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Abstract

Unemployment in the big continental European economies like France and Germany has been substantially increasing since the mid 1970s. So far it has been difficult to empirically explain the increase in unemployment in these countries via changes in supposedly employment unfriendly institutions like the generosity and duration of unemployment benefits. At the same time, there is some evidence produced by Ball (1996, 1999) saying that tight monetary policy during the disinflations of the 1980s caused a subsequent increase in the NAIRU, and that there is a relationship between the increase in the NAIRU and the size of the disinflation during that period across advanced OECD economies. There is also mounting evidence suggesting a role of the slowdown in productivity growth, e.g. Nickell et al. (2005), IMF (2003), Blanchard and Wolfers (2000).

This paper introduces endogenous growth into an otherwise standard New Keynesian model with capital accumulation and unemployment. We subject the model to a cost push shock lasting for 1 quarter, 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 a standard interest feedback rule calibrated to an estimate of a Bundesbank reaction function. About 40 quarters after the shock has vanished, unemployment is still about 1.7 percentage points above its steady state, while annual productivity growth has decreased. Over a similar horizon, a higher weight on the output gap increases employment (i.e. reduces the fall in employment below its steady state). Thus the model generates an increase in unemployment following a disinflation without relying on a change to labour market structure.

We are also able to coarsely reproduce cross country differences in unemployment. A higher disinflation generated by a larger cost push shock causes a stronger persistent increase in unemployment, the correlation noted by Ball. For a given cost push shock, a policy rule estimated for the Bundesbank produces stronger persistent increase in unemployment than a policy rule estimated for the Federal Reserve. Testable differences in real wage rigidity between continental Europe and the United States, namely the presence of the labour share in the wage setting function for Europe with a negative coefficient but it's absence in the U.S. also imply different unemployment outcomes following a cost push shock: If the real wage does not depend on the labour share, the persistent increase in unemployment is about one percentage point smaller than in it's presence. To the extent that the wage setting structure is due to labour market rigidities, "Shocks and Institutions" jointly determine the unemployment outcome, as suggested by Blanchard and Wolfers (2000).

We also perform a comparison of the second moments of key variables of the model with German data for a period ranging from 1970 to 1990. We find that it matches the data better than a model without endogenous growth but with otherwise identical

features. This is particularly true for the persistence in employment as measured by first and higher order autocorrelation coefficients.

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Contents

1 Introduction

> "Short-run macroeconomics and long-run growth theory have never been properly integrated. It is only a slight caricature to say that once upon a time the long run was treated casually as forward extension of the short run, whereas nowadays the tendency is to treat the short run casually as a backward extension of the long-run."
>
> Robert M. Solow/Athanasios Orphanides (1990).[1]

One of the most widespread beliefs in mainstream macroeconomic theory is the separation of short- and long run analysis. While aggregate demand may cause temporary output fluctuations, output ultimately returns to potential as prices adjust. What is more, potential output itself and the "non-accelerating-inflation-rate-of-unemployment" (NAIRU) are not affected. Accordingly, unemployment depends only on the institutions affecting the wage setting power of employees and the price setting power of firms, like the duration and generosity of unemployment benefits, union membership or product market competition. By contrast, monetary policy has only a short run effect on unemployment.

Labour market economists have applied this framework to the steady rise in continental European unemployment since the 1970s. They tried to estimate the effects of changes in labour market institutions. The results have not been entirely conclusive. At the outset, labour economist where encouraged by the fact that labour market rigidities seem to be able to explain why unemployment is so much lower in the flexible labour market of the United States, than in Europe. However, as it comes to the evolution of European unemployment over time, Blanchard notes that "explanations based solely on institutions also run into a major empirical problem: Many of these institutions where already present when unemployment was low, and, while many became more employment-unfriendly in the 1970s, the movement since then has been largely in the opposite direction."[2]

At the same time, Ball (1996, 1999) has produced evidence which links part of the increase in the NAIRU to a desire to disinflate the economy and more hawkish conduct of monetary policy in Europe as opposed to the United States. Furthermore, in many countries, the increase in the NAIRU has been accompanied by a substantial slowdown in productivity growth. Early on Bruno and Sachs (1982) and more recently Blanchard and Wolfers (2000), Fitoussi et. al. (2000), the IMF (2003) and Nickel et. al.(2005) have produced evidence for a statistically significant relationship between the two.

[1] Solow/ Orphanides (1990), p. 258.

