Insider-Outsider Labor Markets, Hysteresis and Monetary Policy*

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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 European unemployment. I study the implications of that environment for the design of monetary policy. The optimal policy calls for strong emphasis on unemployment stabilization which a standard interest rate rule fails to deliver, with the gap between the two increasing in the degree of hysteresis. A simple interest rule that includes the unemployment rate is shown to approximate well the optimal policy.

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Much discussion on the European unemployment problem has tended 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. 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 too little persistent relative to the data.

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– the *insiders*– when setting wages. The second feature implies that the measure of insiders evolves 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, and under a "realistic" monetary policy rule.

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 environment for the design of monetary policy. Firstly, I derive and characterize the equilibrium under the optimal policy with commitment and compare it to that associated with a simple interest rate rule. I show that the gap between the economy's equilibrium response to different shocks under the two policies is increasing in the degree of hysteresis. Furthermore, the welfare gains generated by the adoption of the optimal policy can be large, the more so the higher the degree of price stickiness.

Finally, I study how the simple interest rate rule can be modified in

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

order to approximate the optimal policy. In particular, I show how a rule that responds to the unemployment rate, in addition to inflation and output growth, does a good job at approximating the outcomes of the fully optimal policy.

The paper is organized as follows. Section 2 presents 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 persistence, and contrasts it with the standard New Keynesian model. Section 5 derives the optimal monetary policy in the presence of insider-outsider labor markets, and characterizes the implied equilibrium. Section 6 analyzes the welfare consequences of the different rules considered. Section 7 concludes.

1 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 1970Q1-2016Q4, 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 seems to pull 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 (as in 1980 or 2012). In any event, the unemployment rate shows no clear tendency to gravitate towards some constant long-run equilibrium value.[3]

The previous visual assessment is confirmed by the estimated autocorrelogram for the euro area unemployment rate, which is displayed in Figure 2.a (line with circles). The estimated autocorrelations decay very slowly, a trademark of highly persistent time series. As a benchmark for comparison, the figure also shows the median and mean estimates (as well as 95 per cent confidence bands) of the distribution of the estimated autocorrelogram for a random walk, based on 200 simulated time series with the same number of observations as our sample (188 observations). Note that the esti-

[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 17 of that data set.

[3] The latter observation is in stark contrast to the U.S. unemployment rate, which fluctuates around a value not far from 5 percent.

mated autocorrelogram for the euro area unemployment rate lies outside the confidence interval, and well above the median and mean autocorrelations associated with the random walk, pointing to greater persistence than the latter process.[4]

When I drop from the sample the first fifteen years, during which the unemployment rate shows a (nearly) continuous increase, and start the sample period at 1985Q1, the estimated autocorrelogram comes down uniformly, as shown in Figure 2.b. Note, however, that it remains close to the estimated autocorrelogram for a simulated random walk (with 128 observations), and well within the corresponding confidence interval.

The outcome of unit root tests applied to the euro area unemployment rate tends to accord with the previous evidence. In particular, and as reported in Table 1, an Augmented Dickey-Fuller (ADF) test (with 1 and 4 lags) does not reject the null of unit root in the unemployment rate at a 5 percent significance level for the full sample period. When I start the sample period in 1985Q1, the null of a unit root is rejected when only one lag of the first-differenced unemployment rate is used in the ADF regression, but cannot be rejected again when four lags are used. Finally, when I restrict myself to the single currency period proper (1999Q1-2016Q4) I cannot reject the null of a unit root again.

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.

2 A New Keynesian Model with Insider-Outsider Labor Markets

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

[4] A similar finding is obtained when I use 1985Q1-2014Q4 and 1999Q1-2014Q4 as alternative sample periods (adjusting the number of observations in the simulated random walks accordingly), though in those cases the estimated autocorrelogram lies inside the confidence interval associated with the random walk.

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.

2.1 Households

I assume a large number of identical households. Each household has a continuum of members distributed uniformly over 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. Employed individuals work a constant number of hours. Employment for each occupation, $\mathcal{N}_t(j) \in [0,1]$, is demand-determined and taken as given by each 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:

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

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 $C_t(i)$ being 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.

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 denotes dividends from the ownership of firms.[5] $\beta \in [0, 1]$ is the household's discount factor.

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

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

where $\pi_t^p \equiv p_t - p_{t-1}$ denotes price inflation, and $\rho \equiv -\log \beta$ is the discount rate.[6]

Following Galí (2011a,b), I define $L_t(j)$ as the marginal participant for occupation j, determined by condition:

$$\frac{1}{C_t} \frac{W_t(j)}{P_t} = \chi L_t(j)^{\varphi}$$

Taking logs and aggregating over all occupations one can derive the following aggregate participation equation:

$$\omega_t \equiv w_t - p_t = c_t + \varphi l_t + \xi \tag{2}$$

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

[6] See Woodford (2003) or Galí (2015b) for a derivation of these and other equilibrium conditions unrelated to the labor market.

where $w_t \equiv \int_0^1 w_t(j)dj$ is the average (log) nominal wage, $l_t \equiv \int_0^1 l_t(j)dj$ can be interpreted as the (log) labor force (or participation), and $\xi \equiv \log \chi$.

Thus, the unemployment rate can be (naturally) defined as:

$$u_t \equiv l_t - n_t \tag{3}$$

where $n_t \equiv \int_0^1 n_t(j)dj$ is (log) aggregate employment, which is demand determined.

2.2 Firms

I assume the existence of a continuum of differentiated goods $i \in [0,1]$, each produced by a monopolistic competitor, with a production function:

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{4}$$

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 (10) introduced above. Technology is assumed to follow an $AR(1)$ process in logs, i.e.

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a$$

where $a_t \equiv \log A_t$ and $\rho_a \in [0,1]$.

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)

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} - \lambda_p(\mu_t^p - x_t) \tag{5}$$

where

$$\mu_t^p \equiv a_t - \alpha n_t + \log(1-\alpha) - \omega_t \tag{6}$$

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.[7] The latter is assumed to follow an $AR(1)$ process with mean $\log \frac{\epsilon_p}{\epsilon_p - 1}$ autoregressive coefficient $\rho_x \in [0,1)$.

[7] See chapter 3 in Galí (2015) for a derivation.

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

$$\begin{aligned}\mu_t^p - x_t &= a_t - \alpha\widehat{n}_t - \alpha n + \log(1-\alpha) - x_t - \omega_t \\ &= -\alpha\widehat{n}_t - \widetilde{\omega}_t \end{aligned} \tag{7}$$

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:

$$y_t = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{t+1}^p\} - \rho) + (1-\rho_z)z_t \tag{8}$$

Given equilibrium output, employment is given by

$$(1-\alpha)n_t = y_t - a_t \tag{9}$$

2.3 Wage Setting

Next I turn to a description of wage setting. First I describe wage setting in the standard New Keynesian model, and then turn to wage setting in the insider-outsider model. In both cases, I adopt the Calvo model of staggered nominal wage setting, which assumes that 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.

