Shocks, Monetary Policy and Institutions:
Explaining Unemployment Persistence in
“Europe” and the United States

Ansgar Rannenberg
University of St Andrews
Shocks, Monetary Policy and Institutions: Explaining Unemployment Persistence in “Europe” and the United States*
Ansgar Rannenberg†
University of St Andrews

MAY 2009

ABSTRACT

This paper examines the rise in European unemployment since the 1970s by introducing endogenous growth into an otherwise standard New Keynesian model with capital accumulation and unemployment. We subject the model to an uncorrelated cost push shock, in order to mimic a scenario akin to the one faced by central banks at the end of the 1970s. Monetary policy implements a disinflation by following an interest feedback rule calibrated to an estimate of a Bundesbank reaction function. 40 quarters after the shock has vanished, unemployment is still about 1.8 percentage points above its steady state. Our model also broadly reproduces cross country differences in unemployment by drawing on cross country differences in the size of cost push shock and the associated disinflation, the monetary policy reaction function and the wage setting structure.

* I would like to thank Andrew Hughes-Hallett, Arnab Bhattacharjee, Atanas Christev, Campbell Leith, Charles Nolan and the participants of the RES Easter School 2008 for helpful comments. All remaining errors are of course my own. Furthermore, I am grateful for generous financial support which I am receiving from the Centre for Dynamic Macroeconomic Analysis (CDMA) at the School of Economics and Finance at the University of St. Andrews.
† School of Economics and Finance, Castlecliffe, The Scores, St Andrews, Fife KY16 9AL, Scotland, UK. Tel: +44 (0) 1334 462445. E-mail: ar435@st-andrews.ac.uk.
1 Introduction

The persistent increase in continental European unemployment since the 1970s is often blamed on labour markets having become more rigid. There is however growing evidence that labour market institutions, while powerful at explaining cross country differences in unemployment at a given point in time, are less so at explaining the evolution of unemployment across time, or at least leave a lot to be explained. Findings along these lines include the IMF (2003), Nickell (2002), Blanchard and Wolfers (2000), Fitoussi et al. (2000) and Elmeskov (1998).

This paper examines the rise in European unemployment by introducing endogenous growth into a New Keynesian model featuring unemployment. We subject the economy to a 1 quarter non-serially correlated cost-push shock and let the central bank disinflate the economy - as happened in many industrialised economies at the beginning of the 1980s. This temporary shock can cause a persistent and substantial increase in unemployment, lasting over 10 to 20 years in an order of magnitude of 1 percentage points or more. The model also sheds light on some cross-country differences in the unemployment experience.

More precisely, we aim to shed light on the following set of stylised facts and empirical findings:

- Unemployment has increased substantially in many large European economies since the 1970s. Figure 1 displays quarterly unemployment rates from 1975 to 2000 for six selected European Economies and the United States. Note that unemployment is very persistent: It increases relatively quickly, as for instance during the recessions at the beginning of the 80s, but reverts only relatively slowly, incompletely, or not at all. By contrast, unemployment in the United States shows less persistence. It also does not show much of a trend.

- There has been a decline in the growth rate of labour productivity (measured as output per hour worked) across OECD countries in the 1980s. This decline has been substantially larger in Western European Economies than in the United States. Average annual productivity growth in Western European economies was 1.5% lower in the period from 1981 to 1990 than in the previous decade, while it declined by merely 0.2% in the United States. Skoczylas and Tissot (2005) estimate changes in trend productivity growth for OECD economies from 1960 to 2004. They locate declines between one and 3.9% between 1976 and 1985 in 9 Western European Economies but none in the United States.

- It is a consistent finding that a decline in productivity growth increases unemployment. Examples include Bassanini and Duval (2006), Pissarides and

---

The number is based on cross country averages for 1971-1980 and 1981-1990 of the productivity growth rates of Belgium, Denmark, Western Germany, Ireland, Spain, France, Italy, the Netherlands, Finland, Sweden, the United Kingdom and Norway. These rates are based on the series on GDP at constant prices and total hours worked from AMECO (2008).
Vallanti (2005), Nickel (2002, 2005), Ball and Moffitt (2001) and Fitoussi et al. (2000). Three of these studies (Bassanini and Duval, Blanchard and Wolfers, Fitoussi et al.) explicitly model interactions between productivity growth declines and labour market institutions. They find that macroeconomic shocks help to explain the evolution of unemployment across time while cross country-differences in institutions help to explain why in some countries unemployment responds more strongly to macroeconomic shocks than in others.

- Based on a study of 17 OECD countries, Ball (1999) argues that those central banks willing to aggressively lower real interest rates during the recessions of the early 1980s reduced the subsequent increase in the NAIRU in their countries.

- There seems to be a negative medium run relationship between the change in inflation and the change in the NAIRU. This is illustrated in Figure 2, which plots the change in the NAIRU against the change in CPI Inflation for 21 OECD countries from 1980 to 1990 and from 1990 to 2000. The negative correlation is not perfect but still obvious: Countries with a larger decrease in inflation suffered on average a larger increase in their NAIRU.\(^2\) Ball (1996) was the first to draw attention to this link and also investigated it more formally.

Our results resemble in some respects those of Sargent and Ljungqvist (1998, 2007) in that the model proposed here generates an increase in unemployment without relying on changes in labour market rigidity, while the "level" of labour market rigidity does matter.\(^3\) However, their approach differs from ours in that in their model, unemployment increases via the interaction of an unemployment insurance paying benefits linked to past income and a permanent increase in "microeconomic turbulence". "Microeconomic turbulence" is the probability that a worker loses his human capital in case his job is exogenously destroyed. The increase in turbulence creates a fraction of unemployed workers who enjoy high benefits (because they used to be high skilled) but are now low skilled and thus have a low earnings potential on the labour market. Therefore they have little incentive to engage in (costly) job search, which reduces their probability of regaining employment. By contrast, our approach is a macroeconomic one in that the driving force pushing up unemployment is an inflationary shock and the response of the central bank to this shock.

This paper is structured as follows: Section 2 develops a model which broadly reflects the mainstream consensus on the long and short run dynamics of unemployment as for instance developed by Jackman et al (1991). In this model, a temporary cost push shock only has a short lived effect on unemployment and so has the monetary policy response to the shock. We coin this model "Jackman, Layard, Nickell",

\(^2\) The data is taken from the OECD Economic Outlook. The countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, U.S.A.

\(^3\) See Sargent and Ljungqvist (1998) and (2007).
or JLN economy. We then add the New Growth extension. Section 3 discusses the calibration, which is informed by empirical evidence on some of the model parameters and by the comparison of the second moments of a couple of model variables with their empirical counterparts. This moment comparison can be found in an extended version of this paper.\textsuperscript{4} Section 4 then discusses the response of the economy to a one quarter cost push shock calibrated to induce a disinflation of about 4 percentage points and focuses on the induced evolution of unemployment across time. It also looks at the tradeoffs policymakers face between stabilising inflation and stabilising unemployment. Section 5 adds a cross-country dimension to our analysis. First, we vary the size of the cost push shock and record the resulting changes in inflation and the NAIRU over a 10 year horizon. We then compare the differences in the unemployment response generated by a Bundesbank and a Federal Reserve Policy rule as estimated by Clarida et al. (1998), and finally we investigate the effects differences in real wage rigidity between Europe and the United States. Section 6 concludes.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Unemployment for 6 European Economies and the United States}
\end{figure}

\textsuperscript{4}See Rannenberg (2009). This version is available online: http://mpra.ub.unimuenchen.de/13610/
2 The Model

In this section we will present a New Keynesian model with unemployment and endogenous growth which contributes to explaining the above findings. To stress the fact our results stem from the introduction of endogenous growth, we also present an otherwise identical model without endogenous growth which we take as the starting point of our analysis. This is a model to approximate the prevailing consensus on the relationship between unemployment and the NAIRU. We will refer to this model as the JLN economy. This consensus says that while unemployment both in the short and in the long run is determined by aggregate demand, only the NAIRU is consistent with stable inflation. Inflation targeting central banks will push unemployment towards this level. The NAIRU itself will be affected by any variable which directly increases wages in spite of excess supply in the labour market, increases the pricing power of firms or reduces the efficiency of the labour market to match jobs to workers\(^5\)

Below we list the aggregate equations of the JLN economy. After that we introduce endogenous growth. Almost all equations are the same in both models. A longer version of this paper (Rammenberg (2009)) provides the microfoundations.

\(^5\)See Nickell et al. (2002), pp. 2-3.
2.1 JLN Economy

Aggregate demand \(AD_t\) is the sum of consumption \(C_t\), investment \(I_t\), the amount of price adjustment costs \(\frac{\varphi}{2}(\pi_t - \pi_{t-1})^2Y_t\), and expenditure on government employees \(w_t n^s\):

\[
AD_t = C_t + I_t + \frac{\varphi}{2}(\pi_t - \pi_{t-1})^2Y_t + w_t n^s
\]

Price adjustment costs are the source of nominal rigidities in this model which will give rise to the Phillips curve discussed below. Government employees account for a fixed fraction \(n^s\) of the workforce.\(^6\)

The representative household consists of a continuum of members who might be employed or unemployed but are all allocated the same level of consumption. The household is infinitely lived and chooses its consumption expenditure, bond holdings and investment expenditure in order to maximise the expected present value of its lifetime utility. We assume a logarithmic instantaneous utility function and, following Smets and Wouters (2002), external habit formation in consumption and adjustment costs in investment. Investment adjustment costs mean that only a fraction of investment expenditure is transformed into additional capital \(K_t\). They are convex and vanish when the economy is growing at the steady state growth rate \(g\).

The first order conditions imply that consumption is governed by

\[
1/(C_t - hab_{t-1}) = \beta(1 + i_t)E_t \left[ \frac{1}{(C_{t+1} - hab_t) (1 + \pi_{t+1})} \right]
\]

where \(i_t\), \(\pi_t\), \(\beta\) and \(hab_{t-1}\) denote the nominal interest rate, the rate of inflation, the individual discount factor and the level of habit respectively, the last of which is determined by

\[
hab_{t-1} = jC_{t-1}
\]

Capital accumulation is given by

\[
K_{t+1} = (1 - \delta)K_t + I_t \left( 1 - \frac{\kappa}{2} \left( \frac{I_t}{I_{t-1}} - (1 + g) \right)^2 \right)
\]

\(^6\)The reason for introducing both state employees and overhead workers \(\pi\) is to achieve a reasonable calibration of steady state values. In the Romer (1986) endogenous growth model, the level of employment affects the growth rate. This is due to the fact that the marginal product of capital is an increasing function of employment. The marginal product of capital governs the growth rate by determining the willingness of households to save. To achieve a reasonable steady state growth rate, we remove a fraction of the labour force from "productive" sector by assuming that they perform necessary tasks without which the productive sector could not operate (managerial work in case of overhead workers, policing etc. in case of the state employees). We assume that government employees are paid the same wage as private sector employees and are funded by means of lump sum taxes. Overhead workers will be interpreted as managers who split the profits of the monopolistically competitive firms.
The optimal investment dynamics are then given by

\[ \lambda_t = \frac{1}{C_t - hab_{t-1}} \]  
\[ \beta E_t \left( \frac{\lambda_{t+1}}{\lambda_t} (r^k_{t+1} + q_{t+1} (1 - \delta)) \right) = q_t \]  
\[ \lambda_t q_t \left[ \left( 1 - \frac{\kappa}{2} \left( \frac{I_t}{I_{t-1}} - (1 + g) \right)^2 \right) - \frac{I_t}{I_{t-1}} \kappa \left( \frac{I_t}{I_{t-1}} - (1 + g) \right) \right] + \beta E_t \left[ \lambda_{t+1} q_{t+1} \left( \frac{I_{t+1}}{I_t} \right)^2 \kappa \left( \frac{I_{t+1}}{I_t} - (1 + g) \right) \right] = \lambda_t \]

where \( \lambda_t, r^k_t \) and \( q_t \) denote the marginal utility of consumption, the real capital rental, and the real value of another unit of capital, also referred to as Tobin’s \( q \), respectively. The second equation says that the value (or price) of another unit of capital is given by the present value of the \( t+1 \) rental income it generates plus its \( t+1 \) value. The last equation says that firms invest until the value of the additional unit of capital produced plus the present value of \( t+1 \) adjustment costs equals equals one.