[2] Blanchard/ Wolfers (2000), p. C2. He recently somewhat qualified that statement by suggesting the problem might not lie with the story but with the crude measurement of labour market institutions, see Blanchard (2005), p. 417. This is by now means a new idea and does not materially change the problems the empirical literature on labour market institutions and unemployment has run into.

As an exception among macroeconomists, Blanchard (2000, 1998) suggested a role for monetary policy, arguing that the implementation of high real interest rates by European central banks in the 1980s in order to reduce inflation required the marginal product of capital to increase. The subsequent decline of the capital labour ratio would reduce the marginal product of labour. If real wages are rigid, unemployment has to rise to implement the corresponding decline in real wages.[3] However, while long-term real interest rates indeed did rise in the 1980s, they have declined in the second half of the 1990s. They are now at about the level they had been at the end of the 60s, while unemployment in the big European economies remains stubbornly high.

This paper contributes to the explanation of this evidence -the rise in the NAIRU, the slowdown in productivity growth and Ball's evidence on the impact of disinflations on the NAIRU- by introducing endogenous growth into a New Keynesian model featuring unemployment. We implement this in a very simple fashion by assuming that technological progress is realised through investment and thus linking total factor productivity to the capital stock. We subject the economy to a 1 quarter temporary cost-push shock and let the central bank disinflate - as happened in many industrialised economies at the beginning of the 1980s. It turns out the employment effects can indeed be quite persistent and that unemployment might remain below its steady state value by more than 1 percentage point for more than 10 years, associated with stable inflation: the NAIRU increases. A fall in the productivity growth rate caused by a fall in investment depresses the real wage growth rate consistent with stable inflation, which, with real wage growth being rigid, requires higher unemployment.

Our results resemble those of Sargent and Ljungqvist 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.[4] However, their approach differs from ours in that in their model, unemployment increase 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 looses 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.

The paper is structured as follows: Sections 2 to 4 are some brief discussions of the evidence highlighted above, namely on the role of labour market institutions (section 2), the role of productivity growth (section 3) and monetary policy (section

[3] See Blanchard (1998), pp. 5-18 and Blanchard (2000), pp. 2-15, and also Bean (1997), p. 95.

[4] See Sargent and Ljungqvist (1998) and (2007).

4) in explaining unemployment. Section 5 develops a model which coarsely encompasses the mainstream consensus on the relationship between monetary policy and unemployment sketched above, which we coin "Jackman, Layard, Nickell", or JLN economy, and then add the New Growth extension whose consequences we want to investigate in this paper. Section 6 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 in German data, while Section 7 presents a more complete moment comparison. Section 8 then discusses the response to the economy of a one quarter cost push shock calibrated to induce a disinflation of about 4 percentage points. We also conduct a couple of robustness experiments in that section: We vary the output gap coefficient in the central banks reaction function and summarise the trade-off which policymakers face by computing medium run average unemployment rates and NAIRUs and the resulting Phillips Curves are downwards sloping. Furthermore, we check the robustness of our results against changes in real wage rigidity and the slope of capital stock adjustment costs. While section 8 thus aims at establishing that our model can produce a persistent increase increase in unemployment following a one quarter cost push shock, section 9 aims to add a cross country dimension to our analysis in three different ways. First, we vary the size of the cost push shock and record the resulting changes in Inflation and the NAIRU over 10 year horizon, then we compare the differences in the unemployment response generated by Bundesbank and a Federal Reserve Policy rule as estimated by Clarida, Gali and Gertler (1998), and thirdly we investigate the effects differences in real wage rigidity between Europe and the United States. Section 9 concludes.

2 Tests of the Institutional Approach

There have been various attempts to provide evidence for the institutional hypotheses. Most often these attempts consist of regressing unemployment on (indicators of) the institutional variables like the duration and generosity of unemployment benefits, employment protection. This approach runs into problems when trying to explain the dynamics of unemployment. A recent IMF (2003) study over a period from 1965 to 1998 concluded that institutions "hardly account for the growing trend observed in most European countries and the dramatic fall in U.S. unemployment in the 90's": The part of the unemployment rate not explained by institutions increases over time.[5] Similarly, Blanchard and Wolfers (2000) noted that "while labour market institutions can possibly explain cross country differences today, they do not appear to able to explain the general evolution of unemployment over time."[6] Furthermore, it turns out that institutions are especially weak in explaining the evolution of unemploy-

[5] IMF (2003), p. 134.