When setting the new wage $w_t^*(j)$, a union representing occupation j takes into account current and (expected) future demand for its work services, as given by:

$$n_{t+k|t}(j) = -\epsilon_w(w_t^*(j) - w_{t+k}) + n_{t+k} \tag{10}$$

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.

As a result the evolution of the average (log) nominal wage is described by the difference equation:

$$w_t = \theta_w w_{t-1} + (1-\theta_w)w_t^* \tag{11}$$

where $w_t^* \equiv (1-\theta_w)^{-1} \int_{j \in \mathcal{J}_t} w_t^*(j) dj$, where $\mathcal{J}_t \subset [0,1]$ represents the subset of occupations resetting their wage in period t. Thus, w_t^* is the average newly set wage in period t, expressed in logs.[8]

The previous features are common to the two models of wage setting considered below.

2.3.1 Wage Setting in the Standard New Keynesian Model

In the standard New Keynesian model (e.g. Erceg, Henderson and Levin (2001)) it is assumed that, when resetting the wage, each union seeks to maximize the utility of the representative household, to which all union members (employed or unemployed) belong.[9] This gives rise to a (log-linearized) wage setting rule of the form:

$$w_t^* = \mu^w + (1-\beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ \underline{w}_{t+k|t} \right\} \tag{12}$$

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. 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 (11) and (12) allows one to derive the wage inflation equation:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w(\mu_t^w - \mu^w) \tag{13}$$

where $\pi_t^w \equiv w_t - w_{t-1}$ denotes wage inflation and

$$\mu_t^w \equiv \omega_t - (c_t + \varphi n_t + \xi) \tag{14}$$

is the average wage markup in period t, where $\omega_t \equiv w_t - p_t$ is the average (log) real wage, and $\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$.

[8] The previous equation, like others used in the present analysis, are log-linear approximations in a neighborhood of a zero inflation steady state to the exact equilibrium condition. See Galí (2015) for detailed derivations.

[9] See, e.g., Galí (2015, chapter 6) for a discussion of the union's problem and a derivation of the optimal wage setting rule.

Note that equations (2) and (14) can be combined with the definition of the unemployment rate in (3) to yield a simple relation linking the average wage markup and unemployment:

$$\mu_t^w = \varphi u_t \tag{15}$$

Finally, one can combine the latter condition with (13) to derive the following New Keynesian wage Phillips curve, linking wage inflation and unemployment:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w \varphi (u_t - u) \tag{16}$$

where $u \equiv \frac{\mu^w}{\varphi}$ is the *natural* rate of unemployment, i.e. the unemployment rate that would obtain under flexible wages (and, hence, a constant wage markup μ^w).

It is easy to see that the previous model of wage setting guarantees the tendency of the unemployment rate to gravitate towards its natural rate, even in the presence of permanent shocks. Thus, (16) makes clear that in the face of a high (low) unemployment rate (relative to the natural rate u), wages will tend to decrease (increase), thus lowering (raising) marginal cost, inflation, and the interest rate (through a policy rule like the one introduced below) and, as a result, boosting (dampening) output and reducing (increasing) the unemployment rate.

The implied stationarity of the unemployment rate becomes apparent by noting that (12) can be equivalently rewritten as

$$(1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{\mu_{t+k|t}^w\right\} = \mu^w \tag{17}$$

where $\mu_{t+k|t}^w \equiv w_t^* - \underline{w}_{t+k|t}$ is the markup k periods after the wage is set and conditional on the latter remaining in place. Thus, when reoptimizing, unions choose a wage such that, *in expectation*, a relevant weighted average of the wage markups that will prevail over the life of the newly set wage equals the desired or frictionless wage markup μ^w. Since all wage-setting unions behave in a similar way, the economy's average wage markup μ_t^w will fluctuate about μ^w. Accordingly, and given (15), the unemployment rate will display mean-reverting fluctuations about the constant natural rate u.

2.3.2 An Insider-Outsider Model of Wage Setting

Insider-outsider models of the labor market, as originally 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 (1986):

> "...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 adapt the Blanchard-Summers (1986) version of the insider-outsider model in order to make it consistent with the Calvo wage setting formalism so that it 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 is assumed to choose a wage, $w_t^*(j)$, such that the following condition is satisfied

$$(1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{n_{t+k|t}(j)\right\} = n_t^*(j) \tag{18}$$

with $n_{t+k|t}(j)$ given by (10), for $k = 0, 1, 2...$In words, the wage is set so that, in expectation, a weighted average of employment in occupation j over the period in which the wage remains effective equals some employment *target* $n_t^*(j)$. The latter can interpreted as representing the measure of *insiders* in occupation j.[10]

Thus, and in contrast with the standard NK model in which, when setting a nominal wage, unions target a weighted average of expected wage markup over the life of the wage, in the insider-outsider model they target an identical weighted average of expected employment levels.

Substituting (10) into (18) yields the wage setting rule:

$$w_t^*(j) = -\frac{1}{\epsilon_w}n_t^*(j) + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{w_{t+k} + \frac{1}{\epsilon_w}n_{t+k}\right\} \tag{19}$$

[10] 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. A formal treatment is beyond the scope of the present model.

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:

$$n_t^*(j) = \gamma n_{t-1}(j) + (1-\gamma)n^* \tag{20}$$

where n^* is the union's *long run target* for (log) employment, which is assumed to be common across occupations. Note that (18) implies that n^* 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 property 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 be 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 from the wage setting process.

Plugging (20) into (19) and averaging over $j \in \mathcal{J}_t$ we obtain:

$$w_t^* = -\frac{\gamma}{\epsilon_w}\widehat{n}_{t-1}^* + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{w_{t+k} + \frac{1}{\epsilon_w}\widehat{n}_{t+k}\right\} \tag{21}$$

where $\widehat{n}_t \equiv n_t - n$, $\widehat{n}_t^* \equiv n_t^* - n$, and $n_t^* \equiv (1-\theta_w)^{-1}\int_{j\in\times_t} n_t^*(j)dj$ is the average (log) employment target for unions resetting their wage in period t.

Combining (21) with (11) yields (after some algebra) the following wage inflation equation for the insider-outsider economy:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + (1-\gamma)\lambda_n(1-\beta\theta_w)\widehat{n}_t + \gamma\lambda_n\Delta n_t \tag{22}$$

where $\lambda_n \equiv \frac{1-\theta_w}{\theta_w\epsilon_w}$, which is decreasing in the degree of wage rigidities. Note that both the (log) employment change and its deviation from steady state, $\widehat{n}_t$, are the drivers of fluctuations in wage inflation, with the weights on each being a function of γ, the degree of hysteresis.

