Insider-Outsider Labor Markets, Hysteresis and Monetary Policy*

Jordi Galí
CREI, UPF and Barcelona GSE

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Abstract

I develop a version of the New Keynesian model with insider-outsider labor markets and hysteresis that can account for the high persistence of of European unemployment. I study the implications of that environment for the design of monetary policy. A simple interest rule that includes the unemployment rate is shown to approximate well the optimal policy.

Keywords: wage stickiness, New Keynesian model, unemployment fluctuations, Phillips curve, insider-outsider model.
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1 Introduction

Much discussion on the European unemployment problem tends to focus on its high level, relative to the U.S. and other advanced economies. But a look at the path of the European unemployment rate over the past four decades points to another defining characteristic of that variable: its high persistence.

*Correspondence: CREI, Ramon Trias Fargas 25, 08005 Barcelona (Spain). I am grateful for comments and suggestions to Juanjo Dolado, Nils Gottfries and participants at the NBER Summer Institute. Cristina Manea and Alain Schlaepfer provided excellent research assistance. E-mail: jgali@crei.cat

The latter property has been emphasized by many authors, going back to Blanchard and Summer's influential *hysteresis* paper.[1]

Can the standard New Keynesian model, the workhorse framework of modern macroeconomics, account for the high persistence of European unemployment? My analysis below suggests that the answer is a negative one. In particular, I show that simulations of a (realistically calibrated) version of that model tend to generate fluctuations in the unemployment rate that are either too little persistent relative the data, and/or at odds with some other observed properties of that variable.

Motivated by the previous findings, I develop a variant of the New Keynesian model whose equilibrium properties can be more easily reconciled with the evidence on unemployment persistence. The modified model, inspired by the seminal work of Blanchard and Summers (1986), Gottfries and Horn (1987) and Lindbeck and Snower (1988), has two key distinctive features: (i) insider-outsider labor markets, and (ii) hysteresis. The first feature leads unions to give a disproportionate weight to a subset of the labor force– referred to as *insiders*– when setting wages. The second feature makes the measure of insiders evolve endogenously over time as a function of employment. I show how a calibrated version of the modified model can generate a degree of unemployment persistence comparable to that observed in the data, in response to a variety of shocks.

Having made a case for insider-outsider labor markets and hysteresis as a potential explanation for the high persistence of European unemployment, I turn to the implications of that modification for the design of monetary policy. Firstly, I derive and characterize the implied optimal policy with commitment and compare it to that associated to the standard New Keynesian model, as derived, e.g. in Erceg et al. (2001). Then I study how a simple interest rate rule can be modified in order to approximate the optimal policy. In particular, I show how a rule that responds to inflation and the unemployment rate does a good job at approximating the outcomes of the fully optimal policy, and improves considerably over a rule that focuses exclusively on stabilizing inflation.

The paper is organized as follows. Section 2 present the evidence. Section 3 develops the New Keynesian model with insider-outsider labor markets. Section 4 analyzes the ability of that model to generate unemployment per-

[1] Blanchard and Summers (1986). See Ball (2008) for an analysis of unemployment persistence across a number of OECD countries.

sistence, and contrasts it with the standard New Keynesian model. Section 5 derive the optimal monetary policy in the presence of insider-outsider labor markets, and compares it with that associated with the standard model. Section 6 analyzes the performance of a variety of simple rules. Section 7 concludes.

2 Evidence

The high persistence of European unemployment is apparent in Figure 1, which displays the unemployment rate for the euro area over the sample period 1970Q1-2014Q4, together with CEPR-dated recessions (as shaded areas).[2] The unemployment rate can be seen to wander about a (seemingly) upward trend, showing variations that are smooth and highly persistent. Each recession episode pulls the unemployment rate towards a new plateau, around which it appears to stabilize. The unemployment rate eventually declines as the economy recovers, or increases further if a new recession hits the economy (as in 1980 or 2012). In any event, the unemployment rate shows no clear tendency to gravitate towards some constant long-run equilibrium value.

The previous visual assessment of high persistence is confirmed by a number of formal statistics performed on the euro area unemployment rate. Table 1 reports the t-statistics for an Augmented Dickey-Fuller (ADF) test of the null of a unit root (with 1 and 4 lags). Non-standard, sample size adjusted, critical values are shown in brackets. When the full sample period is used the unit root null cannot be rejected at a 5 percent significance level. If I drop the first fifteen years, during which the unemployment rate shows a continuous increase, and start the sample period in 1985Q1, the null of a unit root is (marginally) rejected when only one lag of the first-differenced unemployment rate is used in the regression, but cannot be rejected again when four lags are used. Finally, when I restrict myself to the single currency period proper (1999Q1-2015Q4) I cannot reject the null of a unit root again.[3]

Figure 2a-2c display the estimated autocorrelogram of the unemployment

[2]Source: ECB's Area Wide Model quarterly data set, originally constructed Fagan, Henry and Mestre (2001) and subsequently updated by ECB. I am using update 14, which corresponds to 18 countries.

[3]Farmer (2015) provides evidence of nonstationarity of logistic transformation of the U.S. unemployment rate and of its cointegration with the stock market index.

rate, for the three samples considered. It also shows the median and mean estimates (and 95 per cent confidence bands) of the distribution of estimated autocorrelograms based on 200 simulated time series generated by a random walk, with 180, 120 and 64 observations, respectively. Note that the autocorrelogram declines very slowly, a trademark of a highly persistent series. In most cases, the size of the autocorrelations lies above the median and mean autocorrelation associated with the random walk, pointing to greater persistence than the latter process.

The evidence above makes it clear that the unemployment rate in the euro area displays very high persistence. Here I do not take a stance as to whether it has or does not have a unit root. Yet, it is clear that given the size of the sample periods considered, the observed persistence is comparable to that of a random walk.

3 A New Keynesian Model with Insider-Outsider Labor Markets and Hysteresis

In the present section I modify an otherwise standard New Keynesian framework by embedding in it a model of wage setting along the lines of insider-outsider models of the labor market. With the exception of the assumptions on wage setting, the environment is similar to that described in Galí (2015, chapter 7), in which the household block of the New Keynesian model is reformulated in order to bring a meaningful concept of unemployment into the model.

3.1 Households

I assume a large number of identical households. Each household has a continuum of members represented by the unit square. Each member is indexed by a pair $(j, s) \in [0,1] \times [0,1]$. The first index, $j \in [0,1]$, represents the type of labor service ("occupation") that she is specialized in. The second index, $s \in [0,1]$, determines her disutility from work. The latter is given by χs^{φ} if she is employed and zero otherwise, where $\chi > 0$ and $\varphi > 0$ are exogenous parameters. Those employed work a constant number of hours, which is exogenously given. Employment for each occupation, $\mathcal{N}_t(j) \in [0,1]$, is demand determined and taken as given by the household, which allocates it to the members with the lowest work disutility among those specialized in the given occupation, i.e. $s \in [0, \mathcal{N}_t(j)]$. Full risk sharing within the household is assumed. Given the separability of preferences, this implies the same level of consumption for all household members, independently of their occupation or employment status.

The household's period utility is given by the integral of its members' utilities:

$$\begin{aligned} U(C_t, \{\mathcal{N}_t(j)\}; Z_t) &\equiv \left(\log C_t - \int_0^1 \int_0^{\mathcal{N}_t(j)} \chi s^{\varphi} ds dj\right) Z_t \\ &= \left(\log C_t - \chi \int_0^1 \frac{\mathcal{N}_t(j)^{1+\varphi}}{1+\varphi} dj\right) Z_t \end{aligned}$$

where $C_t \equiv \left(\int_0^1 C_t(i)^{1-\frac{1}{\epsilon_{p,t}}} di\right)^{\frac{\epsilon_{p,t}}{\epsilon_{p,t}-1}}$ is a consumption index, with $C_t(i)$ is the quantity consumed of good i, for all $i \in [0, 1]$. Parameter $\epsilon_{p,t}$ denotes the elasticity of substitution, which is (possibly) time-varying. The exogenous preference shifter $z_t \equiv \log Z_t$ is assumed to follow an $AR(1)$ process:

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z$$

where $\rho_z \in [0, 1]$ and ε_t^z is a white noise process with zero mean and variance σ_z^2.

Each household seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, \{\mathcal{N}_t(j)\}; Z_t)$$

subject to a sequence of flow budget constraints given by

$$\int_0^1 P_t(i) C_t(i) di + Q_t B_t \leq B_{t-1} + \int_0^1 W_t(j) \mathcal{N}_t(j) dj + D_t \tag{1}$$

where $P_t(i)$ is the price of good i, $W_t(j)$ is the nominal wage for occupation j, B_t represents purchases of a nominally riskless one-period discount bond paying one unit of account ("money"), Q_t is the price of that bond, and D_t is a lump-sum component of income (which may include, among other items, dividends from the ownership of firms).[4] $\beta \in [0, 1]$ is the household's discount factor.