[6] See Blanchard/ Wolfers (2000), p. C2.

ment in Germany and France, which are most often cited as examples of "sclerotic" economies.[7]

A study by Nickell (2002, 2005) covering about the same time period reveals similar problems in that institutions explain virtually nothing for Western Germany and Finland and only a minor part of the unemployment increase in Spain and New Zealand. Substantial movements of unemployment are left unexplained for Ireland, France, the UK and Italy.[8] The explanatory power of both the Nickell et al and the IMF regressions rely on including lagged unemployment in the regression, with coefficients of 0.79 (IMF) and 0.87 (Nickell et al) respectively. In the words of Nickell et al,: "This reflects a high level of persistence and/or the inability of the included variables to explain what is going on."[9] A study by Elmeskov et al. (1998) confirms this impression. They ask how much of the change in structural rather than actual unemployment is accounted for by institutional changes, and how much is due to a country specific effect.[10] The country specific effect explains most of the change in structural unemployment in almost every country.[11]

Furthermore, the results from estimations of specifications of the above kind are not very robust. Baker et. al survey six recent papers[12] and find that the estimated effects of changes to the tax wedge, benefit duration and the replacement rate vary quite substantially: For instance, the effect of an increase in benefit duration by one year ranges from 0.7% to 1.4%.[13] Baker et.al. also report that an earlier version of the Nickell et al paper covering a period shorter by three years produced estimates which were very different from the final version, implying that Nickell et al's results are apparently very sensitive to the inclusion of additional data.[14] Finally, Belot/ van Ours (2004) find that the significance of institutional variables is extremely sensitive to the inclusion of time and country fixed effects.[15]

One of the crucial the underlying assumptions of panel data regressions of unemployment on labour market institution is that labour market institutions are exogenous and are not affected by those force which are affecting unemployment or by unemployment itself. This assumption might for instance be violated with respect to the tax wedge, as rising unemployment increases expenditures on transfers and erodes the tax base. The problem is sometimes mentioned but is not addressed, and rarely tested for.[16] The Elmeskov et a. (1998) study argues that causality could run

[7] See IMF (2003), pp. 138-141.

[8] See Nickell (2002), pp. 44-45.

[9] See Nickel et al (2005), p. 15.

[10] See Elmeskov et. al (1998). This paper was part of the research following up the Job study.

[11] See Elmeskov et. al (1998), p. 220, Table 3a.

[12] (Nickel 1997, Elmeskov et al 1998, Belot/van ours 2002, Nickel et al 2002, Blanchard/Wolfers 2000, Bertola et. al. 2001)

[13] See Baker et al (2002), pp.43-44.

[14] See Baker et. al (2003), p. 35.

[15] See Belot/Van Ours (2004), p. 635.

[16] See for instance Nickell et al (2002), p.2, or IMF (2003). See also Blanchard (2007), p. 415.

both ways in case of benefit generosity and the tax wedge. Unemployment Granger causes benefit generosity in Belgium, France, Italy, the UK, the United States and the Netherlands, while it Granger causes unemployment in Austria, Ireland and Norway.[17]

3 Productivity Growth and Unemployment

There is plenty of evidence that changes in productivity growth affect unemployment using various approaches. An early example are Bruno and Sachs (1982), who argue that a labour productivity slowdown which was unanticipated by workers wage demands caused unemployment in British manufacturing to increase.[18] Productivity growth or total factor productivity growth are sometimes controlled for in regressions aiming to assess the impact of labour market institutions. For instance, in the IMF study cited above, a one p.p. reduction in productivity growth increases unemployment by 0.32 percentage points, while the Nickel et al study cited above finds that a 1 percentage point decrease in total factor productivity (TFP) growth causes a 1.28 p.p. increase in unemployment. Fitoussi et al. (2000) test for the role of productivity growth and other shocks, the effects of which are allowed to vary across countries. For Germany, the equation predicts that one percentage point reduction in productivity growth would cause a 0.79 percentage point increase in unemployment, while for France, Italy or Spain the effect would be as high as 1.6, 1.22 or 2.22 p.p.[19] Ball and Moffitt (2001) use a Phillips Curve based approach and argue that differences between workers wage aspirations and productivity growth can explain the non-inflationary unemployment reduction in the United States in the 1990s.[20] Pissarides and Vallanti (2005) uses a multi equation approach to investigate the effects of a productivity slowdown and find an (implied effect) of a 1 percentage point reduction in TFP growth on unemployment of 1.31 percentage point in the EU.[21]