Aggregate demand determines aggregate output:

\[ AD_t = Output_t \]

Total output is given by the sum of private sector output and the output of state employees, where private sector output is produced using a Cobb-Douglas production function:

\[ Output_t = AK_t^\alpha (TFP_t c_t (n_t - \bar{n} - n^*))^{1-\alpha} + w_t n^* \]  
\( TFP_t \) and \( c_t \) denote total factor productivity and the effort level of employees, respectively.\(^7\) In the absence of endogenous growth, \( TFP_t \) evolves exogenously. Firms choose capital and labour to minimise their costs of producing a given level of output. The capital rental is given by

\[ r^k_t = \alpha mc_t \frac{Y_t}{K_t} \]

where \( Y_t \) denotes private sector output.

Following Dantine and Kurman (2004), the members of the household supply one unit of labour inelastically but have preferences over effort while they are at work. One of the first order conditions of the household is thus an effort function which determines the level of effort. Households are willing to make a higher effort if they are compensated with a higher wage relative to the past real wage. In addition, the effort level is determined by a couple of other variables as well. We assume that for a given real wage effort also depends negatively on past productivity (as

\(^7\)Firms find it optimal to choose a constant effort level.
the firm gets more productive, employees demand a higher wage) and the level of
unemployment income (for instance benefits), which in turn depends on past real
wages and productivity as well.

Firms choose the real wage as they are aware of the relationship between workers
morale, effort and the real wage. An extensive survey of Bewley (1998) provides
strong support for this view of wage setting. An increase in any of the variables
listed before will induce firms to increase their wage offer. Accordingly, the real wage
does not clear the labour market but evolves according to the following wage setting
function:

\[ \log w_t - \log w_{t-1} = a + b * (n_t - \bar{n}) + c \log \left( \frac{w_{t-1} (n_{t-1} - \bar{n} - n^*)}{Y_{t-1}} \right), \quad b > 0, \ c < 0. \tag{9} \]

This is very close to a specification derived by Blanchard and Katz (1999) from
intuitively plausible relationships between average wages, the reservation wage and
productivity.\(^8\) The growth rate of the real wage \(w_t\) is positively related to employment
and negatively to the labour share. The effect of the labour share stems from the
direct impact of productivity on effort and the indirect impact through benefits. If
these are absent, we have \(c=0\).

Empirical estimates of (9) (usually replacing \(n_t\) with the unemployment rate) or
variants thereof repeatedly find \(c=0\) (or even \(c>0\)) for the United states but \(c<0\) for
European countries.\(^9\) The difference could be due to the direct effect of productivity
on effort being close to zero in the U.S. but positive in Europe because of a larger
influence of unions who establish the idea that the reference wage should be linked to
productivity, as is also argued by Blanchard and Katz (1999). Using individual data
on compensation matched with firm level data on performance and inputs, Abowd et
al. find that the relationship between firm level wages and performance measures like
value added and sales per employee is stronger in France than in the United States.

One could also imagine that benefits are linked more closely to productivity in Europe
because policymakers are more likely to believe in concepts of relative poverty rather
than absolute poverty and therefore would aim to link benefits to a country’s overall
income.\(^10\)

Marginal cost \(mc_t\) is given by

\[ mc_t = \frac{ \left( r_t^k \right)^\alpha w_t^{1-\alpha} }{ A \alpha^n (1 - \alpha)^{1-\alpha} (\phi_t T F P_t)^{1-\alpha} } \tag{10} \]

The evolution of inflation \(\pi_t\) is determined by the Phillips Curve. It is derived
from the maximisation problem of a monopolistically competitive firm producing a

\(^8\)Blanchard and Katz (1999) specify the wage as a function of productivity and the reservation
wage, which in turn is a convex combination of average wages and productivity, as in our model.
variety from a CES basket. It faces quadratic price adjustment costs in the change
of the inflation rate. The resulting non-linear Phillips Curve is given by

\[-\frac{(\theta - 1)}{\theta} + mc_t - \frac{\varphi}{\theta} (\pi_t - \pi_{t-1} - u_t) (1 + \pi_t - u_t) + \frac{\varphi}{2} (\pi_t - \pi_{t-1} - u_t)^2
\]

\[+ \beta E_t \left[ \frac{C_t - \text{hab}_{t-1} \varphi Y_{t+1}}{C_{t+1} - \text{hab}_t \theta Y_t} (\pi_{t+1} - \pi_t - u_t) (1 + \pi_{t+1}) \right] = 0 \]  

(11)

where $u_t$, $\theta$ and $\varphi$ denote a cost push shock, i.e. a shock increasing inflation for a given
level of marginal costs, and the elasticity of substitution between different varieties
of the output good the household is consuming, respectively. It can be easily shown
that up to first order, this equation is a hybrid Phillips Curve with coefficients on
lagged inflation and expected future inflation of $\frac{1}{1+\gamma}$ and $\frac{\beta}{1+\gamma}$, respectively.

Finally, monetary policy is specified by

\[i_t = (1 - \rho) \left( \tilde{i} + \psi \pi_t + \frac{\psi Y}{4} gp_{t-1} \right) + \rho \pi_{t-1} \]  

(12)

with $gp_t$ denoting the percentage deviation of output from potential output. The later
is defined as the output level at which inflation is not accelerating in the absence
of cost push shocks, given the level of technology, the capital stock and past real wages.
As can be easily checked, this output level has to satisfy $mc_t = \frac{(\theta - 1)}{\theta}$, where $\frac{(\theta - 1)}{\theta}$ is
the inverse of the mark-up firms would charge in the absence of any nominal rigidities.
The unemployment rate associated with output at its potential is the NAIRU.

2.2 Introducing Endogenous Growth

We introduce endogenous growth following Romer (1986). We assume that investing
firms discover ways to produce more efficiently and that knowledge is a public
good. Therefore total factor productivity $TFP_t$ is assumed to be proportional to the
aggregate capital stock. Hence we replace $TFP_t$ with $K_t$ in the above equations. The
equations for output and marginal costs are modified as follows:

\[Output_t = AK_t((n_t - \bar{n} - n^s) \phi_t)^{1-\alpha} + w_t n^s \]  

(13)

while in the presence of endogenous growth, we have

\[mc_t = \frac{(r_t^k)^{\alpha} w_t^{1-\alpha}}{A^\alpha(1 - \alpha)^{1-\alpha}(\phi_1 K_t)^{1-\alpha}} \]  

(14)

The capital stock now has a stronger effect on both marginal costs and output than
in the JLN economy. An increase in the capital stock by 1% for a given employment

\[11\text{The exposition here follows Barro and Sala-i-Martin (2004), pp. 212-215.} \]
level (implying that output expands at the same rate) reduces marginal costs by 1%. In the absence of endogenous growth the effect is only $\alpha\%$, where $\alpha$ would typically be calibrated to match the capital share and would thus be substantially smaller than one. This can be seen by substituting the capital rental out of equations (14) and (10) and then substituting $\frac{K'}{K}$ using the respective production functions. For the New Growth economy, the real wage - capital ratio is now the main driver of marginal costs.

3 Simulation Setup and Calibration

We aim to create a scenario akin to the one faced by central banks in Western Europe at the end of the seventies and the beginning of the 1980s. That means we would like to create a situation where annual inflation increases several percentage points above its target level for some time and is then subsequently reduced. Therefore $u_t$ is set equal to 0.03 for the first quarter and the model is simulated under perfect foresight. To put it differently, for given values of marginal cost, past and expected inflation, inflation in that quarter is increased by three percentage points. In the baseline simulation, this will give rise to a disinflation of a bit more than 4.6 percentage points over 5 years, if we compare annual rates in the first and the sixth year. This is at the lower end of disinflations actually experienced during that period. For instance, in Germany, annual inflation was at 6.3% in 1981, which was then reduced to -0.1% in 1986, which is a rather small disinflation compared to the UK, France or Italy where inflation declined by 8.6, 10.8 and 13.7 percentage points over the same period, respectively. Note that there is no endogenous persistence in the shock itself beyond the first quarter, implying that any persistence in the path of the variables and in particular unemployment beyond that point is endogenous. The models are solved employing a second order approximation to the policy function using the approach of Schmitt-Grohe and Uribe (2004). We use the software Dynare to implement the solution.\footnote{To be able to solve our two growth models, we normalise with respect to the capital stock and total factor productivity (see Appendix).}

The calibration of the non-monetary policy model parameters for the experiment described above is presented in table 1. It was arrived at as follows. We distinguish between four different types of parameters. The first set is calibrated according to standard values in the literature. This set contains the discount factor $\beta$, the private output elasticity of capital $\alpha$, the elasticity of substitution between varieties of goods $\theta$, the depreciation rate $\delta$, and the price adjustment cost parameter $\varphi$. $\varphi$ is calibrated as to generate marginal cost coefficient in the linearised version of equation (12) which would also be generated in a Calvo Phillips Curve with full backward indexing of unchanged prices and a probability of no re-optimisation is 2/3.

The second set, consisting of $n^*, a, b$ and $c$, is based on empirical evidence. $n^*$
is calculated from data of the German statistical office on the number of full time
equivalent employees in the public sector and on total hours worked in the economy
in 2006. b and c are calibrated to be consistent with an estimate of that function.
We estimate (9) on German data on hourly labour costs, unemployment (instead of
employment, as is done in the empirical literature) and the labour share in GDP
ranging from 1970 to 2000. We then calibrate the intercept a to achieve a steady
state unemployment rate of 4%.

The third set consists of the three "free" parameters A, κ and j the production
function shifter, the parameter indexing adjustment costs and the degree of habit
formation. They were calibrated to match second moments of a couple of important
variables in German data. The results are discussed in an extended version of this
paper.

Table 1: Baseline Calibration of non-policy Parameters

<table>
<thead>
<tr>
<th>α</th>
<th>β</th>
<th>j</th>
<th>A</th>
<th>θ</th>
<th>δ</th>
<th>φ₁</th>
<th>φ</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>κ</th>
<th>u₁</th>
<th>π</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33</td>
<td>0.99</td>
<td>0.4</td>
<td>0.38</td>
<td>6</td>
<td>0.025</td>
<td>0.452</td>
<td>30</td>
<td>-0.1123</td>
<td>0.08</td>
<td>-0.1</td>
<td>0.65</td>
<td>0.03</td>
<td>0.1793</td>
</tr>
</tbody>
</table>

n_{s} \quad \bar{i} \quad g_{TFP} \quad \sigma_{u'}

| 0.18 | 0.0181 | 0.0079 | 0.003 |

The baseline calibration of the monetary policy reaction function is taken from
Clausen and Meier (2003), who estimate a Bundesbank policy rule over the period
from 1973 to 1998 for quarterly data. Clausen and Meier’s best performing model
yields the statistically significant coefficients on output, inflation and the lagged in-
terest rate reported in table 2 which in fact correspond to the original coefficients
proposed by Taylor (1993) to characterise the policy of the Federal Reserve. Their
estimate of the output gap coefficient is of particular interest because the Bundes-
bank was often perceived as paying less attention to output than the Fed. This is
also borne out by other Taylor-rule estimates, one of which we discuss below. For
the purpose at hand, we consider using the least hawkish baseline coefficients for the
policy rule in the literature of Bundesbank Taylor rule estimates. It will become clear
why this is the case when we discuss the simulation results.

Table 2: Baseline Calibration of the Policy Rule: Clausen and Meier
(2003)\(^{13}\)

<table>
<thead>
<tr>
<th>ψ_π</th>
<th>ψ_Y</th>
<th>ρ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>0.52</td>
<td>0.75</td>
</tr>
</tbody>
</table>

However, we are also interested in comparing the effects of different policies esti-
imated for the Bundesbank and the Federal Reserve. Therefore we would like to draw
on a study using the same methodology to estimate policy rules for different coun-
tries, Clarida et al. (1998). Their rule is estimated using monthly data. A quarterly
data version of their specification would be

\[ i_t = (1 - \rho) \left( \bar{i} + \psi_\pi E_t \left( \frac{\pi_{t+1} + \pi_{t+2} + \pi_{t+3} + \pi_{t+4}}{4} \right) + \frac{\psi_Y}{4}gp_t \right) + \rho i_{t-1} \]  

\(^{13}\)See Clausen and Meier (2003), p. 22.
Hence the central bank responds to a one year forecast of inflation, the current output gap and the lagged interest rate.\textsuperscript{14} They measure potential output using a quadratic trend of a West German industrial production index and their data set stretches from 1979 to 1993 and estimate the policy rule using the general method of moments.\textsuperscript{15} The point estimates are replicated in table 3. Clearly, the small coefficient on the output gap corresponds more to the conventional wisdom on how the Bundesbank was conducting policy.

| Table 3: Forward looking interest rate Rule: Clarida et al. (1998)\textsuperscript{16} |
|----------------|----------------|----|
| $\psi_\pi$    | $\psi_Y$      | $\rho$ |
| 1.31           | 0.25           | 0.91 |

4 Explaining the Evolution of Unemployment across Time

We now discuss the response of the New Growth and the JLN economy to a cost push shock. This section focusses on understanding the induced evolution of unemployment and inflation across time. We first examine the results under the baseline calibration, while subsection 4.3 examines the effects of varying the output gap coefficient $\psi_Y$ in the interest feedback rule.