[4] The above sequence of period budget constraints is supplemented with a solvency condition that prevents the household from engaging in Ponzi schemes.

Independently of the nature of wage setting, the household's problem above gives rise to two types of optimality conditions: a set of optimal demand schedules for each consumption good and a standard intertemporal optimality condition (or Euler equation). Those take the familiar form (using lower case letters to denote logs):

$$c_t(i) = -\epsilon_{p,t}(p_t(i) - p_t) + c_t$$

for all $i \in [0, 1]$, and

$$c_t = E_t\{c_{t+1}\} - (i_t - E_t\{\pi^p_{t+1}\} - \rho) + (1 - \rho_z)z_t$$

where $\pi^p_t \equiv p_t - p_{t-1}$ denotes price inflation, and $\rho \equiv -\log \beta$ is the discount rate.

See Woodford (2003) or Galí (2015b) for a derivation of these and other equilibrium conditions unrelated to the labor market. Here I focus my discussion on the assumptions regarding wage setting and the definition of unemployment.

3.2 An Insider-Outsider Model of Wage Setting

I introduce nominal rigidities by assuming the Calvo model of staggered wage setting originally proposed in Erceg, Henderson and Levin (2001) and generally adopted by the literature due to its tractability. A constant fraction $1-\theta_w$ of occupations (or the unions representing them), drawn randomly from the set of existing occupations, are allowed to reset their nominal wage in any given period. As a result the evolution of the average (log) nominal wage is described by the difference equation:

$$w_t = \theta_w w_{t-1} + (1 - \theta_w)w^*_t \tag{2}$$

where w^*_t is the newly set (log) wage in period t. The fact that the wage remains unchanged for several periods makes the implied optimal wage setting decision to be forward-looking. In particular, when setting the wage $w^*_t(j)$, a union representing occupation j takes into account current and (expected) future demand for its work services, as given by:

$$n_{t+k|t}(j) = -\epsilon_w(w^*_t(j) - w_{t+k}) + n_{t+k} \tag{3}$$

for $k = 1, 2, 3, ...$where $n_{t+k|t}(j)$ denotes period $t + k$ (log) employment for occupation j whose wage has been reset for the last time in period t, and

n_{t+k} is (log) aggregate employment in period $t+k$. Note that $\epsilon_w > 1$ is the wage elasticity of labor demand.

Insider-outsider models of the labor market, as developed in Blanchard and Summers (1986), Gottfries and Horn (1987) and Lindbeck and Snower (1988), emphasize the segmentation of the labor force between insiders and outsiders and the dominant role of the former in wage determination. In the words of Blanchard and Summers:

> "...there is a fundamental asymmetry in the wage-setting process between insiders who are employed and outsiders who want jobs. Outsiders are disenfranchised and wages are set with a view to ensuring the jobs of insiders. Shocks that lead to reduced employment change the number of insiders and thereby change the subsequent equilibrium wage rate, given rise to hysteresis..."

Here I use a version of the insider-outsider model consistent with the Calvo wage setting formalism, and hence one that can be readily embedded in the standard New Keynesian model.

In the insider-outsider model proposed here a union resetting the wage for occupation j in period t chooses a wage, $w_t^*(j)$, such that the following condition is satisfied

$$(1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{n_{t+k|t}(j)\right\} = n_t^*(j) \tag{4}$$

with $n_{t+k|t}(j)$ given by (3), for $k = 0, 1, 2...$In words, the wage is set so that, in expectation, a specific weighted average of employment in occupation j over the period the wage remains effective equals some employment *target* $n_t^*(j)$. The latter can interpreted as representing the measure of *insiders* in occupation j.[5]

Substituting (3) into (4) yields the wage setting rule:

$$w_t^*(j) = -\frac{1}{\epsilon_w}n_t^*(j) + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{w_{t+k} + \frac{1}{\epsilon_w}n_{t+k}\right\} \tag{5}$$

[5] A possible justification for this type of behavior may involve some deviation from perfect consumption risk sharing within households, with each individual's consumption being related to her individual wage income.

Define the *average* newly set wage and employment target as $w_t^* \equiv (1-\theta_w)^{-1}\int_{j\in\times_t} w_t^*(j)dj$ and $n_t^* \equiv (1-\theta_w)^{-1}\int_{j\in\times_t} n_t^*(j)dj$, respectively, where $\times_t \subset [0,1]$ represents the subset of occupations resetting their wage in period t. Averaging over the latter, the wage setting rule (4) can now be written in recursive form as follows:

$$w_t^* = \beta\theta_w E_t\left\{w_{t+1}^*\right\} - \frac{1}{\epsilon_w}(n_t^* - \beta\theta_w E_t\left\{n_{t+1}^*\right\}) + (1-\beta\theta_w)\left(w_t + \frac{1}{\epsilon_w}n_t\right)$$

The previous difference equation can be combined with (2) to yield (after some algebra), the following wage inflation equation for the insider-outsider economy:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n[(1-\beta\theta_w)(n_t - n_t^*) + \beta\theta_w E_t\left\{\Delta n_{t+1}^*\right\}] \qquad (6)$$

where $\pi_t^w \equiv w_t - w_{t-1}$ denotes wage inflation and $\lambda_n \equiv \frac{1-\theta_w}{\theta_w\epsilon_w}$. Thus, wage inflation is driven by a weighted average of (i) the log deviation between employment and its target and (ii) the change in that target.

I follow Blanchard and Summers (1986) and assume that the measure of insiders (and, hence, the employment target) in any given occupation j evolves over time according to the difference equation:

$$n_t^*(j) = \gamma n_{t-1}(j) + (1-\gamma)n^* \qquad (7)$$

where n^* is the union's *long run target* for (log) employment, which is assumed to be common across occupations. Note that (4) implies that n^* also corresponds to equilibrium employment in the perfect foresight steady state, i.e. $n = n^*$. Parameter $\gamma \in [0,1]$ determines the extent to which changes in employment affect the economy's state, by changing the measure of insiders. This is the phenomenon referred to in the literature as *hysteresis*.

Beyond the particular specification chosen, the motivation behind that assumption is the notion that the concerns of employed workers are given a disproportionate weight in the bargaining of wages. This may the case for a variety of reasons: they are more likely to participate or remain close to the bargaining process, they are the ones with the ability to strike and hence are an important source of the union's bargaining power, they are more likely to pay their union fees, etc. On the other hand, those who are unemployed are to some extent disenfranchised in the wage setting process.

Note that the assumption that unions that reset wages in any given period are drawn randomly from the population allows us to average over $j \in \times_t$ to obtain:

$$n_t^* = \gamma n_{t-1} + (1-\gamma)n^*$$

Thus, the implied wage inflation equation in this case can be written as

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n[(1-(1-\gamma)\beta\theta_w)\Delta n_t + (1-\beta\theta_w)(1-\gamma)\widehat{n}_{t-1}] \quad (8)$$

i.e. both the employment change and its (lagged) deviation from steady state, $\widehat{n}_{t-1} \equiv n_{t-1} - n$, are the drivers of fluctuations in wage inflation.

A special case of interest is given by $\gamma = 1$. In that case, already singled out in Blanchard and Summers (1986), the set of insiders is made up *only* by workers employed at the end of the previous period, with no weight attached to the unemployed. In that case equation (8) collapses to

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n \Delta n_t$$

with the employment change being the only driving force. As shown below, under that extreme assumption the model displays full hysteresis: employment is permanently affected by any shock that has a short run effect on that variable. That unit root property is inherited by many other macro variables, including the unemployment rate. There is no well defined steady state in that case.

At the other extreme, when $\gamma = 0$, then we have

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n(1-\beta\theta_w)\widehat{n}_t$$

with the only current employment gap $\widehat{n}_t$ emerging now as the driving variable.

3.2.1 The Standard Wage Setting Model

The previous wage setting model contrasts with that found in the standard New Keynesian model, and originally developed in Erceg, Henderson and Levin (2001). In the latter, when resetting the wage, each union seeks to maximize the utility of the representative household, to which all union members (employed or unemployed) belong.[6] This gives rise to a (log-linearized) wage setting rule of the form:

$$w_t^* = \mu^w + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{\underline{w}_{t+k|t}\right\} \quad (9)$$

[6] See, e.g., Galí (2015, chapter 6) for a derivation.

where $\underline{w}_{t+k|t} \equiv p_{t+k} + c_{t+k} + \varphi n_{t+k|t} + \xi$ is the relevant reservation wage in $t+k$ for a union that has reset its wage for the last time in period t, and $\mu^w \equiv \log \frac{\epsilon_w}{\epsilon_w - 1}$ is the desired or *natural wage markup* (over the reservation wage), which is assumed to be constant in the baseline version of the model. It is easy to show that the latter is the wage markup that any union (acting independently) would choose if wages were fully flexible, given a labor demand schedule with a constant wage elasticity ϵ_w.