Blanchard and Wolfers (2000) estimate a specification which explicitly models the interactions of shocks and institutions, i.e. institutional variable effectively become part of the coefficient on the shocks. The shocks include TFP growth, the long run real interest rate and a measure of labour demand, while the institutions considered are the replacement rate as measured in Nickell (1997), benefit duration (in years), employment protection (simple ranking from 1 to 20), the tax wedge as in Nickell et al (2002) and measures of union contract coverage, union density and bargaining coordination.[22] Both shocks and institutions are significant, though concerning the later this finding is not robust against variations in the way the variables are mea-

[17] See Elmeskov et. al. (1998), pp. 248-249.
[18] See Bruno/ Sachs (1982), p. 700/701.
[19] See Fitoussi et al (2000), pp. 247 to 250.
[20] Ball and Moffit (2001).
[21] See Pissarides and Vallanti (2005), p.20, table 4.
[22] See Blanchard/Wolfers (2001), p. C19.

sured.[23] A one percentage point reduction in TFP growth increases unemployment by 0.71 p.p. if institutions are at the sample average. More employment unfriendly institutions cause the shock to have higher effects, so that the model can explain both cross country differences and the evolution of unemployment over time.

In this paper we will develop a model generating a slowdown in productivity growth endogenously via a slowdown in capital stock growth, which will then in turn increase unemployment.

4 Monetary Policy and the NAIRU

Ball argues the change in the NAIRU during the 1980s can be explained by the monetary policy stance. He measures the stance of policy during that period indirectly by the behaviour of inflation (Ball (1996)), and directly by examining the evolution of real interest rates (Ball(1999)) during the recessions at the beginning of the 1980s. In the first paper, Ball employs two measures of inflation dynamics: The size of the disinflation from 1980 to 1990 and the length of the longest disinflation during that period. Those matter because the former is related to the size of the unemployment increase, while the latter indicates for how long the actual unemployment rate exceeded the NAIRU.

Ball finds that while the length and the size of disinflation explain a substantial share of the increase in the NAIRU over the ten year period, large prediction errors remain. He examines whether interaction between benefit duration and the policy stance does a better job at explaining the rise in the NAIRU. [24] The fit is substantially superior to when the policy variables are not interacted with benefit duration, especially for the change in inflation. [25] Ball then subjects this procedure to a series of robustness experiments, all of which basically confirm the previous results.[26] The correlation between the change in inflation and the change in the NAIRU emphasized by Ball is illustrated in Figure 1, which plots the change in the NAWRU 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 very obvious.[27]

Ball then turns towards the role of monetary as measured by the largest cumulative decrease of short term real interest rates in any part of the recession's first year.[28] He considers two dependent variables: the change in the NAIRU from the peak before the

[23] See Blanchard/Wolfers (2000), p. C31.

[24] See Ball (1996), p. 13. The motivation for the joint role are theories of labour market hysteresis.

[25] Ball (1996), p. 12.

[26] See Ball (1996), pp. 13-15.

[27] The data is taken from the OECD 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.

[28] Ball notes that his dating criterion for recessions yields only two countries with two recessions and thus is stricter than the one used with quarterly data. See Ball (1999), p. 205.

first recession until five years after the peak, and this change divided by the change in actual unemployment over the same time period. The later variable is called degree of hysteresis and accounts for the fact that the severity of recessions and thus the increase in actual unemployment vary over the sample and hence one would observe different increases in the NAIRU even if actual unemployment fed into the NAIRU to the same extent in all countries, i.e. if monetary policy and benefit duration had been the same.[29] Fit is substantially better when the degree of hysteresis is used as a dependent variable, with an adjusted R^2 of 0.62 as opposed to 0.43. Concerning the quantitative impact of the two variables on the degree of hysteresis, "The coefficient on maximum easing implies that raising that variable from 0 to 6 (Sweden's value, the highest in the sample) reduces the degree of hysteresis by 0.54. Reducing the duration of unemployment benefits from indefinite to half a year reduces the degree of hysteresis by 0.35. Thus policymakers can reduce hysteresis through both macroeconomic and labour market policy, and the former has somewhat larger effects."[30] Hence both paper's evidence suggests that monetary policy affect the NAIRU and the more so the more rigid the labour market.