In all figures, the initial value is the steady state value of the respective variable. Furthermore, when we refer to “Baseline” in figures or in the text, we always mean the New Growth economy in its baseline calibration. The abbreviation "NGE" used in the figures refers to "New Growth Economy".

4.1 Unemployment and the NAIRU in the New Growth and JLN Economy

Figure 3 plots the response of actual unemployment for the JLN and the New Growth economy to the one quarter cost push shock. In the JLN economy, unemployment increases by about 3 percentage points on impact but starts recovering after reaching a maximum of 10.4%. It then quickly recovers and in quarter 8 practically returns to its steady state value and then slightly overshoots for some time. Employment would be expected to decrease because the cost push shock will increase inflation which will ultimately lead to an increase in ex ante real interest rates via equation 13. As consumers and investors are forward looking, this causes a contraction of aggregate demand on impact. Figure 4 plots the inflation rate, which peaks in quarter 1 at a value of about 3.8% and then quickly declines back to zero.

\textsuperscript{14}See Clarida et al. (1998), p. 1039 and 1042.
\textsuperscript{15}See Clarida et al. (1999), p. 1040.
Figure 3: Unemployment in the New Growth and the Economy

Figure 4: Inflation in the New Growth and the JLN Economy
By contrast, in the New Growth economy, unemployment increases by more on impact than in the JLN economy. Even more important, the increase is far more persistent. After about 11 quarters (10 quarters after the end of the shock), when employment is already overshooting in the JLN economy, only a bit more than half of the on-impact loss in employment has vanished and employment is still about 3.2 percentage points below its steady state value. What is more, employment growth then comes to a halt: quarterly increases are around 0.06 percentage points per quarter or less. As can be seen in table 4, in the New Growth economy, after 10 years unemployment is still about 1.8 percentage points above its steady state value and after 15 years the difference is still about 1.2 percentage points. Thus as often observed in the Europe, unemployment increases quickly but falls only very slowly. Furthermore, Figure 5 reveals that the persistent increase in actual unemployment is matched by an increase in the NAIRU, as after six quarters, actual unemployment falls below the NAIRU, which gradually increases during and after the recession. A glance at Figure 4 shows that inflation (after peaking in quarter 1 at a quarterly rate of about 3.3 percentage point) indeed stops declining at about the same time actual unemployment falls below the NAIRU, as we would expect from the definition of the NAIRU. Thus the disinflation engineered by the central bank, while clearly successful, has come at a cost beyond a temporary reduction in employment: The unemployment level consistent with constant inflation has increased.
Table 4: Unemployment deviation from the Steady State in the New Growth Economy, Baseline and \( \psi_y = 5 \), percentage Points

<table>
<thead>
<tr>
<th>Quarters</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>3.1</td>
<td>2.8</td>
<td>2.3</td>
<td>1.8</td>
<td>1.5</td>
<td>1.2</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>( \psi_y = 5 )</td>
<td>1.9</td>
<td>1.5</td>
<td>1.2</td>
<td>1.0</td>
<td>0.8</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Associated with the increase in unemployment in the New Growth economy is a persistent slowdown in labour productivity growth. This is in line with the evidence cited above. After 10 quarters it falls short of its steady state value by about 0.21% per quarter or 0.88% at an annualised rate, while 40 quarters after the shock it is still about 0.13% lower than in the steady state, or 0.54% at an annualised rate. Average annualised productivity growth over the first 10 years after the shock equals 2.46%. Assuming that average productivity growth before the shock hit equalled its steady state rate of 3.42%, this implies a decline of average productivity growth from one decade to the next of 0.96%. Interestingly, average German productivity growth did decline by 1.44% from the 1970s to the 1980s.\(^{17}\)

4.2 Understanding the Evolution of Unemployment in the New Growth Economy

We know from (9) that an increase in unemployment will reduce real wage growth which would tend to lower marginal costs, so there must be a strong countervailing force pushing marginal costs up in order to explain why inflation stops falling. Figure 6 shows that while real wage growth drops sharply, in quarter 2 the growth rate of the capital stock falls by even more and remains considerably below real wage growth for about 9 quarters. After that they are about equal. Slower capital stock growth entails slower technological progress and thus slower growth of labour productivity, which will tend to generate a higher trajectory of marginal cost for a given level of real wage growth. In the New Growth model, the movement of real wages relative to labour productivity for a given employment level is thus captured by the evolution of the wage capital ratio. This variable matters a lot for marginal cost, as shown by (14). Figure 7, which plots the deviations of marginal cost and the wage capital ratio from their steady state values confirms that it is the movement of the real wage capital ratio which drives marginal cost back up, as both move broadly in parallel.

\(^{17}\)Productivity is measured as real GDP per hour worked. The data was taken from Statistisches Bundesamt Wiesbaden (2007b). A sophisticated analysis of changes in trend productivity growth by Skoczylas and Tissot (2005) finds a negative break for Germany in 1979 of -2.75%.
Figure 6: New Growth Economy, Baseline
- Capital Stock Growth and Real Wage Growth

Figure: e ro th Economy aseline
eal age apital atio and arginal ost
By contrast, in the JLN economy, the effect of the capital stock on marginal costs is much weaker. The major determinant of marginal costs apart from real wages is total factor productivity $TFP_t$. This grows exogenously no matter whether output and investment are contracting or growing. Thus marginal costs or, to put it differently, the permissible, non-inflationary rate of real wage growth are much less affected by changes to the capital stock.

Turning back to the New Growth economy, the recovery of actual employment has to slow down after about 6 quarters because unemployment arrives at a level beyond which any reduction would cause inflation to accelerate as it pushes real wage growth above the growth rate of the capital stock and thus pushes up marginal cost. This would trigger interest rate increases via the policy rule. In fact this is already happening as actual unemployment is falling below the NAIRU and inflation starts to pick up. To put it differently, the central bank does not have a reason to boost employment by aggressively lowering the interest rate because although inflation is somewhat below target, the output gap is closed as marginal cost equals its steady state value. Figure 8 shows that the central bank stops lowering the real interest rate $i_t - E_t \pi_t$ after 8 quarters, when it is 0.45 percentage points (about 1.81 percentage points at an annualised rate) below the steady state value, and begins to tighten again.

This level of the real interest rate, while below its steady state value, is not very expansionary. Figure 9 summarises the benefits from investing by plotting the present discounted value of an additional unit of capital, $q_t$. $q_t$ recovers quickly after the shock has passed and reaches its steady state value of one after five quarters. It then slightly exceeds it’s steady state level for six quarters. However, this is not sufficiently high to move the capital stock growth rate up quickly because of the investment adjustment costs: The first order condition (6) determines the investment growth rate, which due to fast recovery of $q_t$, moves much closer to it’s steady state value as well. However, the capital stock growth rate depends on the investment capital ratio, as can be seen from equation (3), which has declined during the recession and subsequent period of slow growth. Thus a faster recovery of capital stock growth would require an investment growth rate exceeding the steady state, which would have to be induced by an above steady state $q_t$ which in turn would require a lower real interest rate.
Figure 8: New Growth Economy, Baseline
Real Interest Rate

Figure 9: New Growth Economy, Baseline
- Tobin's q

Baseline - Tobin's q
The speed of recovery is then governed by the relative growth rates of real wages and the capital stock. From quarter 9 onwards, the capital stock grows slightly faster than real wages. This causes a slow decline in the wage-capital ratio (figure 8), and a slow reduction in unemployment as higher productivity growth implies firms can accommodate the increased real wage growth associated with a tighter labour market without facing an increase in marginal costs. This, in turn, again increases capital stock growth by increasing the marginal product of capital.

4.3 The Inflation-Unemployment Trade-Off

These results provoke the question how changes to the central bank’s reaction function would affect the long-run paths of employment and inflation. Intuition suggests that a stronger weight on the output gap in the reaction function would lead to a smaller decrease in employment not just in the short but also in the long run. As investment would be squeezed less, there would be a smaller decline in capital stock growth which could accommodate higher non-inflationary employment after the recovery from the recession. To show this we increase the coefficient on the output gap, $\psi_y$, to 5, leaving all other parameters the same. The corresponding evolution of unemployment can be obtained from figure 10. Indeed unemployment not only increases considerably less in the short run (in fact it decreases on impact), and after 40 quarters, it is still about 0.8 percentage point lower than in the Baseline case, as can be obtained from the second line of table 4. Hence a less hawkish monetary policy has indeed very long-lasting benign effects on unemployment.
The lower increase in unemployment comes at the cost of a considerably stronger short run inflation surge. While in the baseline simulation, inflation peaks at a (quarterly) rate of 3.3%, it now increases as high as 4.9% in the first quarter (figure 11),
while the annual inflation rate over the first year amounts to 15%. Note however that the increase in inflation is only temporary. After 10 quarters, it has already decreased to 0.42%. Thus the stronger acceleration in inflation is a short run phenomenon. The gain in employment is of more persistent nature.

As mentioned above, Ball (1999) finds that during the recessions of the early 1980s, countries whose central banks aggressively lowered interest rates experienced smaller increases in the NAIRU than those which did not. Ball calculates the difference between the NAIRU in the year before the recession and five years after. He defines a recession as one year with GDP growth below 1%. He regresses this on the maximum reduction of the ex-post real interest rate during any time of the recessions first year, which he refers to as maximum easing.\textsuperscript{18} The coefficient on maximum easing is -0.42 and is significant at the 10% level.\textsuperscript{19} We try to replicate this relationship with our New Growth model by varying the output gap coefficient between 0 and 4, leaving everything else the same, thus obtaining data on maximum easing and the five year change in the NAIRU. Our resulting coefficient on maximum easing is negative as well and varies between -0.24 and -1.16. This is for the most part consistent with Ball’s estimate.

5 Cross Country Aspects

The previous section shows that our New Keynesian model with endogenous growth is able to produce a persistent increase in unemployment as a consequence of a disinflation. This is an important result because economists have been struggling to explain the evolution of unemployment in continental Europe over time. This begs the question whether we can also use the model to replicate differences in unemployment evolutions across countries. We address this issue in three different ways in this section. For that purpose, we will draw on the differences in the size of the disinflation across the OECD, in (estimates of) the policy reaction function coefficients between the Bundesbank and the Federal Reserve and in real wage rigidity.

We noted earlier that there is a negative correlation between the change in inflation and the change in the NAIRU. Ball (1996) investigated this for the 1980s and we plotted it over two decades and across 21 OECD countries in figure 2. There are various possible reasons why countries might have differently sized disinflations. Economies might differ in the way they respond to global supply shocks, perhaps due to differences in energy intensity of production. Their past record of monetary policy might differ as well, (in the sense that some central banks have let inflation spiral more out of bounds than others, leading to larger deviations of inflation from target), as might choices of how much to disinflate (a central bank might just be willing to accept a higher inflation rate following a supply shock). Finally, exchange

\textsuperscript{18}Ball controls for the duration of unemployment benefits.

\textsuperscript{19}See Ball (1999), p. 207.
rate volatility might differ as well. Incorporating these various sources of inflation volatility into our model would be far beyond the scope of this paper. However, we do try to mimic their inflationary impact by varying the size of the cost push shock.

We vary the size of the cost push shock from 0.01 to 0.05, leaving all other parameters unchanged. Then we calculate the change from year 1 to year 10 of the inflation rate during those years and the NAIRU in the first quarter of those years, and plot the later against the former in figure 12. There is a clear negative correlation. The slope of the line varies between -0.41 and -0.56, which is not too far away from the simple regression coefficient of -0.33 (or -0.36 if, like Ball (1996) we exclude Greece) resulting from a regression of the change in the NAIRU on the change in inflation using the OECD data presented earlier.