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 corresponds to the workers employed at the end of the previous period, with no weight attached to the unemployed in the wage setting decision. Accordingly equation (22) 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 only the employment gap $\widehat{n}_t$ emerging now as the driving variable.

Wage inflation equation (22), like its counterpart in the standard New Keynesian model (16), abstracts from many features that are likely to be relevant in actual economies, including indexation and non-linearities (e.g. resulting from downward nominal wage rigidities). The simplicity of both formulations, however, facilitates the optimal monetary policy analysis below, which is the main focus of the present paper, while focusing on the qualitative differences

2.4 Efficient Allocation, Steady State and Equilibrium Dynamics

2.4.1 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.

2.4.2 Steady State

The steady state of the decentralized economy is not invariant to the assumed wage setting environment. Thus in the standard model steady state employment is given by

$$n \equiv \frac{\log(1-\alpha) - (\xi + \mu^w + \mu^p) - \log(1-\tau)}{1+\varphi}$$

where τ denotes a (constant) wage subsidy which can be easily introduced in the framework without affecting any equation describing the equilibrium dynamics. Note that steady state efficiency can be attained by setting $\tau = 1 - \exp\{-(\mu^w + \mu^p)\}$.

By contrast, steady state employment in the model with insider-outsider labor markets is given by the long run employment target n^*, which is assumed to be common across unions. Thus, $n = n^*$ in the modified version of the New Keynesian model proposed above.

In the welfare analysis below it is assumed that the steady state corresponds to the efficient steady state in all cases considered.

2.4.3 Equilibrium Dynamics

Equations (2), (3), (5), (7), (8), (9), (14), (15), and (24), together with the identity

$$\omega_t \equiv \omega_{t-1} + \pi_t^w - \pi_t^p \tag{23}$$

and wage inflation equation (16) (standard model) or (22) (insider outsider 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. For the baseline simulations below I assume an interest rate rule of the form:

$$i_t = \phi_i i_{t-1} + (1-\phi_i)[\rho + \phi_\pi \pi_t^p + \phi_y \Delta y_t] \tag{24}$$

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 Unemployment Persistence in the New Keynesian Model

Can the New Keynesian model account for the observed persistence of European unemployment? In the present section I try to provide an answer to that question by simulating a calibrated version of the New Keynesian model under the two wage setting regimes considered (standard and insider-outsider), 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.

3.1 Calibration

Table 2 lists the baseline settings for the model parameters used 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.[11] 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.[12] 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

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

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

[12] 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).

is roughly consistent with the bulk of the micro evidence for the euro area (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.

3.2 Unemployment Persistence in the Standard New Keynesian Model

I simulate the standard New Keynesian model under the above baseline calibration to evaluate its ability to generate the degree of unemployment persistence observed in the European 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. The middle panel of Table 3 reports the median and a 95 percent confidence interval for each of those statistics, conditional on each shock. The top row reports their empirical counterparts for three different sample periods. 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 extremely persistent. Specifically, I set $\rho_a = \rho_x = \rho_z = 0.99$.

The simulations' outcome, as summarized in middle panel of Table 3, suggests that the standard New Keynesian model has clear difficulties to match the persistence of European unemployment, independently of the nature of the shock driving those fluctuations and despite the assumed high persistence of the driving forces. 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, the empirical autocorrelations (for any of the three sample considered) lie outside the 95 percent confidence interval generated by the model.

Not surprisingly, the degree of unemployment persistence is not independent of the degree of wage rigidities. This is illustrated by the estimated autocorrelations obtained under the assumption of much stronger stickiness. In particular I assume $\theta_w = 0.95$, which implies an average duration of an individual wage of 5 years (!). The implied autocorrelogram of unemployment increases uniformly at all lags, and for all shocks, thus getting closer to its empirical counterpart. That finding can hardly be seen as a success for the standard model, since the required levels of wage stickiness to match the observed unemployment persistence are clearly at odds with the micro evidence.

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, at least under plausible calibrations of the degree of wage stickiness. 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.[13]

3.3 Unemployment Persistence in the New Keynesian Model with Insider-Outsider Labor Markets and Hysteresis

Next I repeat the 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. In contrast with the previous exercise I now assume high (but not extreme) values for the autoregressive coefficient of the two remaining shocks, namely, $\rho_a = \rho_x = \rho_z = 0.92$, implying a half-life of (roughly) two years for the exogenous shocks themselves.

A number of findings are worth stressing. First, note that under $\gamma = 0$, i.e. in the absence of hysteresis (and, hence, a constant employment target), the behavior of unemployment is very similar (though not identical) to that in

[13]In Galí (2015a) I discuss possible sources of unemployment rate nonstationarity in the New Keynesian model. In addition to the hysteresis model proposed below, I point to nonstationarity in the desired wage markup and/or in the inflation target as possible addition sources of a unit root in the unemployment rate. As argued in that paper, however, some of the implications of those alternative hypothesis are hard to reconcile with the observed joint behavior of wage inflation and the unemployment rate.

the New Keynesian model, even though their wage setting rules are different (one targets a constant level of employment, the other targets a constant wage markup). Secondly, and irrespective of the shock considered, the estimated autocorrelation of unemployment increases substantially as γ goes up. Thus, even for $\gamma = 0.9$ the implied values are not too different from those observed in the data, with the latter generally falling within the 95 percent confidence interval, especially when we exclude the early sample period.

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. 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.

Next I turn to the analysis of the implications of the insider-outsider model for the design of monetary policy.

4 Optimal Monetary Policy with Insider-Outsider Labor Markets

In the present section I derive the optimal monetary policy in the New Keynesian model with insider-outsider labor markets developed above. In doing so, I examine the role played by the degree of hysteresis (as measured by parameter γ) in shaping the response of unemployment to different shocks, with a focus on the differential response under the optimal policy relative to the simple policy rule.

4.1 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,

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

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.[14]

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:

$$\frac{1}{2}E_0 \sum_{t=0}^{\infty} \beta^t \left((1+\varphi)(1-\alpha)\widehat{n}_t^2 + \frac{\epsilon_p}{\lambda_p}(\pi_t^p)^2 + \frac{\epsilon_w(1-\alpha)}{\lambda_w}(\pi_t^w)^2 \right) \tag{25}$$

where $\widehat{n}_t \equiv n_t - n$. Loss function (25) is equivalent to that used in the standard New Keynesian model. The reason is that while the Calvo wage dynamics equation (11) (assumed here in both models) is used in the derivation of the loss function, this is not the case for the wage setting equation (12), so the latter's replacement by (19) has no impact on the form of the welfare loss function.[15]

The monetary authority seeks to minimize (25) subject to:

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} + \lambda_p \alpha \widehat{n}_t + \lambda_p \widetilde{\omega}_t \tag{26}$$

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n(1-\gamma)(1-\beta\theta_w)\widehat{n}_t + \lambda_n \gamma \Delta n_t] \tag{27}$$

$$\widetilde{\omega}_{t-1} \equiv \widetilde{\omega}_t - \pi_t^w + \pi_t^p + \Delta a_t - \Delta x_t \tag{28}$$

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

$$(1+\varphi)(1-\alpha)\widehat{n}_t + \lambda_p \alpha \zeta_{1,t} + \lambda_n(1-(1-\gamma)\beta\theta_w)\zeta_{2,t} - \lambda_n \gamma \beta E_t\{\zeta_{2,t+1}\} = 0 \tag{29}$$

[14] 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.