Ball also tries to explain reductions in the NAIRU in OECD countries by referring to the stance of monetary policy relative to the situation of the macro economy, and finds that to some extent, monetary policy can also explain NAIRU reductions.

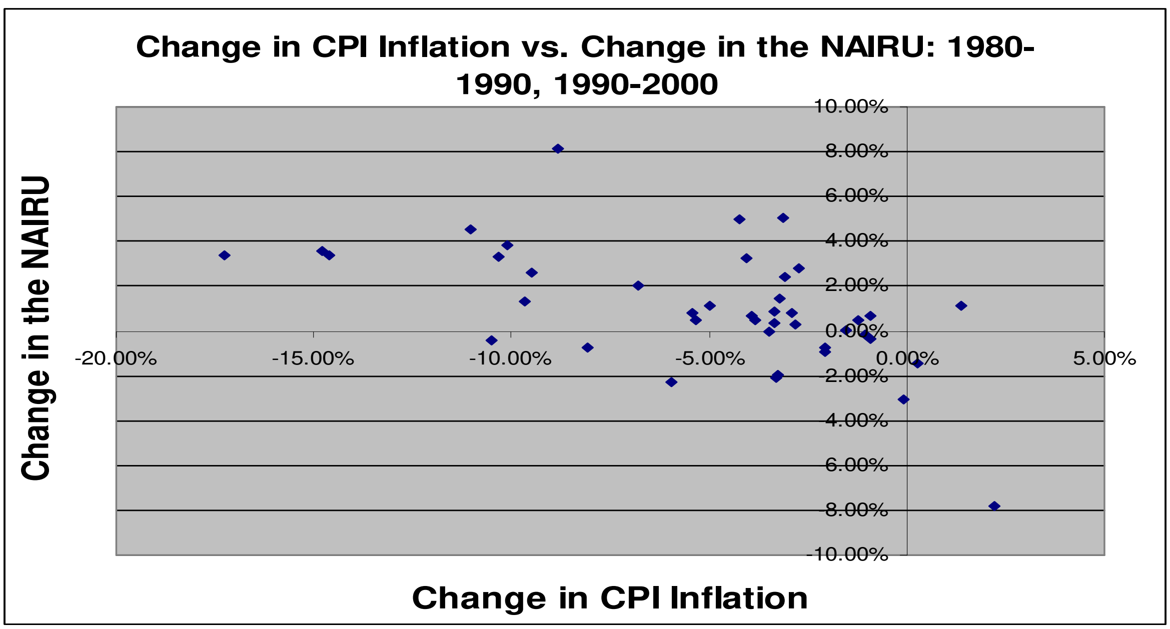

Figure 1

[29]See Ball (1999), p. 205-206.
[30]Ball (1999), p. 207.

5 The Model

While the previous section argues that there exists empirical evidence which links the monetary policy stance to the subsequent evolution of the NAIRU, this section develops a dynamic general equilibrium model which can explain why that might be the case. First, however, we will develop what we consider the starting point of our analysis, a model coarsely incorporating the ruling consensus of the relationship between unemployment and the NAIRU. This consensus has been sketched by Nickell et al as follows:

> First, unemployment in the short-run and in the long-run is determined by real demand. Second, over the long term, real demand d and unemployment generally tend towards the level consistent with stable inflation. This we term equilibrium level. Various possible mechanisms may be at work here. For example, many OECD countries now set monetary policy on the basis of an inflation target which naturally moves real demand and unemployment towards the equilibrium defined above. Third, the equilibrium level of unemployment is affected first, by any variable which influences the ease with which unemployed individuals can be matched to available job vacancies, and second, by any variable which tends to raise wages in a direct fashion despite excess supply in the labour market.[31]

Therefore this section is structured as follows. While 5.1 deals with the household optimisation problem whose first order conditions determine consumption, investment and capital accumulation in our mode in a quite standard fashion, but also the supply of effort which determines the efficiency of a unit of labour. 5.2 then shows how, given this effort function, cost minimisation makes the representative firm pay an efficiency wage. Hence the labour supply condition is replaced by a wage setting function, thus generating unemployment. 5.3 introduces nominal rigidities, thus implying that output is demand determined. Section 5.4 specifies a monetary policy reaction function which sets the interest rate as a function of the deviation of inflation from it's target and the output gap. Section 5.5 discusses how endogenous growth is introduced into the model and how this affects the model's equations derived so far. Section 5.6 summarises the aggregate equations for the convenience of the reader and introduces specific functional forms where that has not been carried out earlier.