Combining (2) and (9) allows one to derive the wage inflation equation:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w(\mu_t^w - \mu^w) \tag{10}$$

where

$$\mu_t^w \equiv \omega_t - (c_t + \varphi n_t + \xi) \tag{11}$$

denotes the average wage markup in period t, where $\omega_t \equiv w_t - p_t$ is the average (log) real wage, and $\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$. Thus, from the viewpoint of the formal equations describing the economy's equilibrium, the difference between the insider-outsider and standard wage setting models boils down to equations (8) and (10) (with (11)). The remaining blocks, described below, are common across the two models.

3.3 Remaining Blocks

The remaining blocks of the model are standard. Their formal description, as well as the derivation of the relevant equilibrium conditions, can be found in Galí (2015, chapter 6). I assume the existence of a continuum of differentiated goods $i \in [0,1]$, each produced by a monopolistic competitor, with a production function:

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{12}$$

where $Y_t(i)$ denotes the output of good i, A_t is an exogenous technology parameter common to all firms, and $N_t(i)$ is a CES function of the quantities of the different types of labor services employed by firm i, whose elasticity of substitution is given by ϵ_w. Cost minimization by firms gives rise to the labor demand schedule (3) introduced above.

Price-setting is staggered à la Calvo, with a constant fraction θ_p of firms that keep prices unchanged in any given period. Aggregation of price-setting decisions, gives rise to an inflation equation of the form (around a zero inflation steady state)

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} - \lambda_p(\mu_t^p - x_t) \tag{13}$$

where

$$\mu_t^p \equiv a_t - \alpha n_t + \log(1-\alpha) - \omega_t \tag{14}$$

is the average price markup, $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p} \frac{1-\alpha}{1-\alpha+\alpha\epsilon_p}$ and $x_t \equiv \log \frac{\epsilon_{p,t}}{\epsilon_{p,t}-1}$ is the desired or *natural* price markup. The latter is assumed to follow an $AR(1)$ process with mean $\log \frac{\epsilon_p}{\epsilon_p-1}$ autoregressive coefficient ρ_x and innovation variance σ_x^2.

Note that we can rewrite the markup gap in terms of employment and wages as follows:

$$\begin{aligned} \mu_t^p - x_t &= a_t - \alpha\widehat{n}_t - \alpha n + \log(1-\alpha) - x_t - \omega_t \\ &= -\alpha\widehat{n}_t - \widetilde{\omega}_t \end{aligned} \tag{15}$$

where $\widetilde{\omega}_t \equiv \omega_t - (a_t - \alpha n + \log(1-\alpha) - x_t)$ is the *wage gap*, defined as the log deviation between the actual wage and the wage that would obtain under flexible prices conditional on employment being at its steady state level.

Goods market equilibrium requires that $c_t = y_t$ for all t, which combined with the household's Euler equation implies:

$$y_t = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{t+1}^p\} - \rho) + (1-\rho_z)z_t \tag{16}$$

Given equilibrium output, employment is given by

$$(1-\alpha)n_t = y_t - a_t \tag{17}$$

Let $l_t(j)$ denote (log) participation among individuals specialized in occupation j. As discussed in Galí (2011a,b) and summarized in the Appendix, the aggregation of a labor market participation decisions gives rise to the following labor force or participation equation for occupation j:

$$w_t(j) - p_t = c_t + \varphi l_t(j) + \xi \tag{18}$$

for all $j \in [0,1]$, where $l_t(j)$ denotes the labor force (or participation) in occupation j, and $\xi \equiv \log \chi$.

Averaging across occupations,

$$w_t - p_t = c_t + \varphi l_t + \xi \tag{19}$$

Following Galí (2011a,b), I define the unemployment rate u_t as the log difference between the labor force and employment:

$$u_t \equiv l_t - n_t \tag{20}$$

Following Galí (2011a,b), one can combine the wage inflation equation (10) with (11), (19) and (20) to obtain:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w \varphi (u_t - u)$$

where $u \equiv \frac{\mu^w}{\varphi}$ can be interpreted as the natural rate of unemployment, i.e. the one that would prevail under flexible wages.

Equations (13), (15), (16), (17), (19) and (20), together with the identity

$$\omega_t \equiv \omega_{t-1} + \pi_t^w - \pi_t^p \tag{21}$$

and wage inflation equation (8) (insider outsider model) or (10) and (11) (standard model) define the non-policy block of the model. In order to close the model one must supplement the previous equilibrium conditions with a description of a monetary policy rule that (directly or indirectly) determines the nominal interest rate i_t.

Foe the baseline simulations below I assume an interest rate rule of the form:

$$i_t = \phi_i i_{t-1} + (1 - \phi_i)[\rho + \phi_\pi \pi_t^p + \phi_y \Delta y_t] \tag{22}$$

For values of ϕ_i close to unity (as assumed in the simulations below) the previous rule is similar to the one proposed in Orphanides (2006) and Smets (2010) as a good approximation to ECB policy.

3.4 The Efficient Allocation

The *efficient* allocation, i.e. the one that maximizes households' utility given the economy's resource constraints, is easy to characterize. Employment is identical across firms and occupations, and all goods are consumed in identical quantities. The efficiency condition equating the marginal rate of substitution and the marginal product of labor implies a constant optimal level of employment, given by:

$$n_t^e \equiv \frac{\log(1-\alpha) - \xi}{1+\varphi} \equiv n^e$$

The efficient level of output is thus given by

$$y_t^e \equiv a_t + (1-\alpha) n^e$$

That allocation provides a useful benchmark in some of the analyses below.

4 Insider-Outsider Labor Markets, Hysteresis and the Persistence of Unemployment

Can the New Keynesian model account for the observed persistence of European unemployment? In the present section I simulate a calibrated version of the New Keynesian model under the two wage setting regimes considered (standard and insiders-outsiders), and use the generated time series to determine the persistence (and other properties) of unemployment, which are then compared to analogous properties in the data.

4.1 Calibration

Table 2 lists the baseline settings for the model parameters uses in the simulations. Parameters ϵ_p is set to 3.8. That value is associated with a steady state price markup of 35 percent, and is consistent with the evidence used in the calibration of the ECB's New Area Wide Model (NAWM) of Christoffel et al. (2008). Given that setting, a value of 1/4 for parameter α is roughly consistent with the observed average labor income share in the euro area.[7] Parameter ϵ_w is set to 4.3, again following Christoffel et al. (2008). Given that setting for ϵ_w, and using the approach developed in Galí (2011a), a value of φ equal to 3.4 can be shown to be consistent with a steady state unemployment rate of 7.6 percent, the average unemployment rate in the euro area over the 1970-2014 period.[8] As to the discount factor, I set $\beta = 0.99$, as is common practice in the business cycle literature. I set the Calvo wage and price stickiness parameters, θ_p and θ_w, to 0.75, which implies an average duration of individual wages and prices of four quarters. That setting is roughly consistent with the bulk of the micro evidence for the euro area

[7] Note that in the steady state the following relation holds:

$$\frac{WN}{PY} = (1-\alpha)\left(1 - \frac{1}{\epsilon_p}\right)$$

[8] Galí (2011) shows that the φ, ϵ_w and the steady state unemployment rate u are related according to equation:

$$\varphi u = \log \frac{\epsilon_w}{\epsilon_w - 1}$$

Interestingly, the resulting setting for φ is nearly identical to the calibrated value in the NAWM of Christoffel et al. (2008).

(see, e.g. Álvarez et al. (2006) and ECB (2009). As to the interest rate rule coefficients, I assume $\phi_\pi = 1.5$, $\phi_y = 0.5$, and $\phi_i = 0.9$. That calibration is close to the one proposed in Orphanides (2006) and Smets (2010) as a good approximation to ECB policy.