![Figure 12: Change in Inflation vs. Change in the NAIRU over 10 Years](image)

Let us now take a look at the effect of observable differences in the monetary policy rule. To get a proper idea of the effects of these it is obviously important

---

20We take the difference of the first quarter of both years since the NAIRU moves up very fast during the first four quarters. Differenting the annual averages of the two years would create a misleading impression of the correlation between the medium run change in the NAIRU (by unduly reducing this change) and the change in inflation. The quarterly movements of the NAIRU in the OECD data are very slow and redoing figure one with the difference in the NAIRU between 1980 quarter1 1990 quarter 1 rather than with the differences in the annual averages as is the case now would not change the result.
to have comparable estimates. Therefore we make use of the fact that Clarida et al. (1998) estimated the same policy rule using the same methodology for several countries, including Germany and the United States. We would have liked to draw on real time estimates as in the previous section but to our knowledge, internationally comparable estimates of this kind do not exist. The coefficient estimates of Clarida et al. of (15) for the Federal Reserve are reproduced in table 3.

We now repeat the same experiment we conducted in the last section for both the estimates for the Bundesbank reaction function and the coefficients of the Federal Reserve. The first two lines of Table 5 show the deviation of unemployment from steady state for both set of coefficients. Note first that the persistent increase in unemployment with the policy rule as specified and estimated by Clarida et al. for the Bundesbank is substantially higher than the increase we saw with the policy rule used in the Baseline. This illustrates that, in terms of the unemployment effects which are the subject of this paper, we were quite conservative in specifying and calibrating our Baseline policy rule. Apart from that, unemployment is persistently higher under the Bundesbank rule than under the Federal Reserve one, though the difference is for the most part less than one percentage point. For instance after 10 years, unemployment and the NAIRU are about 0.5 percentage points higher under the Bundesbank Rule than under the Federal Reserve rule.

It is, however, informative to take a look at the standard errors associated with Clarida et al.’s estimate. For instance, the standard error associated with the coefficient on the lagged interest rate \( \rho \) has as standard error of 0.03. Thus a value for \( \rho \) of 0.06 is still consistent (at a 5% level of confidence) with Clarida et al.’s estimate. The third row of table 9 shows the implied evolution of unemployment if we set \( \rho = 0.91 \). The resulting unemployment trajectory is substantially lower than before. After 40 quarters, the unemployment and the NAIRU are now 1.1 percentage points lower than under the Bundesbank rule, while after 50 quarters, the difference is still 1 percentage point. In the same manner, we can also make use of the standard error of the estimate of \( \psi_Y \), which equals 0.16. Increasing \( \psi_Y \) to 0.88 yields the employment trajectory shown in the final row of table 5, which is again lower than with the point estimate. After 40 quarters, unemployment is and the NAIRU are about 0.9 percentage points lower than under the Bundesbank policy rule. Thus in the New Growth model, differences in policy function parameters consistent with Clarida et al.’s estimate can contribute to explaining the different evolutions of the unemployment rate in Germany as compared to the United States.

Accordingly, differences in monetary policy also explain differences in the change in the productivity growth rate between Germany and United States from the 1970s to the 1980s. As noted above, average US productivity growth declined by only about 0.18% from the 1970s to the 1980s, whereas the decline in Germany was about 1.4%. Table 6 displays the difference between average annualised productivity growth during the first decade after the shock and the decade before the shock.\(^21\) Thus within the

\(^{21}\) As above we assume that during the decade before the shock hits, the average productivity
New Growth model, differences in monetary policy would account for between 0.24 and 0.6 percentage points of the difference in productivity growth.

<table>
<thead>
<tr>
<th>Table 5: Results for Clarida et al.’s Policy Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment Deviation from the Steady State, percentage Points</td>
</tr>
<tr>
<td>Quarter</td>
</tr>
<tr>
<td>Bundesbank</td>
</tr>
<tr>
<td>Federal Reserve</td>
</tr>
<tr>
<td>Federal Reserve, ρ = 0.91</td>
</tr>
<tr>
<td>Federal Reserve, ψ_Y = 0.88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6: Results for Clarida et al.’s Policy Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in ten Year Average productivity Growth, percentage Points</td>
</tr>
<tr>
<td>Bundesbank</td>
</tr>
<tr>
<td>Federal Reserve</td>
</tr>
<tr>
<td>Federal Reserve, ρ = 0.91</td>
</tr>
<tr>
<td>Federal Reserve, ψ_Y = 0.88</td>
</tr>
</tbody>
</table>

Finally, we explore the effects of the observed cross continental differences in the nature of real wage rigidity. As was mentioned above, empirical estimates of wage setting functions repeatedly find that real wage growth is negatively related to the labour share in Europe but not in the United States. Therefore, in our final experiment aimed at highlighting cross country dimensions, we set c = 0 in the Baseline calibration, leaving everything else as in the Baseline. The resulting deviation of unemployment from its steady state can be obtained from table 7. Clearly, the increase in unemployment is persistently lower. After 40 quarters, unemployment is only 0.6 percentage points higher than in the steady state, compared to 1.7 percentage points in the Baseline. Average annualized productivity growth is only 0.36% lower than in the previous decade as opposed to 0.96% in the baseline calibration.

Within our model, c=0 would arise if there is no direct effect of productivity on effort and if benefits are not linked to productivity. We suggested above that these results might be rooted in stronger unions and perhaps a stronger link between unemployment benefits and productivity in Europe. Blanchard and Wolters (2000) find that the impact of macroeconomic shocks on unemployment is affected by the labour market structure. They find that both unobservable macroeconomic shocks (captured by a time effect) as well as a one percentage point reduction in total factor productivity growth increase unemployment by more the higher is union density.\(^{22}\) This result is confirmed by Fitoussi et al. (2000).\(^{23}\) In that sense, our model provides some theoretical to the notion that both "shocks and institutions" (Blanchard and growth rate equalled its steady state.


\(^{23}\)See Fitoussi et al. (2000), p. 250.
Wolfers) are crucial to explaining the cross country evidence on the evolution of unemployment.

Table 7: $c = 0$ - Percentage point Deviation of Unemployment from its Steady State for selected Quarters

<table>
<thead>
<tr>
<th></th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation</td>
<td>0.9</td>
<td>1.1</td>
<td>0.9</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

6 Conclusion

This paper employs a New Keynesian model with unemployment and endogenous growth to explain the persistent increase in continental European unemployment and the lack thereof in the United States. We calibrate key parameters like the coefficients in the wage setting equation and the interest feedback rule of the central bank to Western German data. The model economy is hit with a one quarter cost-push shock calibrated to induce a disinflation of an order of magnitude seen at the beginning of the 1980s in many industrialised OECD economies. We perform the same experiment on a model without endogenous growth: The JLN economy.

Under the baseline calibration, unemployment will still be about 1.8 percentage points above its pre-shock value after about 10 years. As can be observed with continental European unemployment rates, unemployment increases quickly but reverts only very slowly. At the same time, inflation stops declining soon after the cost push shock has vanished, implying that the NAIRU has increased. Unsurprisingly, no such effect is seen in the JLN economy, where unemployment is back to its steady state after about two years.

The increase in the NAIRU in the New Growth economy is brought about by the decline in investment during the recession required to disinflate the economy. In the New Growth economy, for a given employment level, capital stock growth determines labour productivity growth. Hence the real wage–capital ratio is the main driver of marginal costs. Thus, although wage growth declines as employment contracts, marginal cost returns back to its steady state level soon after the shock has vanished because capital stock growth for while declines even more. This stops the disinflation. The subsequent recovery is very slow because the central bank has no reason to lower interest rates. Its reaction function dictates that it reacts solely to inflation, being close to target, and the output gap, defined as the deviation of output from the level consistent with constant inflation, which is zero.

The model thus also contributes, to explaining the productivity slowdown observed across advanced OECD economies, and why negative shocks to productivity growth are frequently significant variables in regression of unemployment on this variable and others.

Finally, apart from generating a persistent increase in unemployment, the model also contributes to explaining cross country differences in unemployment. Varying the
size of the cost push shock generates a relationship between the change in the inflation rate and the change in the NAIRU over a ten year horizon similar to a relationship in the data first observed by Ball (1996). Using comparable policy rule estimates of Clarida, Gali and Gertler (1998) for the Bundesbank and the Federal Reserves while holding the cost-push shock constant creates higher persistent unemployment with the later than with the former. Finally, taking account of a well established cross-continental difference in the structure of the wage setting function, namely the absence of a labour share term, also proves informative. In the absence of the labour share term, we see a lower increase in the NAIRU. The size of the labour share term in wage setting can be linked, if coarsely so, to features of the labour market like union density or the benefit system. Thus the paper lends support to the view that, as suggested by Blanchard and Wolfers (2000), it is both "shocks and institutions" which are at the heart of explaining the evolution of unemployment across time and the differences across countries.

7 Appendix A: Derivation of the JLN and the Endogenous Growth Model

7.1 Households

Danthine and Kurmann (2004) introduce unemployment in a general equilibrium model without moving away from the representative agent framework. In the Danthine-Kurmann setup individuals are organized in infinitely lived households. All decisions regarding the intertemporal allocation of consumption and the accumulation of capital are made at the household level. Each household member supplies one unit of labour in-elastically but derives disutility from the effort $G(e_i)$ he or she supplies in their job. The share of unemployed members is the same for each family. The large family assumption means that although there are unemployed individuals in the economy, it is not necessary to track the distribution of wealth.

In addition, some workers supply overhead labour. They can be thought of as the owners of the monopolistically competitive firms. Overhead workers never become unemployed because no firm can produce without managerial staff. A share $n^*$ of the workforce is employed by the government who is assumed to pay the same wage as the private sector. They are funded by lump sum taxes. All families have the same share of managers and government employees.

Families solve the following constrained maximisation problem by choosing consumption $C_t$ (which is a CES consumption basket $C_t = \left[ \int_0^1 (c_t(i) \frac{(1 + r) - 1}{r} di \right]^{\frac{1}{\sigma}}$), bond-holding $B_t$, investment expenditure $I_t$, next periods capital stock $K_{t+1}$ and the effort
level \( e_t \) of the typical working family member:

\[
U = E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[ u(C_{t+i} - \text{hab}_{t+i-1}) - (n_{t+i} - \bar{n}) G(e_{t+i}) \right] \right\}, \quad u' > 0, \ u'' < 0 \quad (16)
\]

s.t. \((n_t - \bar{n}) w_t + \frac{B_{t-1}}{P_t} (1 + i_{t-1}) + F_t + r_t^k K_t \geq C_t + \frac{B_t}{P_t} + T_t + I_t \) and \( K_{t+1} = (1 - \delta) K_t + I_t \left( 1 - S \left( \frac{I_t}{I_{t-1}} - (1 + g) \right) \right), \quad S(0) = 0, \ S(0)' = 0, \ S(0)'' > 0 \quad (17)
\]

where \( P_t \) denotes the price index of the consumption basket. A family’s period \( t \) income consists wages \( w_t \), interest income \( i_{t-1} \) on risk less bonds they bought in the previous period \( B_{t-1} \), the profits of the monopolistically competitive firms in the economy \( F_t \), and dividends \( r_t^k \) from renting out their accumulated capital \( K_t \). They have to pay lump sum taxes \( T_t \). We assume adjustment costs in investment: Only a fraction of one unit of investment expenditure is actually turned into additional capital. This fraction decreases in the investment growth rate. The assumptions on the first derivative of the \( S(.) \) function imply that adjustment costs vanish when the economy is growing at its steady state growth rate \( g \).\textsuperscript{24} This implies that the steady state growth rate does not depend on the parameters of the adjustment cost function \( S \). Setting up the lagrangian and denoting the lagrange multipliers of the budget constraint and the capital accumulation constraint as \( \lambda_t \) and \( \lambda_t q_t \) yields the following first order conditions with respect to consumption, capital and investment:

\[
u'(C_t - \text{hab}_{t-1}) = \beta E_t \left[ u'(C_{t+1} - \text{hab}_{t+1}) \frac{1}{1 + \pi_{t+1}} \right] [1 + i_t] \quad (19)
\]

\[
\lambda_t = u'(C_t - \text{hab}_{t-1}) \quad (20)
\]

\[
\beta E_t \left( \lambda_{t+1} r_{t+1}^k + \lambda_{t+1} q_{t+1} (1 - \delta) \right) = \lambda_t q_t \quad (21)
\]

\[
\lambda_t q_t \left[ \left( 1 - S \left( \frac{I_t}{I_{t-1}} - (1 + g) \right) \right) - \frac{I_t}{I_{t-1}} S' \left( \frac{I_t}{I_{t-1}} - (1 + g) \right) \right] = \lambda_t \quad (22)
\]

Note that with this notation, \( q_t \) denotes the present discounted value of the future profits associated with buying an additional unit of capital today, also known as Tobin’s \( q \). We assume logarithmic instantaneous utility. Following Schmitt-Grohe

\textsuperscript{24} There are two advantages of assuming investment adjustment costs and external habit formation. Firstly, it facilitates matching the second moments of investment and consumption, and secondly, it makes the on impact response of unemployment to the cost push shock in the simulation we are going to perform later more reasonable. By contrast, the impact on the longer run response of unemployment is rather small.
and Uribe (2005), we assume \( S \left( \frac{h}{h_{t-1}} - (1 + g) \right) = \frac{\alpha}{2} \left( \frac{h}{h_{t-1}} - (1 + g) \right)^2 \). Applying these functional forms yields the expressions discussed in section 2 of the paper.