[15] Note that the loss function is often expressed in terms of the output gap instead of the output gap (see, e.g. Galí (2015, chapter 6). The relation between the two is trivially given by $\widetilde{y}_t = (1-\alpha)\widehat{n}_t$.

$$\frac{\epsilon_p}{\lambda_p}\ \pi_t^p - \Delta\zeta_{1,t} + \zeta_{3,t} = 0 \quad (30)$$

$$\frac{\epsilon_w(1-\alpha)}{\lambda_w}\ \pi_t^w - \Delta\zeta_{2,t} - \zeta_{3,t} = 0 \quad (31)$$

$$\lambda_p \zeta_{1,t} + \zeta_{3,t} - \beta E_t\{\zeta_{3,t+1}\} = 0 \quad (32)$$

for $t = 0, 1, 2, ...$which, together with the constraints (26), (27), and (28) 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.

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

Figures 4 displays the response of the unemployment rate to different shocks in the New Keynesian model with insider-outsider labor markets. For each shock I show four responses, corresponding to the possible combinations of (i) monetary policy (optimal or simple rule) and (ii) degree of hysteresis ($\gamma = 0$ and $\gamma = 1$). 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 in all cases.

Two findings are worth stressing. Firstly, the high stability of the unemployment rate under the optimal policy, in comparison to the responses under the simple rule. This is true independently of the degree of hysteresis and the shock impinging on the economy; it takes an extreme form in the case of demand shocks, in response to which the optimal policy *fully* stabilizes the unemployment rate. It is worth noting that in the case of full hysteresis, and with the exception of demand shocks, the unemployment rate preserves a unit root component, though the latter is tiny (and hardly visible in the Figure).

Secondly, and as the Figure makes clear, in the absence of hysteresis (or when the latter is low, more generally), the discrepancy between the unemployment responses under the simple rule and under the optimal policy is far from negligible, but very short-lived, with the unemployment reverting back rapidly towards its initial level (despite the high persistence of the shocks). On the other hand, under full hysteresis the discrepancy is quantitatively large and, most importantly, permanent.

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, especially in the presence of strong hysteresis. In Table 5 I report the welfare losses under the two policies, as measured by (25), conditional on each of the three shocks considered, and for three alternative values of the hysteresis parameter (0, 0.9 and 1). I also report the welfare loss *relative* to the simple rule (24) (i.e. with the latter normalized 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 seven times larger than in the absence of hysteresis ($\gamma = 0$). That gradient largely disappears under the optimal policy, however.

Secondly, the extent to which the adoption of the optimal policy implies a reduction of welfare losses relative to the simple rule depends strongly on the degree of hysteresis. Thus, the adoption of the optimal policy implies a substantial reduction in welfare losses 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.

4.3 Dynamic Responses to Shocks and Welfare: An Augmented Rule

The comparison of the model's impulse responses under the simple rule (24) and under the optimal policy suggests that what the former may be lacking is a *real anchor* that eliminates or, at least, reduces the persistence of the deviations of employment from its efficient level in response to shocks. The option of increasing the size of the coefficient on output growth in the rule, or to replace it with the output level may overstabilize activity in the face of shocks that change its efficient level, possibly permanently (e.g. technology shocks).[16] Instead I propose an *augmented* rule that incorporates the

[16]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

unemployment rate as an additional argument. In particular, I consider the rule:

$$i_t = \phi_i i_{t-1} + (1 - \phi_i)[\rho + \phi_\pi \pi_t^p + \phi_y \Delta y_t + \phi_u u_t] \tag{33}$$

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.

Figure 5 displays the response of the unemployment rate to the three shocks under the augmented rule, as well as under the optimal and simple rules. To convey the main idea more starkly, I restrict myself to the case of full hysteresis ($\gamma = 1$). The Figure makes clear that the response of unemployment 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 vanishes under the augmented rule.

Figures 6a-6c illustrates the same point with regard to other variables and, in particular, those that influence the level of welfare losses (employment, price inflation and wage inflation). Given the stationarity of the two inflation variables independently of the rule, the gap between the response of those variables under the optimal and augmented rules, on the one hand, and the simple rule on the other is restricted to the short run, and is often small. The largest discrepancies involve, instead, the responses of employment and output, as the Figure makes clear.

Most importantly, note that under strong hysteresis, the large deviations of emploment or output from their efficient levels do not generate inflationary pressures (of either sign) and hence may not elicit a suitable response from the central bank, unless the latter seeks to prevent those deviations to begin with (as in the optimal policy) or systematically responds to them (as in the augmented rule).

The previous findings are also reflected in the analysis of welfare, as 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, 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.

"implementable" simple rule.

Accordingly, the welfare gains from switching from the simple rule to the augmented rule also increase with the importance of hysteresis effects.

5 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 proposed 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 needs 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 levels, 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 a baseline simple rule, in response to any shock. The welfare gains from shifting to the optimal policy are 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 while ignoring the unemployment rate.

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Table 1. ADF Unit Root Tests

Sample period	*1 lag*	*4 lags*
1970Q1-2016Q4	-2.32 (-2.87)	-2.28 (-2.87)
1985Q1-2016Q4	-3.16^{*} (-2.88)	-2.49 (-2.88)
1999Q1-2016Q4	-2.45 (-2.90)	-1.77 (-2.90)

Note: t-statistics of Augmented Dickey-Fuller tests (with intercept) for the null of a unit root in the unemployment rate. Asterisks denote significance at the 5 percent level for the null of a unit root, with the corresponding critical value (adjusted for sample size) shown in brackets.