4.2 Unemployment Persistence in the Standard New Keynesian Model

I simulate the standard New Keynesian model under the above calibration to evaluate its ability to generate the degree of unemployment persistence observed in the data. More specifically, I generate 200 draws of 180 observations each, and conditional on each of the three exogenous shocks separately. For each draw I estimate the autocorrelation of the unemployment rate at 1, 4 and 8 lags, as well as its standard deviation relative to output, and its correlation with (price) inflation. The bottom panel of Table 3 reports the median and a 95 percent confidence interval for each of those statistics, conditional on each shock. The top panel reports their empirical counterparts, for the three different sample periods considered earlier. For the purposes of the present exercise, and in order to maximize the model's chances to match the high unemployment persistence observed in the European data, I assume that the driving forces themselves are highly persistent. Specifically, I set $\rho_a = 1$ and $\rho_x = \rho_z = 0.99$.[9]

The simulations' outcome, as summarized in Table 3, suggests that the standard New Keynesian model has clear difficulties to match the properties of observed unemployment fluctuations, independently of the nature of the shock driving those fluctuations. Firstly, while unemployment is positively autocorrelated in response to each of the shocks, the estimated autocorrelations appear to decline much faster than in the data. The gap is particularly large in the case of demand shocks. Furthermore, with only one exception (the autocorrelation at lag eight conditional on markup shocks) the empirical autocorrelations (for any of the three sample considered) lie outside the 95 percent confidence interval generated by the model. Secondly, the two shocks that induce a (relatively) higher unemployment persistence (markup and technology) stand little chance to be a major source of unemployment

[9] Note that the statistics considered here (autocorrelations, relative standard deviations and cross-correlations) are independent of the variance of the shocks, given the model's linearity.

fluctuations since they fail strongly at matching other key properties of those fluctuations. Thus, technology shocks generate fluctuations in unemployment that are far too small relative to output, as well as comovement of unemployment and inflation of the wrong sign. Markup shocks are able to match the observed relative volatility of unemployment, but they also generate a positive unemployment-inflation correlation, which contrasts with the negative value of its empirical counterparts. Demand shocks, on the other hand, do reasonably well at matching both the relative volatility and the unemployment inflation comovement, but they deliver far too little unemployment persistence, as discussed above.

From the previous exercise I conclude that a calibrated version of the standard New Keynesian model, under a "realistic" policy rule, cannot account for the high persistence of European unemployment. A reasonable conjecture is that the model's failure may lie in its treatment of the labor market itself, which may be at odds with the European reality. Next I analyze how the previous conclusion is affected when the insider-outsider labor market structure described above is embedded in an otherwise standard New Keynesian model.

4.3 Unemployment Persistence in the New Keynesian Model with Insider-Outsider Labor Markets

I repeat the simulations exercise described in the previous subsection using a version of the New Keynesian model with insider-outsider labor markets, as described above. Again, I simulate the model 200 times, conditional on each shock and obtain a set of artificial time series with 180 observation for each draw. I repeat this procedure for three alternative values of the hysteresis parameter γ: 0, 0.9 and 1. In Table 4 I report several statistics pertaining to the behavior of unemployment for those simulated histories, conditional on each shock and calibration of γ. For comparison purposes I also report the corresponding statistics generated by the standard New Keynesian model. In each case, the median and a 95 per cent confidence interval (across simulations) are reported. Except for technology, which is still assumed to follow a random walk, I now assume high but not extreme values for the autoregressive coefficient of the two remaining shocks, namely, $\rho_x = \rho_z = 0.9$.

A number of findings are worth stressing. First, note that under $\gamma = 0$, i.e. in the absence of a hysteresis effect, the behavior of unemployment is very similar (though not identical) to that in the New Keynesian model, even though their wage setting rules are different (one targets employment, the other target the wage markup). Secondly, and irrespective of the shock considered, the estimated autocorrelation of unemployment increases substantially as γ goes up. For both $\gamma = 0.9$ and $\gamma = 1$, the implied values are not too different from those observed in the data, with the latter generally falling within the 95 percent confidence interval. Thirdly, as it was the case in the New Keynesian model, the implied unemployment-inflation correlation has the wrong sign in the case of technology and markup shocks, but the right one in the case of demand shocks. In the latter case, however, and for high values of γ the size of the negative correlation is closer to that observed in the data relative to the standard New Keynesian model. The main discrepancy with the data can be found in the size of the relative volatility of unemployment, which tends to be above its empirical counterpart, with the exception of technology shocks.

It is also worth noting that under $\gamma = 1$, and under the assumed monetary policy rule, the unemployment rate (as well as employment and output) displays a unit root. Accordingly, any shock will generally have a permanent effect on the level of those variables, even when the shock itself is transitory.

Figure 3 illustrates graphically the role of the size of the hysteresis parameter as a source of unemployment persistence, by showing the impulse responses of the unemployment rate under the three values of γ considered, as well as under the standard New Keynesian model, and conditional on each of the shocks. Two results emphasized above are clearly illustrated here: (i) the similarity of the response with the standard model when $\gamma = 0$ and (ii) the positive relation between the size of γ and the observed persistence of the unemployment response.

In addition to its ability to account for the high persistence of European unemployment, and as analyzed in Galí (2015a), the assumption of insider-outsider labor markets combined with (strong) hysteresis also provides a potential explanation for the relative stability of wage inflation in the euro area since the mid-90s, despite the large and persistent fluctuations in the unemployment rate. The reason is that, for high values of γ, even large deviations of employment from steady state have a small (or zero) weight in the determination of wage inflation, with more weight given to while the *change* in employment (which can be small even when the economy is far from steady state).

Having shown that a variation of the New Keynesian model that incorporates insider-outsider labor markets and hysteresis helps improve the model's ability to account for the high persistence of European unemployment I turn to the analysis of the policy implications of such an assumption.

5 Optimal Monetary Policy with Insider-Outsider Labor Markets

Next I analyze the optimal monetary policy in the context of the New Keynesian model with insider-outsider labor markets developed above. In doing so, I focus on the role played by hysteresis parameter γ in shaping the optimal policy response to different shocks.

5.1 The Optimal Monetary Policy Problem

In the analysis below I assume that unions' long term employment goal corresponds to the efficient level of employment. Formally,

$$n^* = n^e$$

Note that the previous assumption implies that the steady state allocation is efficient since, as discussed above, $n = n^*$ (at least in the case of $\gamma \in [0, 1)$, for which a steady state is well defined). The previous assumption simplifies the analysis while allowing me to focus on the role of hysteresis without the (well understood) complications arising from an inefficient steady state.[10]

In particular, and under the previous assumption, one can approximate (up to second order) the representative household's welfare losses in a neighborhood of the steady state by the function:

$$\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left((1+\varphi)(1-\alpha)\widehat{n}_t^2 + \frac{\epsilon_p}{\lambda_p}(\pi_t^p)^2 + \frac{\epsilon_w(1-\alpha)}{\lambda_w}(\pi_t^w)^2 \right) \tag{23}$$

where $\widehat{n}_t \equiv n_t - n$. Note that the welfare loss function is equivalent to that used in the standard New Keynesian model. The reason is that the wage

[10] That assumption plays a role similar to the presence of an "optimal" employment subsidy in standard analyses of the optimal monetary policy in the New Keynesian model.

setting equation (9) is not used in the derivation of the loss function for the New Keynesian model, so its replacement by (5) has no bearing in the form of that function.

The monetary authority will seek to minimize (23) subject to:

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} + \lambda_p \alpha \widehat{n}_t + \lambda_p \widetilde{\omega}_t \tag{24}$$

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n(1-(1-\gamma)\beta\theta_w)\widehat{n}_t - \lambda_n \gamma \widehat{n}_{t-1} \tag{25}$$

$$\widetilde{\omega}_{t-1} \equiv \widetilde{\omega}_t - \pi_t^w + \pi_t^p + \Delta a_t - \Delta x_t \tag{26}$$

for $t = 0, 1, 2, ..$together with some initial conditions for $\widetilde{\omega}_{-1}$ and $\widehat{n}_{-1}$.

Let $\{\zeta_{1,t}\}$, $\{\zeta_{2,t}\}$, and $\{\zeta_{3,t}\}$ denote the sequence of Lagrange multipliers associated with the previous constraints, respectively. The optimality conditions for the optimal policy problem are thus given by

$$(1+\varphi)(1-\alpha)\widehat{n}_t + \lambda_p \alpha \zeta_{1,t} + \lambda_n(1-(1-\gamma)\beta\theta_w)\zeta_{2,t} - \lambda_n \gamma \beta E_t\{\zeta_{2,t+1}\} = 0 \tag{27}$$

$$\frac{\epsilon_p}{\lambda_p}\,\pi_t^p - \Delta\zeta_{1,t} + \zeta_{3,t} = 0 \tag{28}$$

$$\frac{\epsilon_w(1-\alpha)}{\lambda_w}\,\pi_t^w - \Delta\zeta_{2,t} - \zeta_{3,t} = 0 \tag{29}$$

$$\lambda_p \zeta_{1,t} + \zeta_{3,t} - \beta E_t\{\zeta_{3,t+1}\} = 0 \tag{30}$$

for $t = 0, 1, 2, ...$which, together with the constraints (24), (25), and (26) given $\zeta_{1,-1} = \zeta_{2,-1} = 0$ and an initial condition for $\widetilde{\omega}_{-1}$ and $\widehat{n}_{-1}$, characterize the solution to the optimal policy problem.