The cost of effort function of individual \( j \) \( G(e_{t+1}(j)) \) is of the form

\[
G(e_{t}(j)) = \left( e_{t}(j) - \left( \phi_{0} + \phi_{1} \log w_{t}(j) + \phi_{2}(n_{t} - \bar{n}) \right) + \phi_{3} \log w_{t} + \phi_{4} \log w_{t-1} - \phi_{5} \log b_{t} - \phi_{6} \log \left( Y_{t-1}/(n_{t-1} - \bar{n} - n^*) \right) \right)^2
\]

(24)

where \( Y_{t} \) is private sector output. Note that the effort function enters the families’ utility separately which implies that it is independent of the budget constraint. Furthermore, state employees are assumed not to perform any effort while at work. The first order condition with respect to effort is

\[
e_{t}(j) = \phi_{0} + \phi_{1} \log w_{t}(j) + \phi_{2}(n_{t} - \bar{n}) + \phi_{3} \log w_{t} + \phi_{4} \log w_{t-1} - \phi_{5} \log b_{t} - \phi_{6} \left( Y_{t-1}/(n_{t-1} - \bar{n} - n^*) \right)
\]

(25)

(26)

The structure of the cost of effort function is motivated by the idea of "gift exchange" between the firm and the worker. The worker’s gift to the employer is effort. The employer has to show his appreciation for the employees’ contribution by paying an appropriate wage \( w_{t}(j) \). A higher contemporary average wage \( w_{t} \) reduces effort because it represents a "reference level" to which the current employers’ wage offer is compared. Put differently, it requires the firm to pay a higher wage if it wants to extract the same amount of effort. A higher average past real wage \( w_{t-1} \) boosts the workers’ aspirations as well.\(^{25}\) The aggregate employment level of non-overhead workers \( n_{t} - \bar{n} \) summarizes labour market tightness. It is thus positively related to the workers’ outside working opportunities, and thus also tends to reduce effort.

The view that wages have a big effect on workers morale and thus productivity because they signal to the worker how his contribution to the organizational goals is valued is supported by an extensive microeconomic survey conducted by Bewley (1989). Bewley found that wage changes (in particular wage cuts) seem to be especially important. Bewley interviewed over 300 business people, labour leaders and business consultants in search for an explanation why wages are rarely cut in recessions.\(^{26}\)

\(^{25}\)See Danthine and Kurmann (2004), pp. 111-113. It would be desirable to have the individual workers past real wage \( w_{t}(j) \) in the equation but that would considerably complicate the maximisation problem of the representative firm dealt with later, so we follow Danthine and Kurman in assuming a dependence of effort on the average wage. For the same reason we include average productivity rather than the respective firm’s productivity.

\(^{26}\)See Bewley (1998), pp. 459-490. A discussion of further evidence is Bewley (2004). Bewley also argues that his findings contradicts essentially all theoretical justifications of real wage rigidity not based on gift exchange considerations, like implicit contracts, insider outsider models or the efficiency wage models based on no-shirking conditions.
The terms $b_t$ and $(Y_{t-1}/(n_{t-1} - \pi - n^d))$ represent and a modification to the Danthine and Kurman (2004) cost of effort function. $b_t$ denotes unemployment income. This will be chiefly unemployment benefits and black market income. It tends to lower the level of effort.\footnote{Danthine and Kurman (2007) introduce the benefit level as a factor which, ceteris paribus, reduces effort.} Workers want to be valued more than someone who receives benefits or does not have a legal job. $b_t$ is linked both to past real wages and past productivity in the private sector, where $Y_t$ denotes private sector output. This may reflect both the structure of benefits and the manner in which the black market is linked to the official economy. Productivity also has a direct effect on morale and effort as employees desire their due share of the companies’ success. Unions might play a role in this to the extent that they instil a sense of entitlement among employees.

The employer takes this relationship into account when setting the wage, as will be discussed further below.

### 7.2 Cost Minimisation and Efficiency Wages

The production technology is a Cobb Douglas production function,

$$ Y_t(i) = AK_t(i)^{a}(TFPe_t(i)(n_t(i) - \pi))^{1-a} $$

where the output of firm i $Y_t(i)$ depends on the capital stock of firm i $K_t(i)$, the efficiency of its workers $e_t(i)$ and the number of non-overhead workers $n_t(i) - \pi$. In the Danthine and Kurman model (2004), in a first stage the firm minimises its cost of producing a given amount of output. Capital and labour are hired in economy wide factor market. However, the firm does not take the real wage as given but sets it taking into account the relationship between effort and wages given by (27).\footnote{See Danthine and Kurman (2004), pp. 114-115.} Hence the firm’s problem is:

$$ \min_{K_t(i), n_t(i), w_t(i), e_t(i)} r^K_i K_t(i) + w_t(i) (n_t(i) - \pi) s.t. Y_t(i) = AK_t(i)^{a}(TFPe_t(i)(n_t(i) - \pi))^{1-a} $$

and $e_t(i) = \phi_0 + \phi_1 \log w_t(i) + \phi_2(n_t - \pi) + \phi_3 \log w_t + \phi_4 \log w_{t-1} - \phi_5 (Y_{t-1}/(n_{t-1} - \pi - n^d))$

The first order conditions for capital and labour are

$$ r^K_t = \alpha mc_t(i) \frac{Y_t(i)}{K_t(i)} \quad (28) $$

$$ w_t(i) = (1 - \alpha) mc_t(i) \frac{Y_t(i)}{n_t(i) - \pi} \quad (29) $$
where $mc_t(i)$ and $r_t^k$ refer to real marginal costs of firm i and the capital rental rate. It will be shown below that even though all firms set the wage individually, firms will find it optimal to set the same wage and the same efficiency level. Dividing the two first order conditions gives $\frac{k_t(i)}{n_t(i) - \pi} = \frac{\alpha}{1-\alpha} \frac{w_t}{r_t^k}$. Thus the capital labour ratio is the same across firms. It is then easily shown using the production function that the same holds for the output-capital ratio and the output-labour ratio. Hence we have

$$r_t^k = \alpha m c_t \frac{y_t}{k_t}$$

(30)

$$w_t = (1-\alpha) m c_t \frac{y_t}{n_t - n^s - \pi}$$

(31)

This then means that the capital to (productive) labour ratio, the output per unit of productive labour ratio and marginal costs are the same in all firms, as can be easily verified by dividing the two first order conditions. This gives the capital to productive labour ratio as $\frac{k_t(i)}{n_t(i) - \pi} = \frac{\alpha}{1-\alpha} \frac{w_t}{r_t^k}$. Substituting this back into equation (30) yields an equation for $mc_t(i)$ containing only labour augmenting technological progress and the factor price, implying that marginal costs are the same across all firms:

$$mc_t = \frac{\left(r_t^k\right)^{\alpha} w_t^{1-\alpha}}{A(1-\alpha)^{1-\alpha}(\phi_1 TFP_t)^{1-\alpha}}$$

(32)

We now turn to wage setting. The first order conditions with respect to effort and the real wage are

$$n_t(i) - \pi = \frac{\zeta_t \phi_1}{w_t(i)}$$

(33)

$$\zeta_t = (1-\alpha) m c_t \frac{y_t(i)}{e_t(i)}$$

Combining those with the first order condition with respect to labour yields an optimal effort level of $\phi_1$. Substituting this back into the effort function (27), we note that, as the firm’s wage depends only on aggregate variables which are the same for all firms, it must indeed hold that $w_t(i) = w_t$. Substituting for $\log b_t$ and rearranging then yields

$$(\phi_1 + \phi_3) \log w_t = (\phi_5 (1 - \phi_6) - \phi_4) \log w_{t-1} + \phi_1 - \phi_0 + \phi_5 \phi_7 - \phi_2 (n_t - \pi)$$

$$- (\phi_5 \phi_6 + \phi_8) \log \left(1/ \left(\frac{Y_{t-1}}{n_{t-1} - \pi - n^s}\right)\right)$$

Subtracting $(\phi_5 \phi_6 + (1 - \phi_5)) \log w_{t-1}$ on both sides and dividing by $(\phi_1 + \phi_3)$ then yields

30
\[
\log w_t = \frac{\phi_1 - \phi_0 + \phi_5\phi_7}{\phi_1 + \phi_3} - \frac{\phi_2}{\phi_1 + \phi_3} \left(n_t - \bar{n}\right) + \frac{\phi_3 + \phi_8 - \phi_4}{\phi_1 + \phi_3} \log w_{t-1} \\
- \frac{\phi_2}{\phi_1 + \phi_3} \log \left(\frac{\left(n_{t-1} - \bar{n} - n^s\right)}{Y_{t-1}}\right)
\]

(34)

Hence with the coefficient restrictions imposed above, the wage depends positively on the past real wage and non-managerial employment. It will be above its market clearing level and thus there is unemployment in the economy.

Note that the last term in brackets is in fact the private sector labour share. If this were constant in the steady state, as it would be at a constant employment level, equation (34) could be solved for a long run real wage if \(\frac{\phi_5 + \phi_8 - \phi_4}{\phi_1 + \phi_3} < 1\). As mentioned above however, in our model, Danthine and Kurmann’s, is a growth model. Therefore the real wage must be growing in the steady state. Thus a wage setting function simply relating the wage level to employment would not be consistent with a stable employment level. The easiest way to deal with the issue therefore is to set \(\frac{\phi_5 + \phi_8 - \phi_4}{\phi_1 + \phi_3} = 1\). This does not seem too restrictive: It simply says that an increase in the log of the time \(t\) real wage in the economy (including firm \(i\)) has in absolute value the same net effect on effort (remember we have \(\phi_1 + \phi_3 > 0\)) as an increase in the exogenous reference as represented by \(\log w_{t-1}, \log b_t\) and \(\log \left(\frac{Y_{t-1}}{n_{t-1} - \bar{n} - n^s}\right)\). Thus we arrive at a real wage Phillips Curve with a labour share term:

\[
\log w_t - \log w_{t-1} = a + b \cdot (n_t - \bar{n}) + c \log \left(\frac{w_{t-1} \left(n_{t-1} - \bar{n} - n^s\right)}{Y_{t-1}}\right),
\]

with \(a = \frac{\phi_0 - \phi_1 + \phi_5\phi_7}{\phi_1 + \phi_3}, b = -\frac{\phi_2}{\phi_1 + \phi_3} > 0\) and \(c = -\frac{(\phi_2\phi_6 + \phi_8)}{\phi_1 + \phi_3} < 0\)

(35)

Equation (35) is a real wage Phillips Curve plus an "error correction term" represented by the log of the labour share. Note that if there is no effect of productivity on effort and \((\phi_8 = 0)\) and no effect of productivity on benefits \((\phi_6 = 0)\) we have \(c = 0\).