5.1 Households

Danthine and Kurmann (2004) show how to introduce unemployment in a general equilibrium model without moving away from the representative agent framework. In

[31] See Nickel et al (2002), p. 2-3. See also Jackman, Layard and Nickel (1993), p. 8-11.

the Danthine-Kurmann setup (later on referred to as "DK"), individuals are organized in families in a zero-one continuum of families which are infinitely lived. All decisions regarding the intertemporal allocation of consumption and the accumulation of capital are made at the family level. Each family member supplies one unit of labour in elastically but derives disutility from the effort $G(e_{t+i})$ 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, whose nature will be described in more detail below. They can be thought of as the owners of the monopolistically competitive firms. Overhead workers never become unemployed because no firm can produce without a certain amount of overhead staff. A share n^s of the workforce will be employed by the government who is assumed to pay the same wages as the private sector who are funded by lump sum taxes.[32] It is assumed that each family has the same amount of overhead workers.

Families solve the following maximisation problem:

$$U = E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[u(C_{t+i} - hab_{t+i-1}) - (n_{t+i} - \overline{n}) G(e_{t+i}) \right] \right\}, u\prime > 0, u\prime\prime < 0. \quad (1)$$

$$s.t.\ (n_t - \overline{n}) w_t + \frac{B_{t-1}}{P_t}(1 + i_{t-1}) + F_t + r_t^k K_t \geq C_{t+i} + \frac{B_t}{P_t} + T_t \ + I_t \ and \quad (2)$$

$$K_{t+1} = (1-\delta) K_t + I_t \left(1 - S\left(\frac{I_t}{I_{t-1}} - (1+g)\right)\right),\ S(0) = 0,\ S(0)' = 0,\ S(0)'' > 0 \quad (3)$$

Each period families derive instantaneous utility $u(C_t - hab_{t-1})$ from consumption C_{t+i}, which is a CES consumption basket $C_t = \left[\int_0^1 (c_t(i))^{\frac{(\theta-1)}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$. Consumers spread their consumption over the various goods in the CES basket C_t in a cost minimising fashion, implying that the optimal demand for good i is given by $c_t(i) = C_t \left(\frac{p_t(i)}{P_t}\right)^{-\theta}$, where P_t denotes the price index of the consumption basket. Following Smets and Wouters (2002), we introduce external habit formation: $hab_{t-1} = jC_{t-1}$, $j < 1$. This is mainly to make the very short run responses of output

[32] The chief reason of introducing both the share of state employees and overhead workers is to achieve a reasonable calibration of steady state values. As is well known, the Romer model has strong scale effects, i.e. the level of employment affects the growth rate. This is due to the fact that, as shown below, the marginal product of capital becomes an increasing function of employment and a decreasing function of the depreciation rate. The marginal product of capital governs determines the growth rate by determining the willingness of households to save and thus the economy's growth rate. To achieve a reasonable steady state growth rate, it is thus necessary to either assume a very high depreciation rate or to remove part of the labour force from "productive" sector and thus to reduce the impact of employment on the marginal product of capital, 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 opted for the second solution.

and employment to the cost push shock we will perform later more reasonable (i.e. lower) but it does not affect the basic thrust of the results presented here. 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 the capital K_t they have accumulated up to time t. They have to pay lump sum taxes T_t.Families accumulate capital by making investment expenditure I_t according to the capital accumulation equation displayed below the budget constraint. Following Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2002), [33] we assume adjustment costs in investment: only a fraction of one unit of investment expenditure is actually turned into additional capital K_t , and this fraction decreases in the investment growth rate. The assumptions on the first derivative of the $S(.)$ function implies that adjustment costs vanish when the economy is growing at its steady state growth rate g, implying that the steady state growth rate does not depend on the parameters of the adjustment cost function S.[34] Setting up the lagrangian and denoting the lagrange multipliers of the budget constraint and the capital accumulation constraint as λ_t and $\lambda_t q_t$ yields the following first order conditions with respect to consumption, capital and investment:

$$u'(C_t - hab_{t-1}) = \beta E_t \left[u'(C_{t+1} - hab_t) \frac{1}{1+\pi_{t+1}} \right] [1 + i_t] \tag{4}$$

$$\lambda_t = u'(C_t - hab_{t-1}) \tag{5}$$

$$\beta E_t \left(\lambda_{t+1} r_{t+1}^k + \lambda_{t+1} q_{t+1} (1-\delta) \right) = \lambda_t q_t \tag{6}$$

$$\lambda_t q_t \left[\left(1 - S\left(\frac{I_t}{I_{t-1}} - (1+g) \right) \right) - \frac{I_t}{I_{t-1}} S'\left(\frac{I_t}{I_{t-1}} - (1+g) \right) \right] \tag{7}$$

$$+\beta E_t \left[\lambda_{t+1} q_{t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 S'\left(\frac{I_{t+1}}{I_t} - (1+g) \right) \right] = \lambda_t \tag{8}$$