5.2 Dynamic Responses to Shocks and Welfare: Optimal Policy vs. Simple Rule

Figures 4.a-4.c display the response of output, the unemployment rate, wage and price inflation and nominal and real interest rates to adverse technology, markup and demand shocks, respectively, in the New Keynesian model with insider-outsider labor markets. The figures show the responses under two alternative monetary policies: the optimal policy described above and the simple interest rate rule (22). In the interest of space, and to stress the starker findings, only the responses for the case of full hysteresis ($\gamma = 1$) are shown. The remaining parameters (including the coefficients in the simple policy rule) are kept at their baseline settings, as in the simulations of the previous section. The size of the shock is normalized to 1 percent.

A most distinctive feature of the economy's response under the optimal policy is the higher stability of the unemployment rate and output, in comparison to the response under the simple rule. This is true independently of the shock impinging on the economy. The smooth response of (un)employment under the optimal policy is accompanied by a highly stable wage inflation, though not necessarily more stable price inflation. In the case of demand shocks, the optimal policy fully insulates prices and quantities from the change in the discount rate shock, through a commensurate adjustment of the interest rate. This is not the case under the simple rule, which can't prevent a large and persistent decline in output and unemployment.

Furthermore, it can be shown that, with the exception of demand shocks, the optimal policy does not *fully* eliminate the unit root in unemployment. Yet, as Figures 4a and 4b illustrate clearly, the size of that unit root is much smaller under the optimal policy than under the simple rule. In the case of demand shocks neither unemployment nor output is affected under the optimal policy, but the permanent effects on those variables under the simple rule is far from negligible.

The nontrivial gap between the responses under the two policies suggests that the adoption of the optimal policy may bring about considerable welfare gains relative to the simple rule. In TabIe 5 I report the welfare losses under the two policies, as measured by (23), conditional on each of the three shocks considered, and for three alternative values of the hysteresis parameter (0, 0.9 and 1). The Table also reports welfare losses *relative* to those associated with the simple rule (22) to unity, for each value of γ considered.

Two results are worth stressing. Firstly, and independently of the shock, we see that under the simple rule the size of welfare losses is increasing with the degree of hysteresis. More specifically, welfare losses under full hysteresis ($\gamma = 1$) are about 10 times larger than in the absence of hysteresis ($\gamma = 1$). That sensitivity largely disappears under the optimal policy, however.

Secondly, the simple rule appears to be a pretty bad approximation to the optimal policy, also in terms of welfare. Thus, the adoption of the optimal policy implies a large reduction in welfare losses relative to the simple rule, of more than 50 percent in all cases (100 percent in the case of demand shocks, since welfare losses are zero under the optimal policy). Most interestingly, the decline in welfare losses is increasing in the degree of hysteresis. To put it differently, the costs of following the simple rule as opposed to the optimal policy are larger in economies that feature strong hysteresis.

5.3 Dynamic Responses to Shocks and Welfare: An Augmented Rule

The comparison of the model's impulse responses under the simple rule (22) and under the optimal policy suggests that what the former may be lacking is a *real anchor* that eliminates or, at least, reduces the persistent (or even permanent) deviations of activity from its efficient level in response to shocks. One possibility would be to increasing the size of the coefficient on output growth in the rule, or include the output level. But that may over-stabilize output in the face of shocks that change its efficient level, possibly permanently (e.g. technology shocks).[11] Instead I propose an *augmented* rule that incorporates the unemployment rate as an additional argument. In particular, I consider the rule:

$$i_t = \phi_i i_{t-1} + (1-\phi_i)[\rho + \phi_\pi \pi_t^p + \phi_y \Delta y_t + \phi_u u_t] \tag{31}$$

with a baseline setting $\phi_u = -0.5$. The choice of the latter is partly motivated by the analysis in Galí (2011a) in the context of the standard New Keynesian model.

Figures 5a-5c display the responses of the same set of variables to the three shocks under the augmented rule, as well as under the optimal and simple rules. Again, I restrict myself to the $\gamma = 1$ case. It is easy to see that, when it comes to the variables that are relevant for welfare, the response under the augmented rule is much closer to that under the optimal policy than it is the case for the simple rule. In particular, the large highly persistent component in the response of the unemployment rate (and the output gap) vanishes under the augmented rule. The latter also appears to achieve greater stability in both price and wage inflations.

The previous findings are also reflected in the analysis of welfare, shown in Table 5. Note that the welfare losses implied by the augmented rule are of the same order of magnitude and quantitatively similar to (though obviously larger than) those associated with the optimal policy and, hence,

[11] Of course, adding the level of the output gap as an argument would help attain the desired objective, but I take that variable to be unobservable in practice (since the efficient level of output is not observable) and hence not to qualify as an argument in any "implementable" simple rule.

much smaller than under the simple rule. Interestingly, welfare losses under the augmented rule are hardly affected by the size of the hysteresis parameter γ, a property that also characterizes the optimal policy, as discussed above. Accordingly, the welfare gains from switching from the simple rule to the augmented rule also increase with the importance of hysteresis effects.

6 Concluding Remarks

The high persistence of European unemployment constitutes a challenge for conventional macro models, including the standard New Keynesian model. In the present paper I have developed a modified version of that model that can generate highly persistent unemployment. The main modification consists of combining insider-outsider labor markets and hysteresis, as in Blanchard and Summers (1986), with the Calvo-type wage setting structure characteristic of the New Keynesian model. In the modified model the degree of hysteresis is indexed by a parameter, and need to be substantial in order to generate European levels of persistence. Under "full" hysteresis, unemployment and other real variables may experience permanent deviations from their efficient level, even in response to shocks that are transitory. Such deviations, even if large, do not necessarily generate inflationary pressures (of either sign) and hence may not elicit a suitable response from an inflation-focused central bank.

The presence of hysteresis effects has important implications for the conduct of monetary policy. Specifically, the optimal monetary policy calls for a more aggressive stabilization of unemployment (and the output gap) than the baseline simple rule, in response to any shock. The welfare gains from shifting to the optimal policy have been shown to be considerable, and increasing in the degree of hysteresis. Furthermore, I have shown that the outcome of the optimal policy can be approximated well by augmenting the simple rule so that the central bank also responds to the level of unemployment, which thus acts as an anchor. The latter finding may call for a reassessment of monetary policy strategies that put too much weight on inflation stabilization.

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Technical Appendix

Labor Market Participation and Unemployment

Consider individual (j,s) specialized in occupation j and with disutility of work χs^{φ}. *Using the household welfare as a criterion*, and *taking as given* current labor market conditions, that individual will be willing to work (and thus be part of the labor force) in period t if and only if

$$\frac{W_t(j)}{P_t} \geq \chi C_t s^{\varphi}$$

i.e. if and only if the relevant real wage exceeds the disutility from work, where the latter is expressed in terms of consumption by dividing the disutility term χs^{φ} by the household's marginal utility of consumption C_t^{-1}. Thus, the *marginal* supplier of type j labor, denoted by $L_t(j)$, is given by

$$\frac{W_t(j)}{P_t} = \chi C_t L_t(j)^{\varphi}$$

Define the aggregate labor force (or participation rate) as $L_t \equiv \int_0^1 L_t(j)dj$. Taking logs and integrating over j one can derive the following approximate relation:

$$w_t - p_t = c_t + \varphi l_t + \xi$$

where use is made of the first order approximations around the symmetric steady state $w_t \simeq \int_0^1 w_t(j)dj$ and $l_t \simeq \int_0^1 l_t(j)dj$. The previous equation can be thought of as an aggregate labor supply or participation equation.

Table 1. ADF Unit Root Tests

	1 lag	*4 lags*
1970Q1-2014Q4	−2.03 (−2.87)	−1.91 (−2.87)
1985Q1-2014Q4	−2.97* (−2.88)	−1.82 (−2.88)
1999Q1-2014Q4	−2.11 (−2.90)	−0.87 (−2.91)

Note: t-statistics of Augmented Dickey-Fuller tests (with intercept) for the null of a unit root in the unemployment rate. Sample period 1970Q1-2014Q4. Asterisks denote significance at the 5 percent level. Critical value (adjusted for sample size) for the null of a unit root shown in brackets.