Table 2. Calibration

φ	Curvature of labor disutility	3.4
β	Discount factor	0.99
α	Decreasing returns to labor	0.25
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

	$\rho_u(1)$	$\rho_u(4)$	$\rho_u(8)$
Data			
1970Q1-2016Q4	0.99	0.97	0.91
1985Q1-2016Q4	0.98	0.83	0.51
1999Q1-2016Q1	0.98	0.80	0.45
Baseline ($\theta_w = 0.75$)			
Technology	0.86 (0.77,0.90)	0.50 (0.23,0.68)	0.19 (−0.10,0.46)
Markup	0.95 (0.91,0.97)	0.69 (0.49,0.81)	0.33 (−0.01,0.59)
Demand	0.81 (0.72,0.87)	0.41 (0.18,0.60)	0.14 (−0.16,0.42)
High stickiness ($\theta_w = 0.95$)			
Technology	0.97 (0.81,0.56)	0.81 (0.63,0.91)	0.56 (0.21,0.78)
Markup	0.97 (0.94,0.98)	0.80 (0.63,0.91)	0.54 (0.21,0.78)
Demand	0.90 (0.82,0.96)	0.68 (0.43,0.86)	0.50 (0.12,0.76)

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

Table 4
Unemployment Persistence with Insider-Outsider Labor Markets

	$\rho_u(1)$	$\rho_u(4)$	$\rho_u(8)$
Data			
1970Q1-2016Q4	0.99	0.97	0.91
1985Q1-2016Q4	0.98	0.83	0.51
1999Q1-2016Q1	0.98	0.80	0.45
Technology			
Standard	0.62 (0.50,0.72)	0.06 (−0.16,0.26)	−0.09 (−0.25,0.12)
$\gamma = 0.0$	0.61 (0.51,0.71)	0.03 (−0.16,0.22)	−0.10 (−0.32,0.08)
$\gamma = 0.9$	0.83 (0.67,0.93)	0.57 (0.16,0.83)	0.45 (−0.06,0.78)
$\gamma = 1.0$	0.93 (0.74,0.98)	0.82 (0.34,0.94)	0.73 (0.18,0.90)
Markup			
Standard	0.95 (0.91,0.97)	0.63 (0.46,0.76)	0.21 (−0.09,0.46)
$\gamma = 0.0$	0.95 (0.91,0.97)	0.62 (0.40,0.76)	0.15 (−0.20,0.45)
$\gamma = 0.9$	0.97 (0.93,0.99)	0.83 (0.59,0.92)	0.58 (0.20,0.81)
$\gamma = 1.0$	0.97 (0.94,0.99)	0.87 (0.69,0.96)	0.70 (0.36,0.92)
Demand			
Standard	0.80 (0.71,0.87)	0.41 (0.18,0.57)	0.12 (−0.18,0.37)
$\gamma = 0.0$	0.81 (0.69,0.88)	0.42 (0.14,0.62)	0.15 (−0.16,0.40)
$\gamma = 0.9$	0.93 (0.82,0.97)	0.77 (0.45,0.92)	0.60 (0.17,0.85)
$\gamma = 1.0$	0.96 (0.87,0.99)	0.86 (0.58,0.96)	0.73 (0.33,0.91)

Note: Based on 200 simulations of 180 observations each. Persistence of driving forces: $\rho_a = \rho_x = \rho_z = 0.92$. For each statistic, the table reports the median and 95% confidence interval (in brackets).

Table 5
Hysteresis, Monetary Policy and Welfare

	Hysteresis Parameter					
	$\gamma = 0$		$\gamma = 0.9$		$\gamma = 1$	
Technology						
Simple	0.067	1.0	0.101	1.0	0.425	1.0
Optimal	0.017	0.25	0.018	0.17	0.018	0.04
Augmented	0.035	0.52	0.031	0.30	0.032	0.07
Markup						
Simple	0.046	1.0	0.097	1.0	0.410	1.0
Optimal	0.017	0.36	0.018	0.18	0.018	0.04
Augmented	0.040	0.87	0.023	0.23	0.026	0.06
Demand						
Simple	0.135	1.0	0.294	1.0	1.953	1.0
Optimal	0.0	0.0	0.0	0.0	0.0	0.0
Augmented	0.007	0.05	0.004	0.01	0.005	< 0.01