Note that with this notation, q_t denotes the present discounted value of the future profits associated with buying another unit of capital today, also known as Tobin's q. Adjustment cost will be assumed to have the following functional form: $S\left(\frac{I_t}{I_{t-1}} - (1+g)\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - (1+g)\right)^2$.

The effort function of individual j $G(e_{t+i}(j))$ is of the form

$$\begin{aligned} G(e_t(j) &= \left(e_t(j) - \left(\begin{array}{c} \phi_0 + \phi_1 \log w_t(j) + \phi_2(n_t - \overline{n}) \\ +\phi_3 \log w_t + \phi_4 \log w_{t-1} + \phi_5 \log\left(\frac{w_{t-1}(n_{t-1} - \overline{n} - n^s)}{Y_{t-1}^P}\right) \end{array} \right) \right)^2 \\ \phi_1, \phi_5 &> 0, \phi_2, \phi_3, \phi_4 < 0, \phi_1 > -\phi_3 \end{aligned} \tag{9}$$

[33] See Christiano, Eichenbaum and Evans (2005), p.12, and Smets and Wouters (2002), p.13.
[34] See Christiano, Eichenbaum and Evans, p.15.

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, and that state employees are assumed not to perform any effort while at work. The first order condition with respect to effort is

$$e_t(j) = \phi_0 + \phi_1 \log w_t(j) + \phi_2 (n_t - \overline{n}) + \phi_3 \log w_t \tag{10}$$

$$+\phi_4 \log w_{t-1} + \phi_5 \log \left(\frac{w_{t-1} (n_{t-1} - \overline{n} - n^s)}{Y_{t-1}} \right) \tag{11}$$

The first of those is the familiar consumption Euler equation, while the second determines the optimal effort level. The structure of the effort function is motivated by the idea of "gift exchange" between the firm and the worker: The workers gift to the employer is effort, who in exchange responds by good treatment of the worker, summarised here by the wage $w_t(j)$. Accordingly, a higher contemporary average wage w_t reduces effort because it represents a "reference level" which the current employers wage offer is compared with, and a higher average past real wage w_{t-1} boosts the workers aspirations as well.[35] On the other hand, a higher labour share in the previous period $\frac{w_{t-1}n_{t-1}}{Y_{t-1}}$ boosts effort. Finally, the aggregate employment level of non-overhead workers $(n_t - \overline{n})$ summarizes labour market tightness and is thus positively related to the workers outside options, and thus also tends to reduce effort.

The employer takes this relationship into account when setting the wage, as will discussed further below. The view that wages have a big effect on morale because they signal to the worker how his contribution to the organizational goals is valued and that this generates substantial downward wage rigidity has found considerable support by a microeconomic survey conducted by Bewley (1998), who interviewed over 300 business people, labour leaders and business consultants.[36]

5.2 Cost Minimisation and Efficiency Wages

The production technology is a Cobb Douglas production function,

$Y_t(i) = AK_t(i)^{\alpha}(TFP_t e_t(i) (n_t(i) - \overline{n}))^{1-\alpha}$, where the output of firm i $Y_t(i)$ depends on the capital stock of firm i $K_t(i)$, the efficiency of it's workers $e_t(i)$ and the number of non-overhead workers $n_t(i) - \overline{n}$. In the Danthine and Kurman model (2004), in a first stage the firm minimises its cost of producing a given amount of

[35] 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 the private sector labour share rather than the labour share of the firm where the worker is employed.