Table 2. Calibration

φ	Curvature of labor disutility	3.4
β	Discount factor	0.99
α	Decreasing returns to labor	0.26
ϵ_w	Elasticity of substitution (labor)	4.3
ϵ_p	Elasticity of substitution (goods)	3.8
θ_p	Calvo index of price rigidities	0.75
θ_w	Calvo index of wage rigidities	0.75
ϕ_i	Lagged interest rate coefficient	0.9
ϕ_π	Inflation coefficient	1.5
ϕ_y	Output growth coefficient	0.5

Table 3
Unemployment Persistence in the Standard New Keynesian Model

	$\rho_u(1)$	$\rho_u(4)$	$\rho_u(8)$	$\frac{\sigma_u}{\sigma_{\Delta y}}$	$\rho_{u,\pi}$
Data					
1970Q1-2014Q4	0.99	0.97	0.91	4.50	-0.76
1985Q1-2014Q4	0.98	0.83	0.52	2.02	-0.44
1999Q1-2014Q4	0.98	0.81	0.49	2.02	-0.35
Standard NK Model					
Technology	0.96 (0.93,0.98)	0.72 (0.53,0.84)	0.36 (0.03,0.64)	0.90 (0.64,1.14)	0.26 (0.07,0.41)
Markup	0.95 (0.91,0.97)	0.69 (0.49,0.81)	0.33 (-0.01,0.59)	4.33 (3.34,5.89)	0.60 (0.59,0.64)
Demand	0.81 (0.72,0.87)	0.41 (0.18,0.60)	0.14 (-0.16,0.42)	2.61 (2.17,3.17)	-0.81 (-0.89,-0.71)

Note: Based on 200 simulations of 180 observations each. Persistence of driving forces: $\rho_a = 1$, $\rho_x = 0.99$, and $\rho_z = 0.99$. For each statistic, the table reports the median and 95% confidence interval (in brackets).

Table 4
Unemployment Persistence in the NK-IO Model

	$\rho_u(1)$	$\rho_u(4)$	$\rho_u(8)$	$\frac{\sigma_u}{\sigma_{\Delta y}}$	$\rho_{u,\pi}$
Technology					
Std. NK	0.96 (0.93,0.98)	0.72 (0.53,0.84)	0.36 (0.03,0.64)	0.90 (0.64,1.14)	0.26 (0.07,0.41)
$\gamma = 0.0$	0.97 (0.94,0.98)	0.76 (0.56,0.89)	0.42 (0.07,0.72)	1.06 (0.78,1.46)	0.29 (0.14,0.49)
$\gamma = 0.9$	0.99 (0.96,0.99)	0.90 (0.76,0.97)	0.73 (0.39,0.90)	2.55 (1.55,4.56)	0.34 (0.25,0.50)
$\gamma = 1.0$	0.99 (0.96,0.99)	0.92 (0.80,0.98)	0.83 (0.54,0.95)	4.58 (2.25,10.3)	0.12 (−0.15,0.36)
Markup					
Std. NK	0.94 (0.91,0.97)	0.60 (0.43,0.74)	0.17 (−0.14,0.42)	4.12 (3.27,5.31)	0.55 (0.53,0.58)
$\gamma = 0.0$	0.94 (0.90,0.96)	0.58 (0.37,0.72)	0.11 (−0.21,0.37)	4.12 (3.21,5.00)	0.57 (0.55,0.61)
$\gamma = 0.9$	0.97 (0.94,0.99)	0.80 (0.64,0.90)	0.52 (0.18,0.78)	6.09 (4.30,8.98)	0.48 (0.45,0.55)
$\gamma = 1.0$	0.98 (0.93,0.99)	0.86 (0.63,0.96)	0.70 (0.28,0.90)	7.68 (4.35,15.9)	0.28 (0.07,0.44)
Demand					
Std.NK	0.79 (0.69,0.86)	0.38 (0.17,0.55)	0.09 (−0.20,0.34)	2.55 (2.09,3.03)	−0.99 (−0.99,−0.99)
$\gamma = 0.0$	0.80 (0.68,0.86)	0.37 (0.14,0.57)	0.07 (−0.16,0.39)	2.56 (2.04,3.09)	−0.99 (−0.99,−0.99)
$\gamma = 0.9$	0.92 (0.84,0.97)	0.75 (0.48,0.91)	0.58 (0.15,0.85)	4.23 (2.88,7.46)	−0.53 (−0.71,−0.36)
$\gamma = 1.0$	0.96 (0.88,0.99)	0.86 (0.58,0.96)	0.74 (0.24,0.92)	6.21 (3.42,13.6)	−0.36 (−0.63,−0.03)

Note: Based on 200 simulations of 180 observations each. Persistence of driving forces: $\rho_a = 1$, $\rho_x = 0.99$, and $\rho_z = 0.99$. For each statistic, the table reports the median and 95% confidence interval (in brackets).

Table 5
Monetary Policy and Welfare in the NK-IO Model

	Hysteresis Parameter					
	$\gamma = 0$		$\gamma = 0.9$		$\gamma = 1$	
Technology						
Simple	0.085	1.0	0.158	1.0	1.003	1.0
Optimal	0.041	0.48	0.044	0.27	0.045	0.04
Augmented	0.049	0.58	0.050	0.31	0.051	0.05
Markup						
Simple	0.036	1.0	0.071	1.0	0.267	1.0
Optimal	0.014	0.38	0.015	0.21	0.015	0.05
Augmented	0.027	0.74	0.019	0.26	0.021	0.07
Demand						
Simple	0.128	1.0	0.281	1.0	1.765	1.0
Optimal	0.0	0.0	0.0	0.0	0.0	0.0
Augmented	0.007	0.05	0.006	0.02	0.007	< 0.01

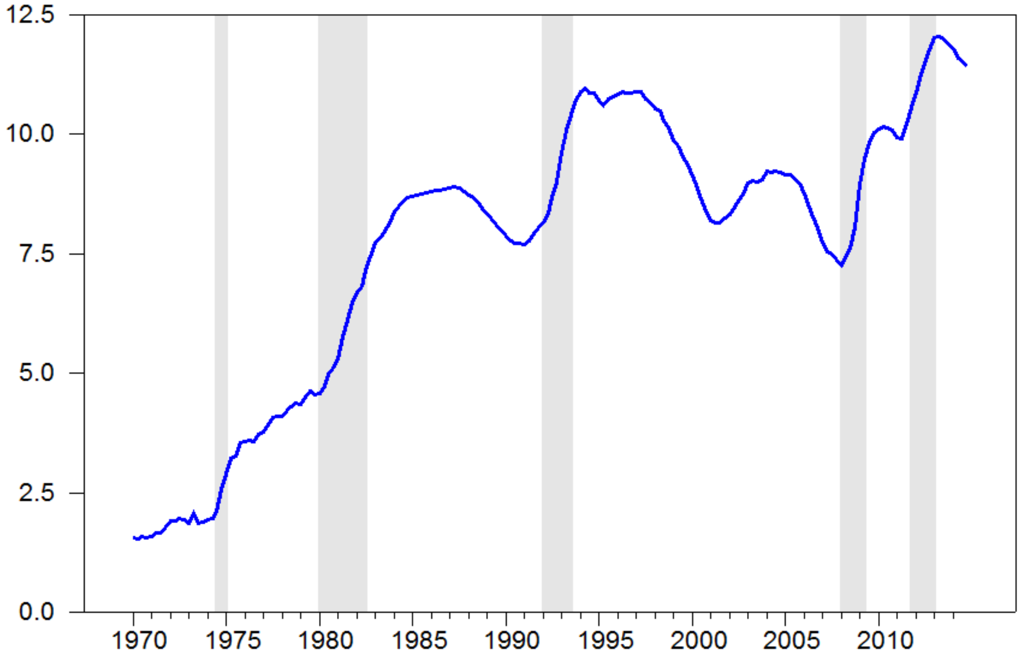

Figure 1. Unemployment Rate in the Euro Area

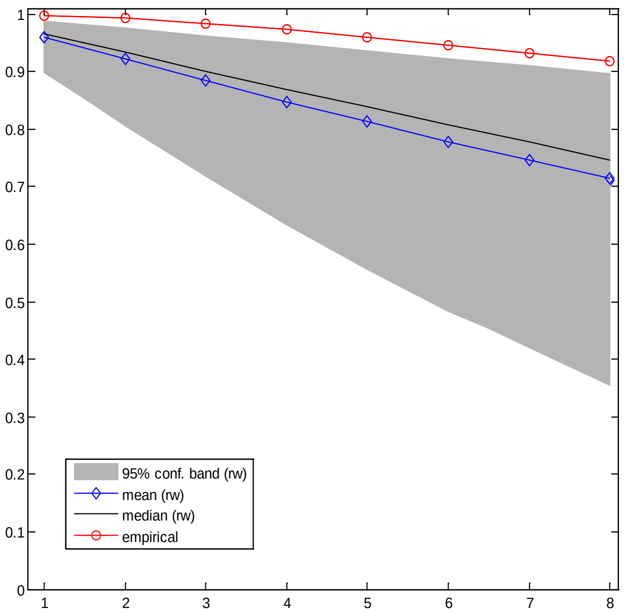

Figure 2.a. Unemployment autocorrelation: 1970Q1-2014Q4 (180 obs.)