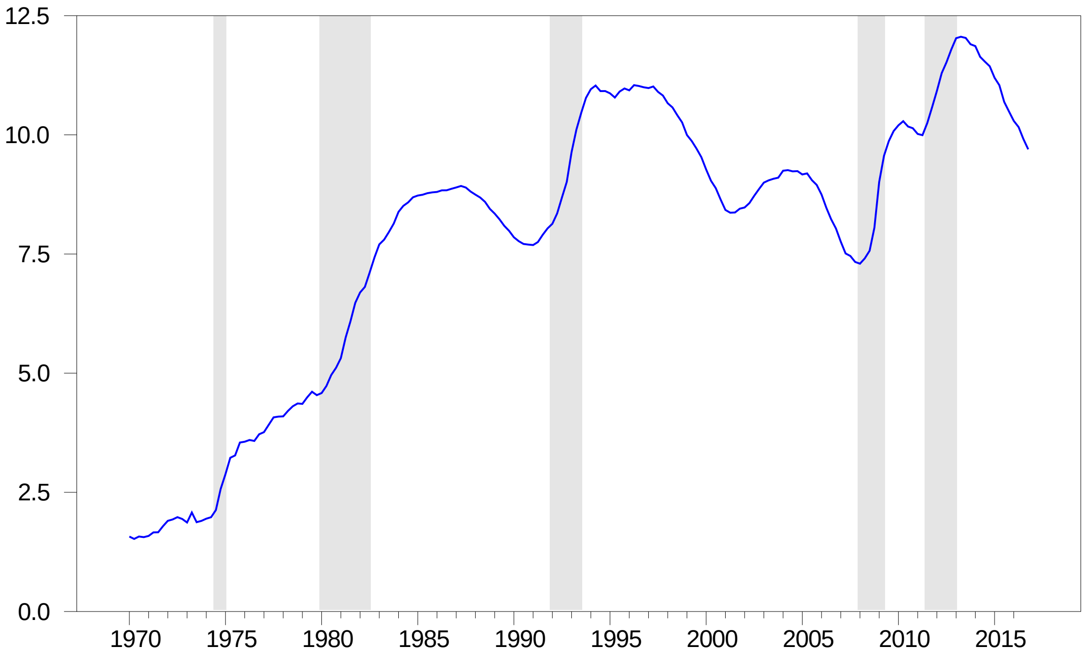

Figure 1. Unemployment Rate in the Euro Area

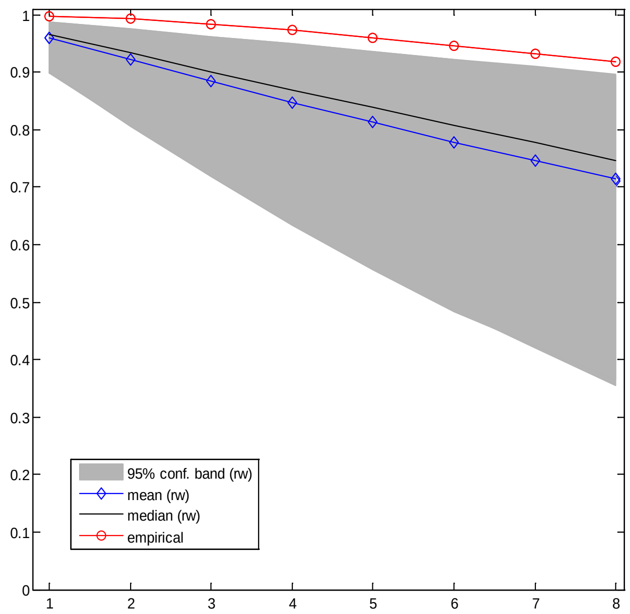

Figure 2.a. Unemployment autocorrelation: 1970Q1-2016Q4

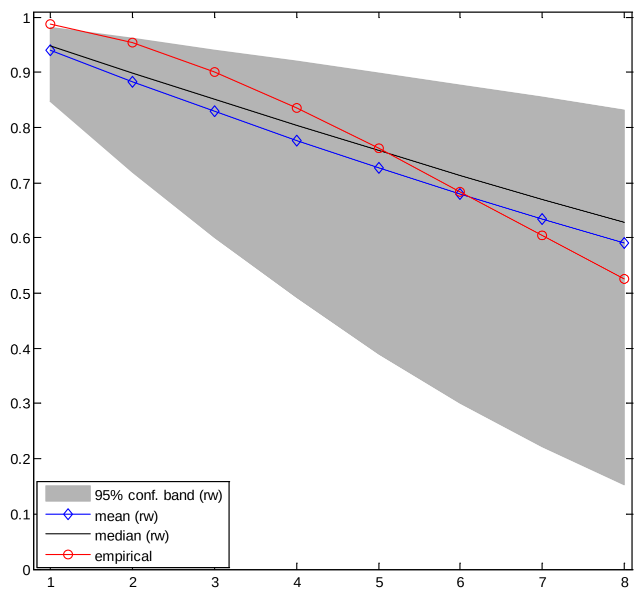

Figure 2.b. Unemployment Autocorrelation: 1985Q1-2016Q4

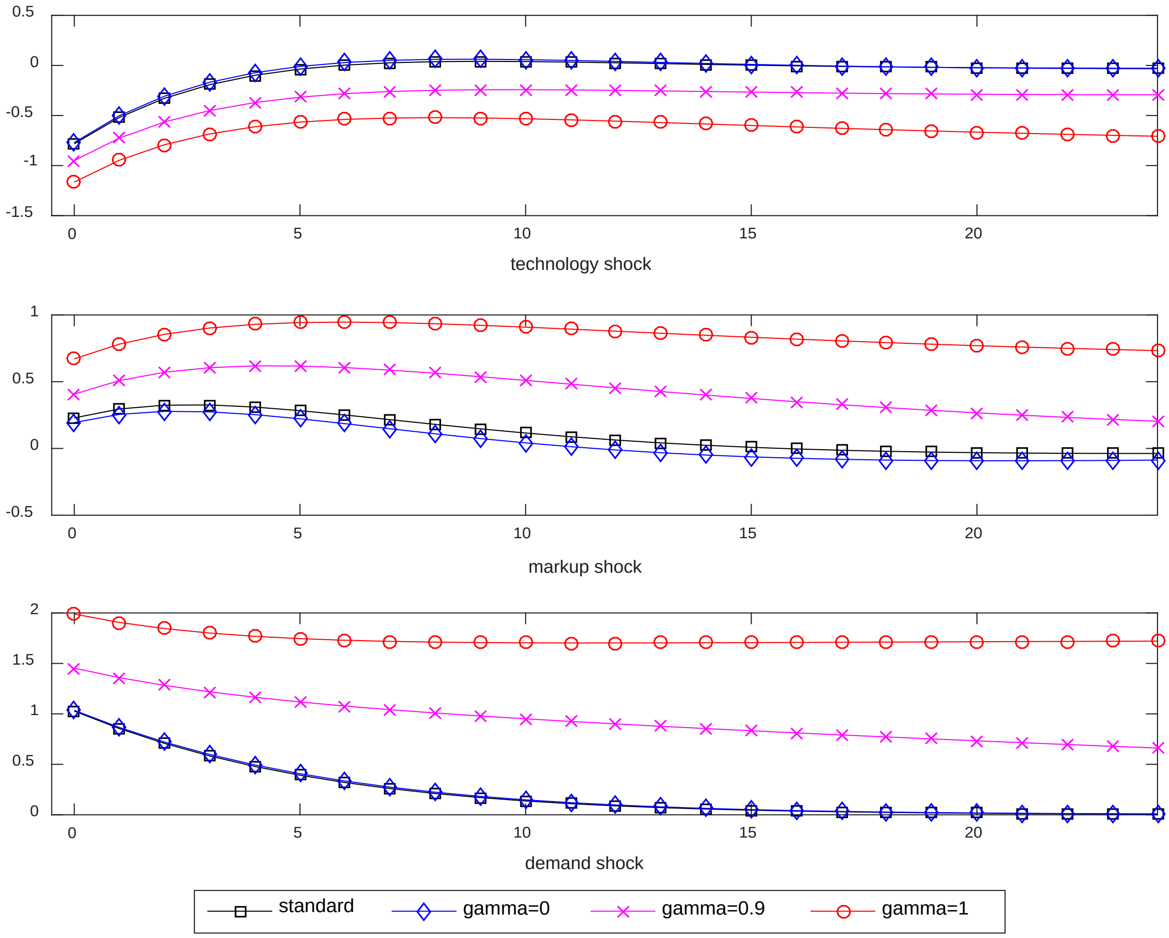