It remains to determine the size of the overhead labour force. Following Rotemberg and Woodford (1999), we assume that in the steady state, all economic profit generated by employing productive labour and capital goes to the overhead staff. Hence the firm ends up with zero profits.\(^{29}\) This is justified because setting up production is impossible without overhead labour and the firm’s profit is thus essentially equal to the collective marginal product of its overhead staff. We assume that the overhead staff splits this profit equally. We assume the amount of overhead workers required to enable production is such that the real wage for overhead and non-overhead workers

\(^{29}\)See Rotemberg and Woodford (2004), pp. 15-16.
will be exactly the same in the steady state. These assumptions allow for a straightforward way to determine the amount of overhead and non-overhead workers as a function of total employment. Zero profit requires

$$\frac{\mu - 1}{\mu} Y_t - w_t \bar{n} = 0$$

where $\frac{\mu - 1}{\mu}$ is the share of firms profits in output. Substituting $w_t = (1 - \alpha)\frac{1}{\mu} \frac{Y_t}{n - n^s - \bar{n}}$ gives, after some manipulation

$$\frac{\mu - 1}{1 - \alpha} = \frac{\bar{n}}{n - n^s - \bar{n}} \equiv \bar{s}$$

This is the ratio of overhead labour to productive labour, which we call $\bar{s}$. Solving for $\bar{n}$ then gives

$$\bar{n} = \frac{\bar{s}}{1 + \bar{s}} (n - n^s)$$

### 7.3 Price Setting and Nominal Rigidities

Each firm produces one of the variants of the output good in the CES basket. Households spread their expenditures across the different varieties in the basket in a cost minimising fashion. Assuming that investment expenditure stretches over these variants in precisely the same way as consumption demand, we can write the demand for variant $j$ as $y_{t+i}(j) = Y_{t+i} \left( \frac{p_{t+i}(j)}{P_{t+i}} \right)^{-\theta}$. Following Rotemberg (1983) we assume that the representative firm faces quadratic costs if it alters its individual inflation from a reference level $\Pi - 1$. This is the steady state level of inflation in the economy. These cost arise because frequent price changes are bad for the reputation of the company. Convincing customers to remain with the company nevertheless is costly. Additional costs arise because deviating from the "standard" level of inflation requires the firm to engage in a costly re-optimisation process. This has to be carried out by high paid marketing professionals, while price changes close to average inflation can be decided by lower paid "frontline" staff. Both kinds of costs are likely to increase in the firms output as well. We assume the following functional form:

$$AC_{t+i}(j) = \frac{\varphi}{2} \left( \frac{p_{t+i}(j)}{p_{t+i-1}(j)} - \Pi \right)^2 y_{t+i}(j)$$  \hspace{1cm} (36)

The firm $j$ chooses its price $p_{t+i}(j)$ in order to maximise

$$\sum_{i=0}^{\infty} E_t \left[ \rho_{t,t+i} \left( \frac{p_{t+i}(j)}{P_{t+i}} y_{t+i}(j) - mc_{t+i} y_{t+i}(j) - AC_{t+i}(j) \right) \right]$$  \hspace{1cm} (37)

where $\rho_{t,t+i}$ denotes the discount factor used to discount real profits earned in period $t+i$ back to period $t$. Note that because households own the firms, we have $\rho_{t,t+i} = \ldots$
\( \beta \cdot u'(c_{t+1}) \). Differentiating with respect to \( p_t(j) \) and noting that, as all firms are the same, \( p_t(j) = P_t \) holds ex post, yields

\[
(1 - \theta) + \theta mc_t - \varphi \left( \frac{P_t}{P_{t-1}} - \Pi \right) \frac{P_t}{P_{t-1}} + \theta \frac{\varphi}{2} \left( \frac{P_t}{P_{t-1}} - \Pi \right)^2 + \mathbb{E}_t \left[ \rho_{t,t+1} \varphi \frac{Y_{t+1}}{Y_t} \left( \frac{P_{t+1}}{P_t} - \frac{P_t}{P_{t-1}} \right) \right] = 0 \tag{38}
\]

which is a nonlinear version of the standard New Keynesian Phillips curve. It is, however, a consistent feature of empirical estimations of Phillips curves that specifications which include lagged inflation as well ("hybrid" Phillips curves") perform better than purely forward looking Phillips Curves. This is because inflation has inertia.\(^{30}\) Backward looking elements are easily introduced into the price setting considerations of the firm by assuming that the reference level of inflation does not remain constant over time. Instead, we assume that it equals last periods inflation, i.e. \( \Pi_t = \frac{P_{t-1}}{P_{t-2}} \).

If the inflation rate becomes higher for several periods, firms will mandate frontline staff to handle price increases of that size in order to keep costs low. Customers will get used to the different pace of price changes as well, making a higher rate of price change less costly for the individual firm. Hence we have

\[
(1 - \theta) + \theta mc_t - \varphi \left( \frac{P_t}{P_{t-1}} - \frac{P_{t-1}}{P_{t-2}} \right) \frac{P_t}{P_{t-1}} + \theta \frac{\varphi}{2} \left( \frac{P_t}{P_{t-1}} - \frac{P_{t-1}}{P_{t-2}} \right)^2 + \mathbb{E}_t \left[ \rho_{t,t+1} \varphi \frac{Y_{t+1}}{Y_t} \left( \frac{P_{t+1}}{P_t} - \frac{P_t}{P_{t-1}} \right) \right] = 0 \tag{39}
\]

The experiment we want to conduct later is a disinflation. Inflation is brought into the economy by a so called "cost-push shock" \( u_t \) widely used in the New Keynesian literature.\(^{31}\) This shock increases current inflation, holding the values of past inflation and marginal costs constant, and is added directly to the Phillip’s curve equation:

\[
(1 - \theta) + \theta mc_t - \varphi \left( \frac{P_t}{P_{t-1}} - u_t \right) - \frac{P_{t-1}}{P_{t-2}} \left( \frac{P_t}{P_{t-1}} - u_t \right) + \frac{\varphi}{2} \left( \frac{P_t}{P_{t-1}} - u_t \right) - \frac{P_{t-1}}{P_{t-2}} \left( \frac{P_{t+1}}{P_{t}} - \left( \frac{P_t}{P_{t-1}} - u_t \right) \right) + \mathbb{E}_t \left[ \rho_{t,t+1} \varphi \frac{Y_{t+1}}{Y_t} \left( \frac{P_{t+1}}{P_t} - \left( \frac{P_t}{P_{t-1}} - u_t \right) \right) \right] = 0 \tag{40}
\]

It is easily shown that up to first order, this Phillips Curve resembles very closely specifications which are obtained by Woodford (2003) under the assumption of Calvo contracts and full indexation of the prices of those firms which can not re-optimise prices to past inflation.\(^{32}\) It is a forward looking accelerationist Phillips Curve. If present and future marginal costs are at their steady state level and present and future values of cost push shock are zero, inflation will remain constant. It will accelerate or decelerate otherwise. Hence the model has a well defined NAIRU.

\(^{30}\)See for instance Gali and Gertler (2000).

\(^{31}\)See for instance Clarida et al (1999), pages 1665 and 1667.

\(^{32}\)See Woodford (2003), p. 215. In fact, the coefficients on expected future inflation and the coefficient on lagged inflation exactly match Woodfords’ results.
7.4 Definition of the Output Gap

The output gap is the percentage deviation of total output, i.e. private sector plus the output of government employees, from its natural level. We calculate the output of government employees by simply adding up their wages, following the convention of national accounts. We assume that government employees earn the same wage as in the private sector. For total output, we then have \( Y_t + w_t n^s \), while total natural output is given by \( Y_t^n + w_t^n n^s \). \( w_t^n \) and \( Y_t^n \) denote the wage rate and the private sector output level consistent with natural employment, or the NAIRU. Thus we have

\[
gp_t = \frac{Y_t + w_t n^s - Y_t^n - w_t^n n^s}{Y_t^n + w_t^n n^s} \tag{41}
\]

\( Y_t^n \) denotes the private sector output level which would set marginal costs equal to its long run level \( \mu^{-1} \), given the capital stock and the previous period’s real wage. As can be obtained from equation (40), this would ensure that in the absence of cost push shocks, inflation is neither rising nor falling. The employment level corresponding to this output level will be referred to as "natural employment" \( n_t^n \). The natural levels of output and employment are derived by substituting the equation for the rental on capital (30) and the wage setting equation (35) into (32) and setting \( mc_t = \mu^{-1} \). The natural levels of output, employment and the real wage are then given by the values of \( Y_t^n \), \( n_t^n \) and \( w_t^n \) solving

\[
\mu^{-1} = \frac{(n_t^n - n^* - \bar{\pi})^\alpha w_t^n}{A (1 - \alpha)(\phi_t TFP_t)^{1-\alpha} K_t^\alpha}
\]

\[
\log w_t^n - \log w_{t-1} = a + b n_t^n (n_t^n - \bar{\pi}) + c \log \left( \frac{w_{t-1} (n_{t-1} - \bar{\pi} - n^*)}{Y_{t-1}} \right)
\]

\[
Y_t^n = AK_t^\alpha (TFP_t \phi_t (n_t^n - n^* - \bar{\pi}))^{1-\alpha} \tag{42}
\]

Note that given the past real wage, the capital stock has a positive effect on natural employment given the past real wage. This effect works through the negative effect of a higher capital stock on the capital rental. This tends to lower marginal costs and thus accommodates a higher real wage given the mark-up. This allows the employer to meet the demands of wage seters associated with higher employment.

7.5 Introducing Endogenous Growth

The basic idea in the knowledge spill-over model of Romer (1986) is to start off with a standard neoclassical production function with labour augmenting technical progress as above.\(^{33}\) An additional feature is that labour augmenting technological progress might be firm specific. Thus the output of firm \( i \) is given by

\[
Y_t(i) = F(K_t(i), TFP_t(i) n_t(i)) \tag{43}
\]

\(^{33}\)The exposition here follows Barro and Sala-i-Martin (2004), pp.212-222.
Romer then makes two crucial assumptions:

- Increasing it’s physical capital simultaneously teaches the firm how to produce more efficiently. This idea was first suggested by Arrow (1962). For simplicity, in the Romer setup, $TFP_t(i)$ is simply proportional to the firm’s capital stock.

- Knowledge is a public good. Hence each firm’s knowledge is in fact proportional to the aggregate capital stock rather than to its own.\(^{34}\) However, the impact of the firm’s capital stock on the aggregate capital stock is so small that they can be neglected. Thus the production function of firm i becomes

$$Y_t(i) = F(K_t(i), K_t n_t(i)) \tag{44}$$

This implies that there are now constant returns to capital at the economy wide level, allowing per capita output to grow. However, there are still decreasing returns to capital at the firm level. In the Romer model, this leads to a growth rate which is inefficiently low. This is because saving is to low as the individual return on capital falls short of the social return on capital.

Thus we set $TFP_t = K_t$ in the equations derived in the previous section. The marginal cost equation (32) and the aggregate production function become

$$mc_t = \left( \frac{(r_t^K)^{n_t} w_t^{1-\alpha}}{A \omega^{\alpha} (1-\omega)^{1-\alpha} (\phi_1 K_t)^{1-\alpha}} \right) \tag{45}$$

$$Y_t = AK_t(\phi_1 (n_t - n^* - \bar{n}))^{1-\alpha} \tag{46}$$

To arrive at from the production function (5), after setting $TFP_t = K_t$, we divide by $n_t(i) - \bar{n}$. As the capital labour ratio and the output per unit of productive labour ratio are the same across all firms, we arrive at (46).

The capital stock now has a stronger effect on both marginal costs and output than in the JLN economy. An increase in the capital stock by 1% for a given employment level (implying that output expands at the same rate) reduces marginal costs by 1%. In the absence of endogenous growth the effect is only $\alpha%$. This can be see by substituting the capital rental out of equations (32) and (45) and then substituting $\frac{Y_t}{K_t}$ using the respective production functions.

Accordingly, the capital stock also has a greater effect on natural employment and the NAIRU. The equivalents of equations (42) are

$$\mu^{-1} = \frac{(n_t^n - n^* - \bar{n})^{\alpha} w_t^n}{A (1-\alpha) (\phi_1)^{1-\alpha} K_t} \tag{47}$$

$$\log w_t^n - \log w_{t-1} = a + b \cdot (n_t^n - \bar{n}) + c \log \left( \frac{w_{t-1} (n_{t-1} - \bar{n} - n^*)}{Y_{t-1}} \frac{Y_t}{Y_{t-1}} \right) \tag{47}$$

$$Y_t^n = AK_t(\phi_1 (n_t^n - n^* - \bar{n}))^{1-\alpha} \tag{47}$$

\(^{34}\)See Barro/ Sala-i-Martin (2004), pp.21-22.
Clearly, an increase in the capital stock now accommodates a larger increase in natural employment than in (42).

8 Appendix B : Normalised Version of the New Growth Model

As we are dealing with two growth models, we have to stationarise all variables which would otherwise be trended in order to be able to solve the model. This appendix applies this normalisation to the New Growth model. The resulting equations are those which have been solved and simulated. We define \( \frac{C_t}{K_t}, \frac{\text{hab}_{t-1}}{K_t}, \frac{Y_t + a_t + a_t'}{K_t}, \frac{I_t}{K_t} \) and \( \frac{a_t}{K_t} \) as \( D_t, \text{Hab}_{t-1}, F_t, R_t \) and \( H_t \), while the gross capital stock growth rate \( \frac{K_{t+1}}{K_t} - 1 \) is defined as \( g_t^k \).