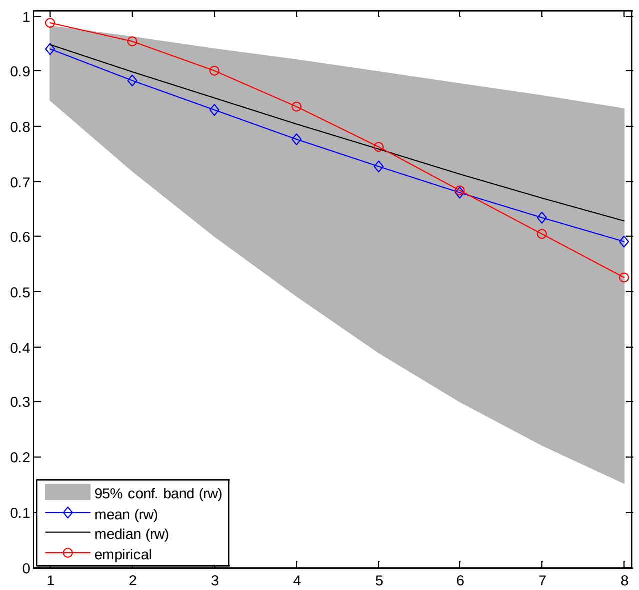

Figure 2.b. Unemployment Autocorrelation: 1985Q1-2014Q4 (120 obs.)

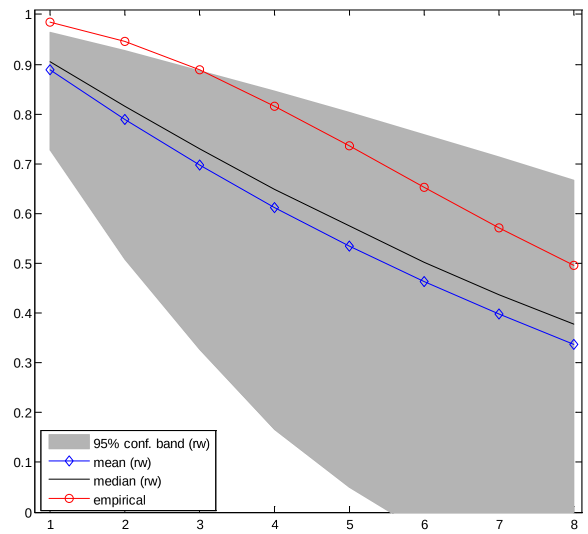

Figure 2.c. Unemployment Autocorrelation: 1999Q1-2014Q4 (64 obs.)