Figure 3. Hysteresis and Unemployment Rate Persistence

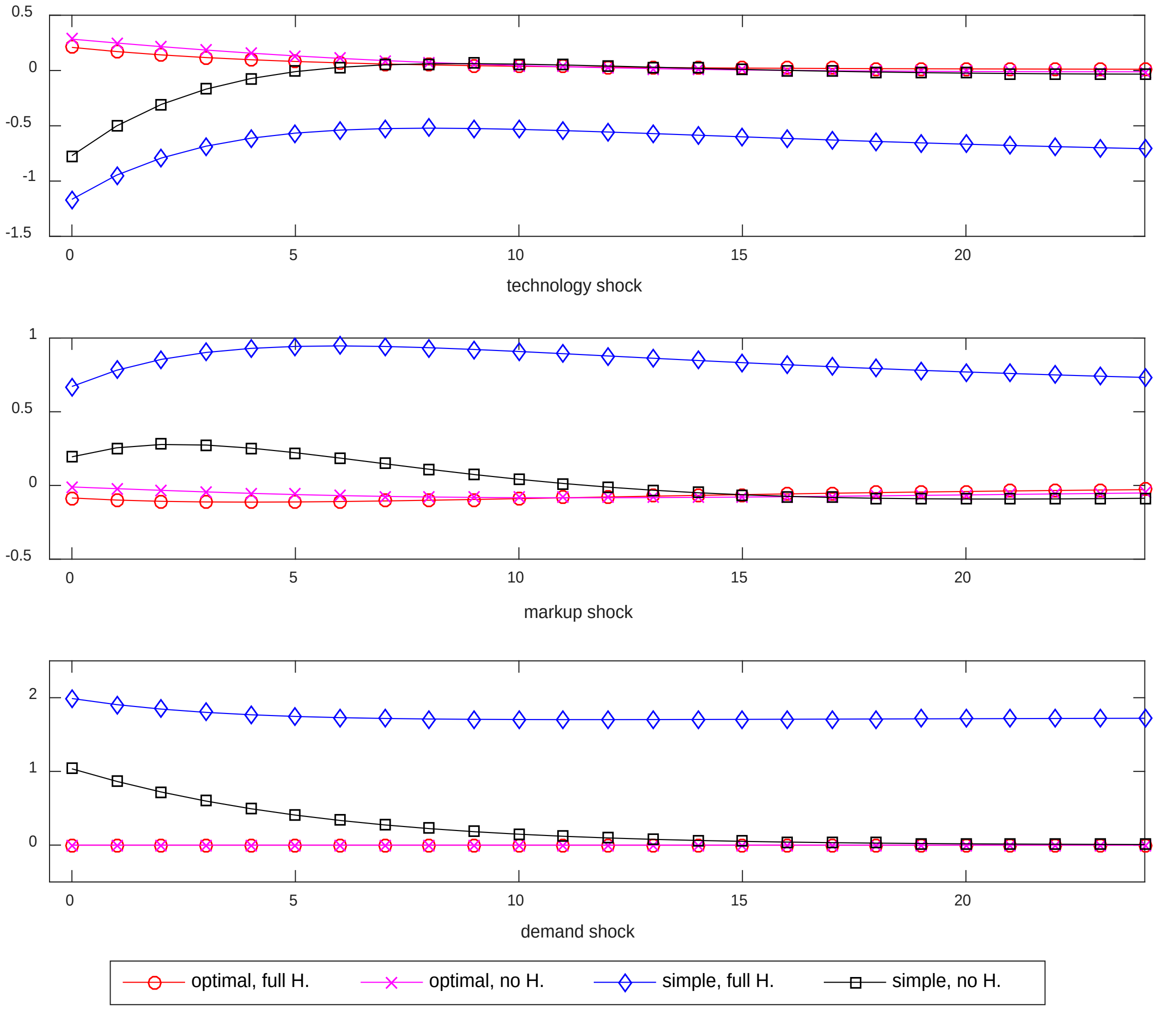

Figure 4. Unemployment Response to Shocks

Optimal Policy vs. Simple rule

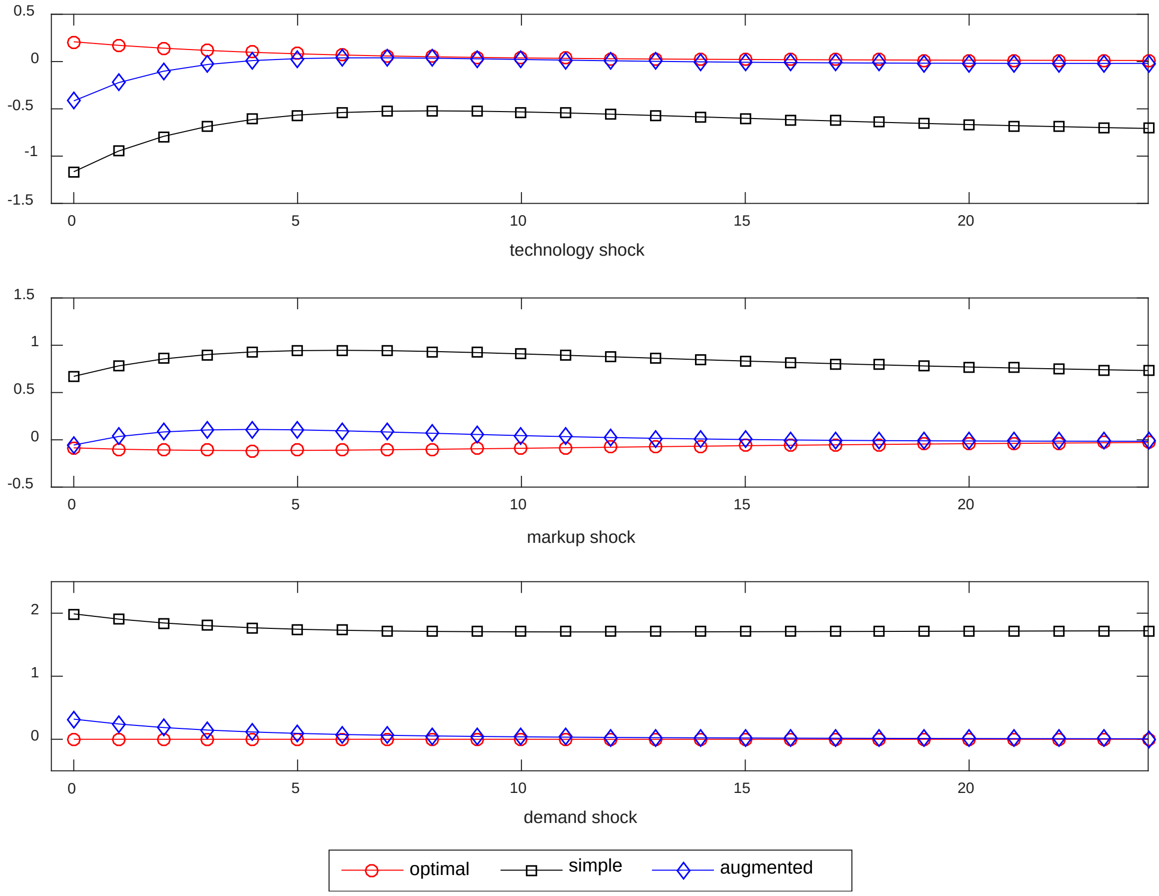

Figure 5. Unemployment Response to Shocks under Full Hysteresis

