the shocks within regions. A similar result holds when we use the model to match the different degrees of nominal price rigidities across sectors. Therefore, assigning higher weights to the regions or sectors with a higher degree of nominal rigidities is not necessarily the optimal policy and there is no simple rule-of-thumb that the central bank can follow to guide the choice of the optimal weights. Simulations show that the welfare gain from choosing the weights optimally may be substantial compared to a pure inflation targeting regime that weights each regional inflation rate according to the economic size of the region.

The analysis shows that further progress is needed for a comprehensive assessment on the welfare consequences of heterogeneity in nominal rigidities across regions and sectors. For instance, it would certainly be interesting to extend the model with a segmented labor market, reflecting the limited labor mobility in Europe. In addition, the analysis should also be extended to investigate other sources of heterogeneity such as heterogeneity in the labor shares or in the shocks disturbing each region and sector. Our paper particularly investigated the effect of asymmetric demand shocks that move relative prices across regions, however more analysis is needed to extend the number of shocks included in the model to study their effect on the optimal weights and enable an empirical evaluation of the structural model. These investigations remain open for future research.

## References


Aoki K. (2001) Optimal Monetary Responses to Relative Price Changes, *Journal of Monetary Economics*, 48, 55–80.

Benigno P. (2004) Optimal Monetary Policy in a Currency Area, *Journal of International Economics*, 63, 293–320.

Benigno P. and Lopez-Salido J.D. (2006) Inflation Persistence and Optimal Monetary Policy in the Euro Area, *Journal of Money Credit and Banking*, 38, 3, 587–614.

Bils M. and Klenow P. (2004) Some Evidence on the Importance of Sticky Prices, *Journal of Political Economy*, 112, 947–985.

Bodenstein M., Erceg C.J. and Guerrieri L. (2008) Optimal Monetary Policy with Distinct Core and Headline Inflation Rates, *Journal of Monetary Economics*, 55, S18–S33.

Bryan M.F. and Cecchetti S.G. (1994) Measuring Core Inflation, in: *Monetary Policy*, The University of Chicago Press, 195–219.

Calvo G. (1983) Staggered Prices in a Utility-Maximizing Framework, *Journal of Monetary Economics*, 12, 383–398.

Carvalho C. (2006) Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks, *Frontiers in Macroeconomics*, 6, 3.

Cogley T. (2002) A Simple Adaptive Measure of Core Inflation, *Journal of Money, Credit and Banking*, 94–113.

Dhyne E., Alvarez L.J., Le Bihan H., Veronese G., Dias D., Hoffmann J., Jonker N., Lünnemann P., Rumler F. and Vilmunen J. (2006) Price changes in the Euro Area and the United States: Some facts from individual consumer price data, *The Journal of Economic Perspectives*, 171–192.

Erceg C.J., Henderson D.W. and Levin A.T. (2000) Optimal Monetary Policy with Staggered Wage and Price Contracts, *Journal of monetary Economics*, 46, 2, 281–313.

Eusepi S., Hobijn B. and Tambalotti A. (2011) CONDI: A Cost-Of-Nominal-Distortions Index, *American Economic Journal: Macroeconomics*, 3, 53–91.

Galí J. and Monacelli T. (2005) Monetary Policy and Exchange Rate Volatility in a Small Open

Economy, *The Review of Economic Studies*, 72, 3, 707–734.

Goodfriend M. and King R. (1997) The New Neoclassical Synthesis and the Role of Monetary Policy, in: *NBER Macroeconomics Annual 1997, Volume 12*, MIT Press, 231–296.

Huang K.X. and Liu Z. (2005) Inflation Targeting: What Inflation Rate to Target?, *Journal of Monetary Economics*, 52, 8, 1435–1462.

Keane M. and Rogerson R. (2012) Micro and macro labor supply elasticities: A reassessment of conventional wisdom, *Journal of Economic Literature*, 464–476.

Lombardo G. (2006) Inflation Targeting Rules and Welfare in an Asymmetric Currency Area, *Journal of International Economics*, 68, 2, 424–442.

Nakamura E. and Steinsson J. (2008) Five Facts about Prices: A Reevaluation of Menu Cost Models, *The Quarterly Journal of Economics*, 1415–1464.

Rotemberg J. and Woodford M. (1997) An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy, in: *NBER Macroeconomic Annual*, Bernanke B. and Rotemberg J., eds., MIT Press, Cambridge, 297–346.

Soffritti M. and Zanetti F. (2008) The Advantage of Tying one's Hands: Revisited, *International Journal of Finance & Economics*, 13, 2, 135–149.

Woodford M. (1999) Optimal Monetary Policy Inertia, *NBER Working Paper*, 7261.

Woodford M. (2003) *Interest and Prices*, Princeton University Press.