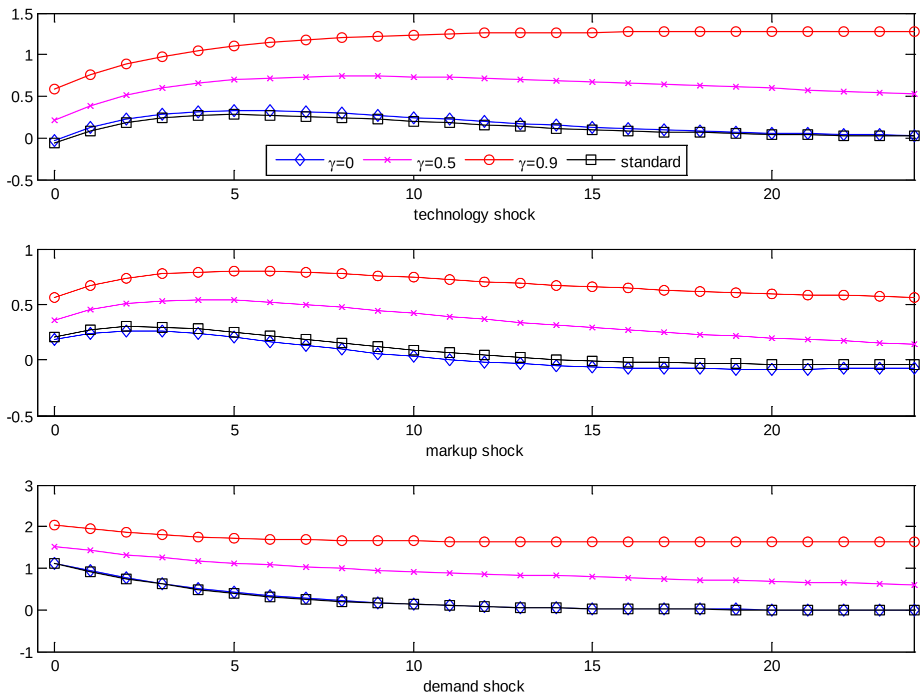

Figure 3. Dynamic Responses of the Unemployment Rate

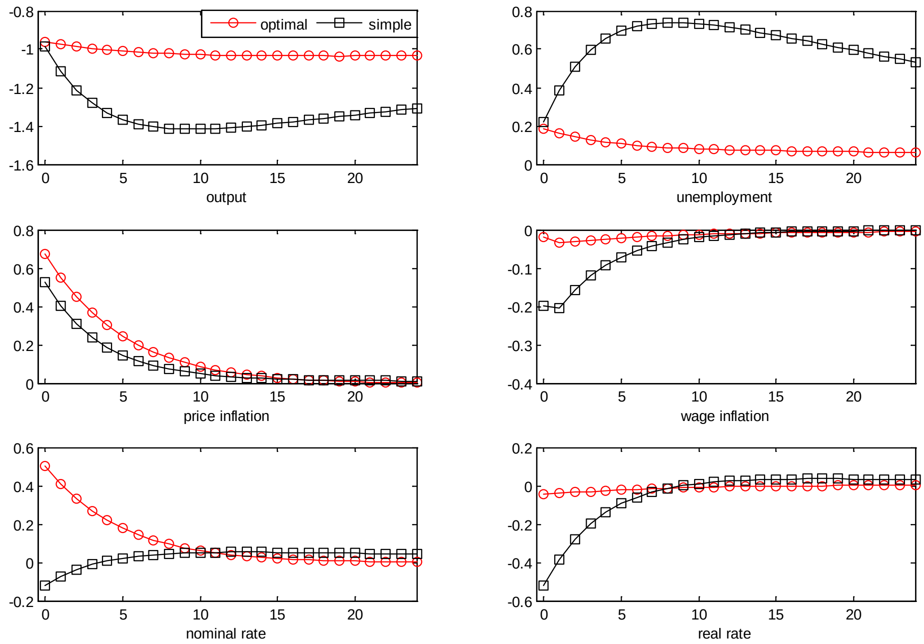

Figure 4.a Optimal Policy vs. Simple Rule: Technology Shocks

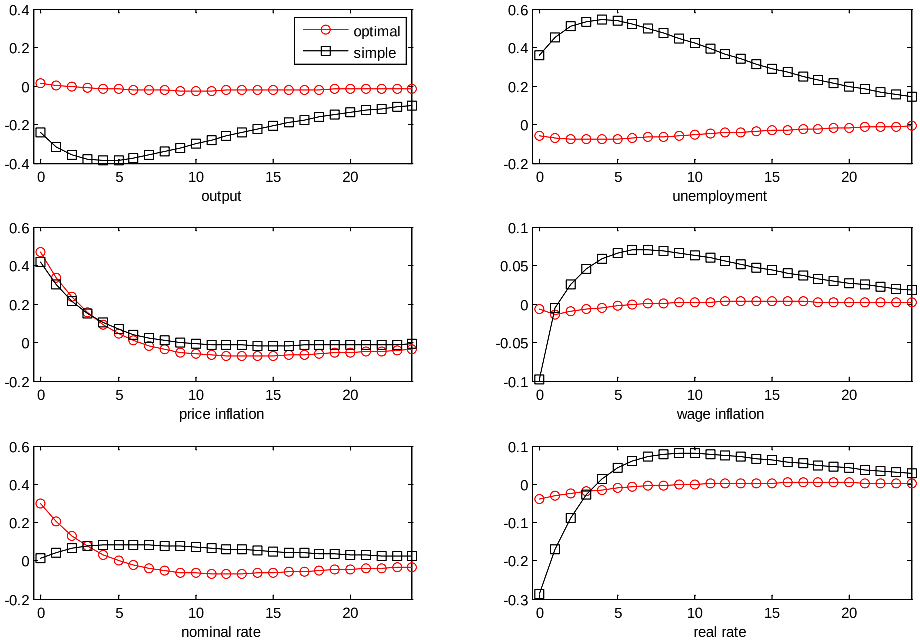

Figure 4.b Optimal Policy vs. Simple Rule: Markup Shocks

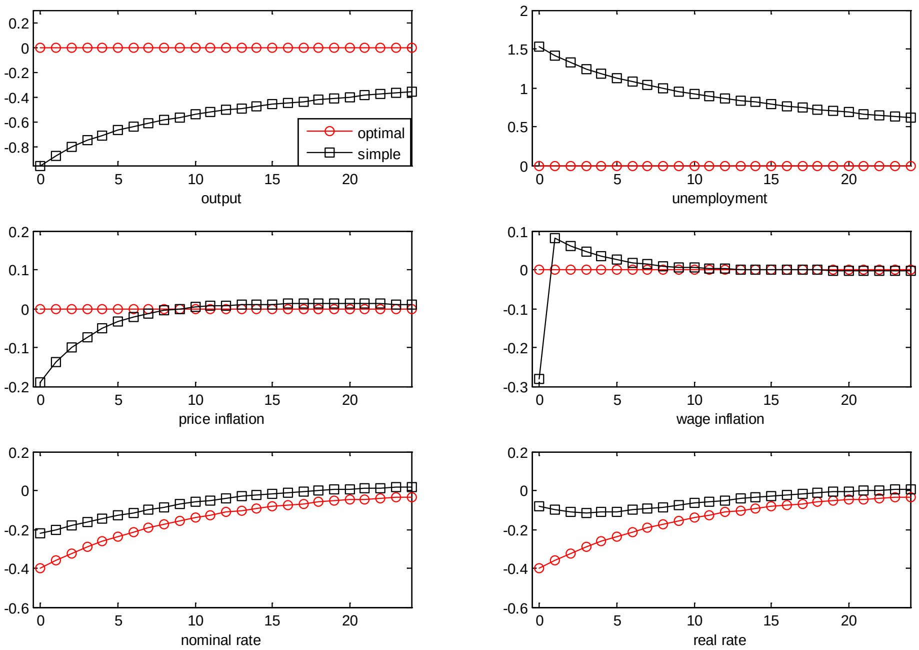

Figure 4.c Optimal Policy vs. Simple Rule: Demand Shocks

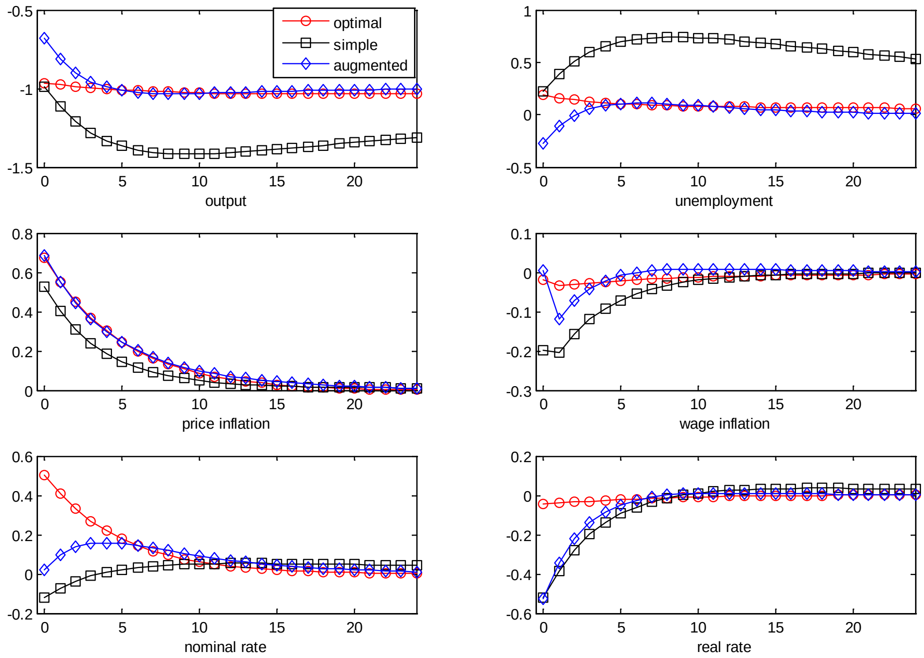

Figure 5.a Optimal vs. Augmented Rule: Technology Shocks

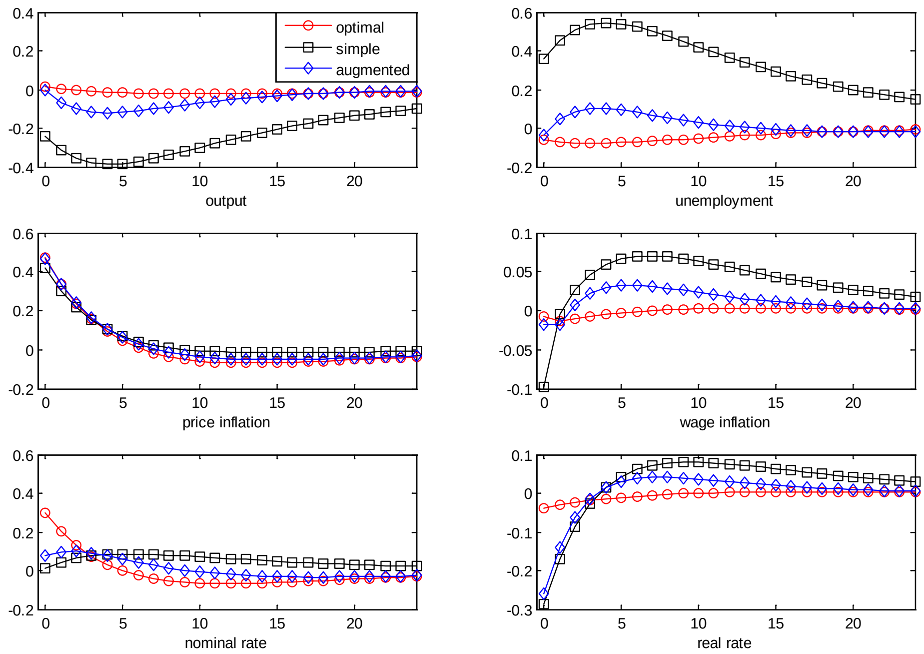

Figure 5.b Optimal vs. Augmented Rule: Markup Shocks

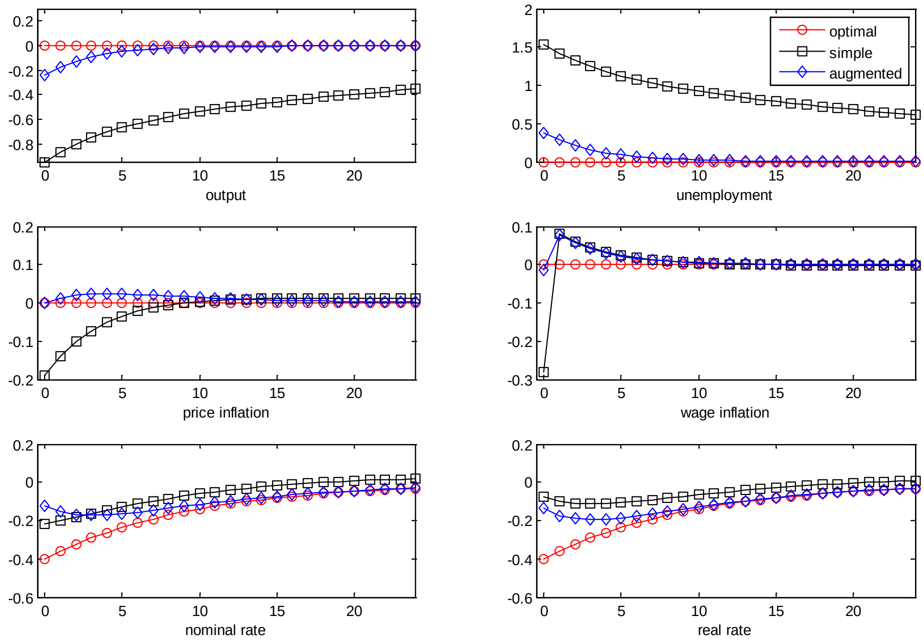

Figure 5.c Optimal vs. Augmented Rule: Demand Shocks