We directly apply the normalisation to the equations of the aggregate demand block:

\[
F_t = D_t + R_t + \frac{\varphi}{2}(\pi_t - \pi_{t-1})^2 (F_t - H_t n^* + H_t n^*)
\]

(48)

Consumption (remember \( \text{hab}_{t-1} = jC_{t-1} \), thus \( \text{Hab}_{t-1} = j \frac{D_{t-1}}{1 + g_t^k} \))

\[
1 / (D_t - \text{Hab}_{t-1}) = \beta E_t \left[ \frac{(1 + i_t) / ((1 + \pi_{t+1}) (D_{t+1} - \text{Hab}_{t+1}) (1 + g_{t+1}^k))}{(1 + g_{t+1}^k) (1 + g_{t+1}^k) + H_t n^*} \right]
\]

(49)

\[
\text{Hab}_t = j \frac{D_t}{1 + g_t^k}
\]

(50)

Investment:

\[
\beta E_t \left( \frac{1}{(D_{t+1} - \text{Hab}_{t+1}) (1 + g_{t+1}^k)} (r_{t+1}^k + q_{t+1} (1 - \delta)) \right) = \frac{1}{D_t - \text{Hab}_{t-1}} q_t
\]

(51)

\[
\frac{1}{D_t - \text{Hab}_{t-1}} q_t \left[ \left( 1 - \frac{\kappa}{2} \left( \frac{R_t}{R_{t-1}} (1 + g_{t+1}^k) (1 + g_t^k) \right)^2 \right) - \frac{R_t}{R_{t-1}} \kappa \left( \frac{R_t}{R_{t-1}} (1 + g_{t+1}^k) - (1 + g_t^k) \right) \right]
\]

(52)

\[
+ \beta E_t \left[ \frac{1}{D_{t+1} - \text{Hab}_{t+1}} q_{t+1} \left( \frac{R_{t+1}}{R_t} (1 + g_{t+1}^k) \right)^2 \kappa \left( \frac{R_{t+1}}{R_t} (1 + g_{t+1}^k) - (1 + g_t^k) \right) \right] = \frac{1}{D_t - \text{Hab}_{t-1}}
\]

From (3) we have

\[
g_{t+1}^k = -\delta + R_t \left( 1 - \frac{\kappa}{2} \left( \frac{R_t}{R_{t-1}} (1 + g_t^k) - (1 + g_t^k) \right)^2 \right)
\]

(53)
The rental on capital becomes:

\[ \tau^k_t = \alpha mc_t (F_t - H_t n^*) \]  

(54)

Substituting (54) into (32) and multiplying by \( \frac{K_{t-\alpha}^{\alpha}}{K_{t-\alpha}} \) yields

\[ mc_t = \frac{(F_t - H_t n^*)^{\frac{1}{1-\alpha}} H_t}{X} \]  

(55)

where \( X = A^{1-\alpha} (1 - \alpha) \phi_1 \).

The wage setting function \( \ln w_t = \ln w_{t-1} + a + b (n_t - \bar{n}) + c \log \left( \frac{w_{t-1}(n_{t-1} - \bar{n} - n^*)}{y_{t-1}} \right) \)

(56)

can be rewritten as (using equation (31)) \( \ln H_t = a + b (n_t - \bar{n}) + \ln \left( \frac{H_{t-1}}{1 + g_t^k} \right) + c \log ((1 - \alpha) mc_{t-1}) \)

\[ H_t = \exp(a + b (n_t - \bar{n})) \cdot \frac{H_{t-1}}{1 + g_t^k} \cdot (1 - \alpha) mc_{t-1} \]  

Employment: from \( Output_t = AK_t((n_t - \bar{n} - n^*) \phi_1)^{1-\alpha} + wt n^* \), we have

\[ F_t = A((n_t - \bar{n} - n^*) \phi_1)^{1-\alpha} + H_t n^* \]  

(57)

The Phillips Curve and the Policy rule do not contain any trended variables and therefore does not need to be normalised. However, we will substitute the real profits stochastic discount factor by its definition, i.e. \( \rho_{t+1} = \beta \frac{\phi'(C_{t+1} - Hab_t)}{\phi'(C_{t+1} - Hab_t)} = \beta \frac{C_{t+1} - Hab_t}{C_{t+1} - Hab_t} \),

which gives

\[ (1 - \theta) + \theta mc_t - \varphi \left( \left( \frac{P_t}{P_{t-1}} - u_t \right) - \frac{P_{t-1}}{P_{t-2}} \right) \left( \frac{P_t}{P_{t-1}} - u_t \right) + \theta \frac{\varphi}{2} \left( \frac{P_t}{P_{t-1}} - u_t \right) - \frac{P_{t-1}}{P_{t-2}} \]  

(58)

\[ + \frac{\beta D_t - Hab_{t-1}}{F_t} \varphi E_t \left[ \frac{F_{t+1}}{D_{t+1} - Hab_t} \left( \frac{P_{t+1}}{P_t} - \left( \frac{P_t}{P_{t-1}} - u_t \right) \right) \right] = 0 \]  

(59)

Replacing \( \frac{P_{t+1}}{P_{t+1} + \pi_{t+1}} = 1 + \pi_{t+1} \) gives

\[ (1 - \theta) + \theta mc_t - \varphi ((\pi_t - u_t) - \pi_{t-1}) (1 + \pi_t - u_t) + \theta \frac{\varphi}{2} ((\pi_t - u_t) - \pi_{t-1})^2 \]  

(60)

\[ + \frac{\beta D_t - Hab_{t-1}}{F_t} \varphi E_t \left[ \frac{F_{t+1}}{D_{t+1} - Hab_t} ((\pi_{t+1} - (\pi_t - u_t)) (1 + \pi_{t+1}) \right] = 0 \]  

(61)

37
For natural output, natural employment and the natural real wage from equation

\[
\mu^{-1} = \frac{(F^m_t)^{\frac{n}{c}} H^n_t}{X} 
\]

\[
F_t^n = A_t((n^n_t - \bar{n} - n^s) \phi_1)^{1-\alpha} + n^n H^n_t 
\]

\[
H^n_t = \exp(a + b(n^n_t - \bar{n})) \frac{H_{t-1}}{(1 + g_t^k)} ((1 - \alpha) mc_{t-1})^c 
\]

given last periods wage/capital ratio \(H_{t-1}\) and this periods capital stock growth rate \(g_t^k\) (which was also determined in the t-1 by the then investment decision). The output gap \(gp_t\) is then calculated as

\[
gp_t = \frac{Output_t - Output^n_t}{Output^n_t} \left( \frac{K_t}{K^n_t} \right) = \frac{F_t - F^n_t}{F^n_t} 
\]

9 Appendix C: Steady State Relations

This Appendix shows how to calculate the steady state values for the system developed in Appendix B. We will first derive a steady state relation between the level of employment and the steady state growth rate for the New Growth Economy.

First apply the fact that in the steady state, \(g_t^k = g\) to (52) which yields \(q = 1\). We then apply this to (51) which yields

\[
\beta (r_t^{k+1} + (1 - \delta)) = (1 + g) 
\]

(65)

In the New Growth economy, we now replace the capital rental with equation (54) and, after using (57) and noting that in the steady state we have \(mc = \mu^{-1}\), arrive at

\[
g = \left[ \beta \left( (1 - \delta) + \alpha \mu^{-1} A ((n - \bar{n} - n^s) \phi_1)^{1-\alpha} \right) \right] - 1 
\]

(66)

This is the steady state growth rate which is borne out by the marginal product of capital in the endogenous growth economy. It is easily verified that it is increasing and concave in employment. It is straightforward to show that in the steady state, the real wage implied by the desired mark-up grows at the same rate as output and the capital stock by using \(mc_t = \mu^{-1}\) and \(r_t^k = r^k\) on (45). This yields

\[
w_t = K_t \phi_1 \left( \frac{\mu^{-1} A \alpha (1-\alpha) (r^k)\overline{\alpha}}{(r^k)^\overline{\alpha}} \right)^{1/(1-\alpha)} 
\]

(67)

Hence in the steady state, the real wage has to grow at the same rate as the capital stock. This means that equation (67) actually the dynamic, endogenous growth version of the familiar macroeconomic textbook price setting function: It gives the real wage growth rate compatible with marginal costs remaining constant and at it’s
long run level. Unlike the textbook price setting function, this real wage growth rate
is not constant but increases in employment: A higher steady state employment level
implies a higher marginal product of capital, which triggers higher investment and
thus faster capital stock- and thus productivity growth. Accordingly, the steady state
levels of employment an the growth rate are determined by the intersection of (66)
with the wage setting function (35), (making again use of the fact that $mc = \mu^{-1}$ in
the steady state).

In practice, we choose a desired steady state employment rate (here 0.96) and
then compute the wage setting function intercept $a$ to support this value, given $g$, $b$
and $\alpha$ and $\pi$.

Having determined $g$ and $n$, the determination of the steady state values of
$F_t, D_t, R_t, H_t, r_t^k$ and $i_t$ is now straightforward. For $F$ we have

$$F = A((n - \pi - n^s) \phi_1)^{1-\alpha}$$

(68)

from the production function. For $R_t$, we have from the capital accumulation equation
in (53)

$$R = g + \delta$$

(69)

$D$ can then be determined as a residual via

$$D = F - R$$

(70)

$H$ is computed using the cost-minimisation first order condition for labour (31)

$$H = (1 - \alpha)\mu^{-1} \frac{F}{n - \pi - n^s}$$

(71)

$r^k$ is computed via

$$r^k = \alpha \mu^{-1} A((n - \pi - n^s) \phi_1)^{1-\alpha}$$

(72)

The steady state value of $i_t$ is computed from (49)

$$i = \frac{1 + g}{\beta} - 1$$

(73)

Note that this is also the intercept of the interest rate rule $\bar{i}$ of the central bank.

10 Appendix D: Normalised Version of the JLN
Economy

Most of the equations from Appendix B just carry over to the JLN economy. However,
there are a few changes related to the production function and the marginal cost equa-
tion. The aggregate production function is now $Output_t = AK_t^\alpha (TFP_t \phi_1 (n_t - \pi - n^s))^{1-\alpha} +
w_t n^s$. Dividing both sides by $K_t$ gives

$$F_t = (l_t \phi_1 (n_t - \pi - n^s))^{1-\alpha} + H_t n^s$$

(74)
where \( l_t \) is defined as \( \frac{TPF}{K_t} \). This variable evolves according to

\[
l_t = \frac{1 + g_{TFP} l_{t-1}}{1 + g_t^K l_{t-1}}
\]  

(75)

In the JLN model, it is convenient to normalise the real wage with respect to \( TFP_t \) rather than with respect to \( K_t \), while all the remaining normalisations carry over to the JLN model. Denoting \( \frac{\bar{w}_t}{TFP_t} \) as \( H_t^nc \), we have from (10), after making use of (8)

\[
m_c = \frac{F_t^{(\alpha/(1-\alpha))} H_t^{nc}}{A^{1/(1-\alpha)} (1 - \alpha) \phi_1}
\]  

(76)

Concerning the capital rental, we employ the JLN expression for \( F_t \) to have

\[
r_t^k = \alpha m_c A l_t^{1-\alpha} \left( (n_t - \overline{n} - n^*) \phi_1 \right)^{1-\alpha}
\]  

(77)

The normalised wage setting equation becomes

\[
H_t^{nc} = \exp(a + b(n_t - \overline{n})) \frac{H_{t-1}^{nc}}{(1 + g_{TFP})} ((1 - \alpha) m_{c-1})^c
\]  

(78)

All the remaining equations are just the same as in the New Growth version. The computation of the steady state values in the neoclassical model is slightly different. The steady state growth rate (of output, consumption, the capital stock, the real wage) is now given by the parameter \( g_{TFP} \) rather than being endogenously determined, which means we have \( g = g_{TFP} \). Hence we can compute the steady state real interest rate from (73), while we compute \( r^k \) from (65). From (78), we have the steady state employment rate. Setting \( m_c = \mu^{-1} \ln \) in (77) then gives the steady state value for \( l_t \) as

\[
l = \left( \frac{1}{(n_t - \overline{n} - n^*) \phi_1} \left( \frac{r^k \mu}{\alpha A} \right)^{1/(1-\alpha)} \right)
\]  

(79)

which allows us to compute \( F \) from (74). Rearranging (76) then yields \( H^{nc} \).