Optimal Policy, Simple Rule, and Augmeted Rule

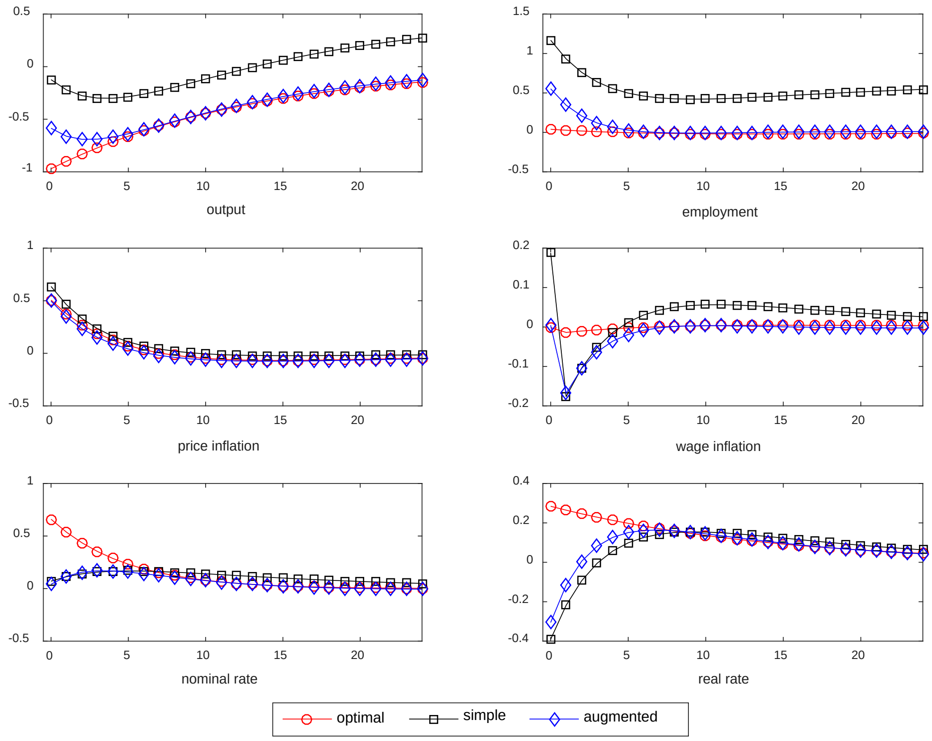

Figure 6.a Optimal vs. Augmented Rule: Technology Shocks

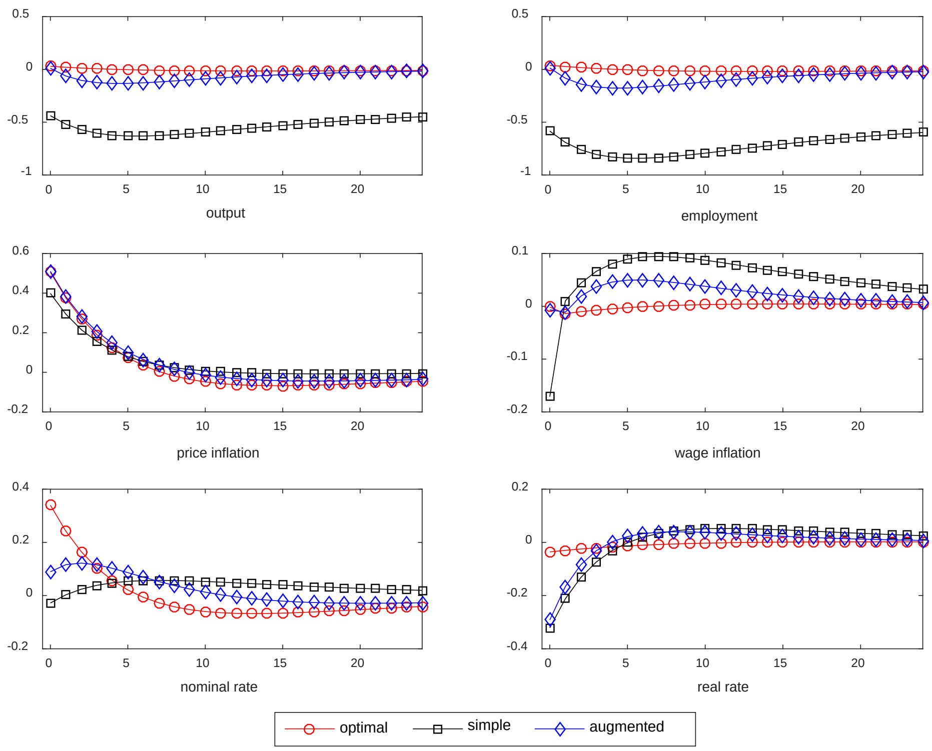

Figure 6.b Optimal vs. Augmented Rule: Markup Shocks

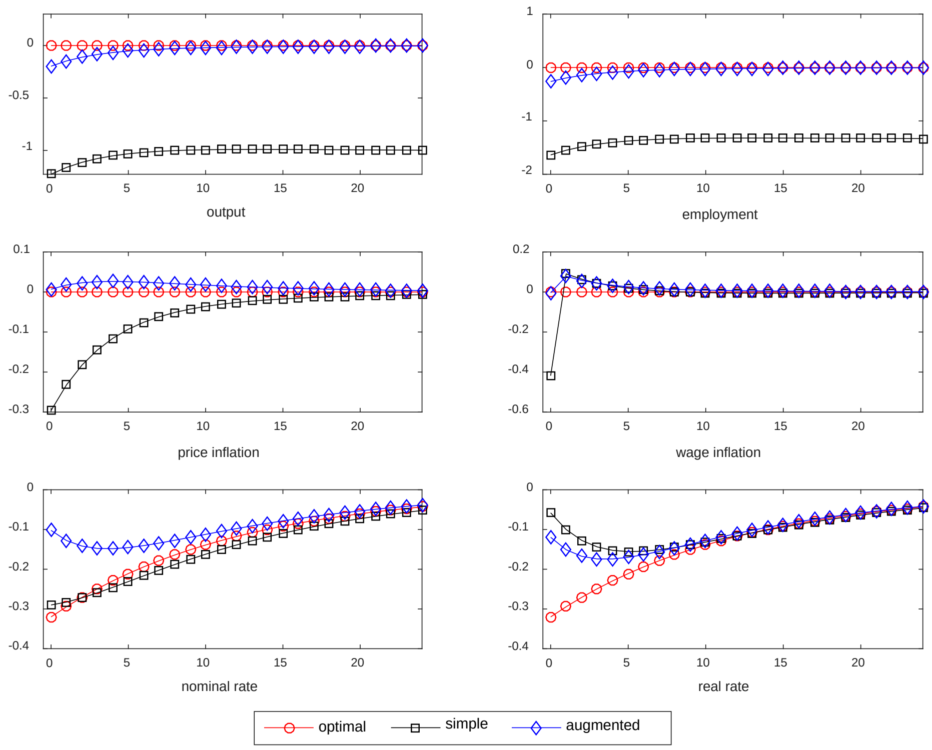

Figure 6.c Optimal vs. Augmented Rule: Demand Shocks