11 Appendix E: Estimation of the Wage Setting Function

We estimate the real wage growth function using German data ranging from 1970Q1 to 2000Q4. Our dataset includes Western German data up to 1991Q4 and following that data for the unified country. All data is taken from a publication of the German "Statistisches Bundesamt", all of which has been seasonally adjusted.\(^{35}\) When estimating the function, we replace the employment rate with one minus the unemployment rate. As a measure for labour costs, we use the "Arbeitnehmerentgelt" per hour

\(^{35}\)See Statistisches Bundesamt (2006a) and Statistisches Bundesamt (2007a).
worked, which is employee compensation including the full tax wedge. This is deflated using the GDP price index. The labour share is given by total nominal compensation (i.e. total "Arbeitnehmerentgeld") divided by total nominal GDP. Denoting the unemployment rate as $U$, we then estimate $\Delta \log w_t = a + b*U_t + c \log (LS_{t-1}) + d92Q1$, where $LS_{t-1}$ denotes the previous period’s labour share in GDP, $d92Q1$ denotes an intercept dummy equalling one in 1992Q1 and zero everywhere else. The later is to account for reunification. We use two-stage least squares to account for the possible endogeneity of employment. As instruments, we choose $\Delta \log \text{real wage}_{t-1}, U_{t-1}$ (following Danthine and Kurman (2004)), $c$ and $d92Q1$.36

Note that we use Newey-West Standard Errors serial correlation consistent standard errors because the Breusch-Godfrey LM test for serial correlation rejects the hypotheses of no serial correlation at the 5% level. The result is reported in table E1, where WG denotes the change in log real wages and $U$ denotes the unemployment rate.

**Table E1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.042273</td>
<td>0.018893</td>
<td>-2.237531</td>
<td>0.0271</td>
</tr>
<tr>
<td>U</td>
<td>-0.120587</td>
<td>0.046582</td>
<td>-2.588689</td>
<td>0.0108</td>
</tr>
<tr>
<td>LOG(LS(-1))</td>
<td>-0.089599</td>
<td>0.032530</td>
<td>-2.754342</td>
<td>0.0068</td>
</tr>
<tr>
<td>D92Q1</td>
<td>-0.112300</td>
<td>0.002188</td>
<td>-51.33630</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared 0.574362  Mean dependent var 0.005890
Adjusted R-squared 0.563541  S.D. dependent var 0.014077
S.E. of regression 0.009300  Sum squared resid 0.010205
F-statistic 52.46032  Durbin-Watson stat 2.535359
Prob(F-statistic) 0.000000

Note that our calibrated value of $b$ is lower than the point estimate of 0.12. However, it is not statistically different from 0.12 with any reasonable level of confidence, in fact it is less than one standard deviation away from the point estimate. The reason for this choice is that while it is possible to preserve the results of this paper in face of higher wage flexibility, this calibration has certain undesirable features. If we aim to achieve a steady growth rate of GDP in the order of magnitude of a reasonable order of magnitude (and one that makes lifetime utility converge), we would have to choose either relatively high depreciation rates or a lower individual discount factor

$\beta$, the later implying a very high steady state risk less rate. We think that these considerations justify the choice of a value smaller than the point estimate.

The reason why the coefficient of the labour share $c$ also falls short of the calibrated coefficient, though the distance is again less than one standard deviation. This is due to the fact that we have experimented with different computations of the labour share in GDP. The alternative computation was based on real values of GDP and employee compensation. The later computations methods generated a value of -0.12 than the -0.1 we use in the simulations. It is not a priori clear which measure is more appropriate. In fact to is common to interpret the labour share term as real wages divided by productivity (i.e. real GDP/hour or real GDP/employee) and enter these variables separately.\textsuperscript{37} Furthermore, a reduction of $c$ by 0.01 has only small effects on our simulation results.

References


43


[28] Juillard, M. (1996), Dynare: A program for the resolution of and simulation of dynamic models with forward variables through the use of relaxation algorithm, CEPRMAP.


ABOUT THE CDMA

The Centre for Dynamic Macroeconomic Analysis was established by a direct grant from the University of St Andrews in 2003. The Centre funds PhD students and facilitates a programme of research centred on macroeconomic theory and policy. The Centre has research interests in areas such as: characterising the key stylised facts of the business cycle; constructing theoretical models that can match these business cycles; using theoretical models to understand the normative and positive aspects of the macroeconomic policymakers’ stabilisation problem, in both open and closed economies; understanding the conduct of monetary/macroeconomic policy in the UK and other countries; analyzing the impact of globalization and policy reform on the macroeconomy; and analyzing the impact of financial factors on the long-run growth of the UK economy, from both an historical and a theoretical perspective. The Centre also has interests in developing numerical techniques for analyzing dynamic stochastic general equilibrium models. Its affiliated members are Faculty members at St Andrews and elsewhere with interests in the broad area of dynamic macroeconomics. Its international Advisory Board comprises a group of leading macroeconomists and, ex officio, the University’s Principal.

Affiliated Members of the School

Dr Fabio Aricò.
Dr Arnab Bhattacharjee.
Dr Tatiana Damjanovic.
Dr Vladislav Damjanovic.
Prof George Evans.
Dr Gonzalo Forgue-Puccio.
Dr Laurence Laselle.
Dr Peter Macmillan.
Prof Rod McCrorie.
Prof Kaushik Mitra.
Prof Charles Nolan (Director).
Dr Geetha Selvaretnam.
Dr Oezg Senay.
Dr Gary Shea.
Prof Alan Sutherland.
Dr Kannika Thampanishvong.
Dr Christoph Thoenissen.
Dr Alex Trew.

Senior Research Fellow

Prof Andrew Hughes Hallett, Professor of Economics, Vanderbilt University.

Research Affiliates

Prof Keith Blackburn, Manchester University.
Prof David Colsham, Heriot-Watt University.
Dr Luisa Corrado, Università degli Studi di Roma.
Prof Huw Dixon, Cardiff University.
Dr Anthony Garratt, Birkbeck College London.
Dr Sugata Ghosh, Brunel University.
Dr Aditya Goenka, Essex University.
Prof Campbell Leith, Glasgow University.
Prof Paul Levine, University of Surrey.
Dr Richard Mash, New College, Oxford.
Prof Patrick Minford, Cardiff Business School.
Dr Gulcin Ozkan, York University.
Prof Joe Pearlman, London Metropolitan University.

Research Associates

Prof Neil Rankin, Warwick University.
Prof Lucio Sarno, Warwick University.
Prof Eric Schaling, South African Reserve Bank and Tilburg University.
Prof Peter N. Smith, York University.
Dr Frank Smets, European Central Bank.
Prof Robert Sollis, Newcastle University.
Prof Peter Tinsley, Birkbeck College, London.
Dr Mark Weder, University of Adelaide.
Mr Nikola Bokan.
Mr Farid Boumediene.
Mr Johannes Geissler.
Mr Michal Horvath.
Ms Elisa Newby.
Mr Angar Rannenberg.
Mr Qi Sun.

Advisory Board

Prof Sumru Altug, Koç University.
Prof V V Chari, Minnesota University.
Prof John Driffill, Birkbeck College London.
Dr Sean Holly, Director of the Department of Applied Economics, Cambridge University.
Prof Seppo Honkapohja, Bank of Finland and Cambridge University.
Dr Brian Lang, Principal of St Andrews University.
Prof Anton Muscatelli, Heriot-Watt University.
Prof Charles Nolan, St Andrews University.
Prof Peter Sinclair, Birmingham University and Bank of England.
Prof Stephen J Turnovsky, Washington University.
Dr Martin Weale, CBE, Director of the National Institute of Economic and Social Research.
Prof Michael Wickens, York University.
Prof Simon Wren-Lewis, Oxford University.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDMA07/10</td>
<td>Optimal Sovereign Debt Write-downs</td>
<td>Sayantan Ghosal (Warwick) and Kannika Thampanishvong (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/11</td>
<td>Bargaining, Moral Hazard and Sovereign Debt Crisis</td>
<td>Sayantan Ghosal (Warwick) and Kannika Thampanishvong (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/12</td>
<td>Efficiency, Depth and Growth: Quantitative Implications of Finance and Growth Theory</td>
<td>Alex Trew (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/13</td>
<td>Macroeconomic Conditions and Business Exit: Determinants of Failures and Acquisitions of UK Firms</td>
<td>Arnab Bhattacharjee (St Andrews), Chris Higson (London Business School), Sean Holly (Cambridge), Paul Kattuman (Cambridge).</td>
</tr>
<tr>
<td>CDMA07/14</td>
<td>Regulation of Reserves and Interest Rates in a Model of Bank Runs</td>
<td>Geethanjali Selvaretnam (St Andrews).</td>
</tr>
<tr>
<td>CDMA07/15</td>
<td>Interest Rate Rules and Welfare in Open Economies</td>
<td>Ozge Senay (St Andrews).</td>
</tr>
<tr>
<td>CDMA07/16</td>
<td>Arbitrage and Simple Financial Market Efficiency during the South Sea Bubble: A Comparative Study of the Royal African and South Sea Companies Subscription Share Issues</td>
<td>Gary S. Shea (St Andrews).</td>
</tr>
<tr>
<td>CDMA07/17</td>
<td>Anticipated Fiscal Policy and Adaptive Learning</td>
<td>George Evans (Oregon and St Andrews), Seppo Honkapohja (Cambridge) and Kaushik Mitra (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/18</td>
<td>The Millennium Development Goals and Sovereign Debt Write-downs</td>
<td>Sayantan Ghosal (Warwick), Kannika Thampanishvong (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/19</td>
<td>Robust Learning Stability with Operational Monetary Policy Rules</td>
<td>George Evans (Oregon and St Andrews), Seppo Honkapohja (Cambridge)</td>
</tr>
<tr>
<td>CDMA07/20</td>
<td>Can macroeconomic variables explain long term stock market movements? A comparison of the US and Japan</td>
<td>Andreas Humpe (St Andrews) and Peter Macmillan (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/21</td>
<td>Unconditionally Optimal Monetary Policy</td>
<td>Tatiana Damjanovic (St Andrews), Vladislav Damjanovic (St Andrews) and Charles Nolan (St Andrews)</td>
</tr>
<tr>
<td>CDMA07/22</td>
<td>Estimating DSGE Models under Partial Information</td>
<td>Paul Levine (Surrey), Joseph Pearlman (London Metropolitan) and George Perendia (London Metropolitan)</td>
</tr>
<tr>
<td>CDMA08/01</td>
<td>Simple Monetary-Fiscal Targeting Rules</td>
<td>Michal Horvath (St Andrews)</td>
</tr>
<tr>
<td>CDMA08/02</td>
<td>Expectations, Learning and Monetary Policy: An Overview of Recent Research</td>
<td>George Evans (Oregon and St Andrews), Seppo Honkapohja (Bank of Finland and Cambridge)</td>
</tr>
<tr>
<td>CDMA08/03</td>
<td>Exchange rate dynamics, asset market structure and the role of the trade elasticity</td>
<td>Christoph Thoenissen (St Andrews)</td>
</tr>
<tr>
<td>CDMA08/04</td>
<td>Linear-Quadratic Approximation to Unconditionally Optimal Policy: The Distorted Steady-State</td>
<td>Tatiana Damjanovic (St Andrews), Vladislav Damjanovic (St Andrews) and Charles Nolan (St Andrews)</td>
</tr>
<tr>
<td>CDMA08/05</td>
<td>Does Government Spending Optimally Crowd in Private Consumption?</td>
<td>Michal Horvath (St Andrews)</td>
</tr>
<tr>
<td>CDMA08/06</td>
<td>Long-Term Growth and Short-Term Volatility: The Labour Market Nexus</td>
<td>Barbara Annicchiarico (Rome), Luisa Corrado (Cambridge and Rome) and Alessandra Pelloni (Rome)</td>
</tr>
<tr>
<td>CDMA08/07</td>
<td>Seignioprage-maximizing inflation</td>
<td>Tatiana Damjanovic (St Andrews) and Charles Nolan (St Andrews)</td>
</tr>
<tr>
<td>CDMA08/08</td>
<td>Productivity, Preferences and UIP deviations in an Open Economy Business Cycle Model</td>
<td>Arnab Bhattacharjee (St Andrews), Jagiit S. Chadha (Canterbury) and Qi Sun (St Andrews)</td>
</tr>
<tr>
<td>CDMA08/09</td>
<td>Infrastructure Finance and Industrial Takeoff in the United Kingdom</td>
<td>Alex Trew (St Andrews)</td>
</tr>
</tbody>
</table>

For information or copies of working papers in this series, or to subscribe to email notification, contact:

Johannes Geissler  
Castlecliffe, School of Economics and Finance  
University of St Andrews  
Fife, UK, KY16 9AL  
Email: ig374@st-andrews.ac.uk; Phone: +44 (0)1334 462445; Fax: +44 (0)1334 462444.