[36] 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 constants, insider outsider models or the efficiency wage models based on no-shirking conditions.

output. To do so it hires capital in an economy wide market and furthermore decides on the wage it is going to pay, taking into account the relationship between effort and wages given by 10.[37] Hence the firm's problem is:

$$\min_{K_t(i),n_t(i),w_t(i)} r_t^k K_t(i) + w_t(i)(n_t(i)-\overline{n}) s.t. Y_t(i) = AK_t(i)^{\alpha}(TFP_t e_t(i)\left(n_t(i)-\overline{n}\right))^{1-\alpha}$$

$$\begin{aligned} and\ e_t(i) &= \phi_0 + \phi_1 \log w_t(i) + \phi_2\left(n_t - \overline{n}\right) + \phi_3 \log w_t \\ &\quad + \phi_4 \log w_{t-1} + \phi_5 \log\left(\frac{w_{t-1}\left(n_{t-1}-\overline{n}-n^s\right)}{Y_{t-1}^P}\right) \end{aligned}$$

by appropriately choosing $K_t(i)$, $n_t(i)$, $w_t(i)$ and $e_t(i)$ as the firm is conscious of the relationship between effort $e_t(i)$ and wages. This yields for capital and labour the first order conditions

$$r_t^k = \alpha mc_t\left(i\right)\frac{Y_t(i)}{K_t(i)} \tag{12}$$

$$w_t(i) = (1-\alpha) mc_t\left(i\right)\frac{Y_t(i)}{n_t(i)-\overline{n}}$$

were $mc_t(i)$ and r_t^k refer to real marginal costs of firm i and the capital rental rate, which is the price at which the capital stock, is traded, respectively. The aggregate capital stock is predetermined each period and it's production will be dealt with in the next section. It will be shown below that even though all firms set the wage individually, firms will find it optimal to set the same wage. This then means that the capital to (productive) labour ratio, the output per unit of 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, which gives the capital to productive labour ratio as $\frac{K_t(i)}{n_t(i)-\overline{n}} = \frac{\alpha}{1-\alpha}\frac{w_t}{r_t^k}$. Substituting this back into equation (12) 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:

$$mc_t = \frac{\left(r_t^k\right)^{\alpha} w_t^{1-\alpha}}{A\alpha^{\alpha}(1-\alpha)^{1-\alpha}(\phi_1 TFP_t)^{1-\alpha}} \tag{13}$$

This also implies that for the capital rental and for the real wage we have

$$r_t^k = \alpha mc_t \frac{Y_t}{K_t} \tag{14}$$

$$w_t = (1-\alpha) mc_t \frac{Y_t}{n_t - n^s - \overline{n}} \tag{15}$$

[37] See Danthine/ Kurman (2004), pp. 114-115.

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

$$\begin{aligned} n_t(i) - \overline{n} &= \frac{\zeta_t \phi_1}{w_t(i)} \\ \zeta_t &= (1-\alpha) mc_t \frac{Y_t(i)}{e_t(i)} \end{aligned} \tag{16}$$

Combining those with the first order condition with respect to labour yields an optimal effort level equal to ϕ_1. Substituting this back into the effort function 10 and noting that, as the firms wage depends only on aggregate variables which are the same for all firms, it must indeed hold that $w_t(i) = w_t$ yields the wage setting relation:

$$\log w_t = \log w_t(i) = \frac{\phi_1 - \phi_0}{\phi_1 + \phi_3} - \frac{\phi_2}{\phi_1 + \phi_3}(n_t - \overline{n}) - \frac{\phi_4}{\phi_1 + \phi_3} \log w_{t-1} \tag{17}$$

$$-\frac{\phi_5}{\phi_1 + \phi_3} \log \left(\frac{w_{t-1}(n_{t-1} - \overline{n} - n^s)}{Y_{t-1}} \right) \tag{18}$$

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

Equation (17) could be solved for a long run real wage if $-\frac{\phi_4}{\phi_1+\phi_3} < 1$. As mentioned above however, in our model, unlike in the Danthine/ Kurmann's, is a growth model, and so the real wage must be growing in the steady state. Therefore a function relating the wage level to employment is not appropriate unless one includes productivity growth as an additional argument. A major driving force of the results of this paper however is that wages are not perfectly indexed to productivity growth. The easiest way to deal with the issue therefore seems to set $-\frac{\phi_4}{\phi_1+\phi_3} = 1$, which means that we have real wage growth function, or real wage Phillips curve:

$$\log w_t - \log w_{t-1} = a + b * (n_t - \overline{n}) + c \log \left(\frac{w_{t-1}(n_{t-1} - \overline{n} - n^s)}{Y_{t-1}} \right), \tag{19}$$

$$\text{with } a = \frac{\phi_0 - \phi_1}{\phi_1 + \phi_3},\ b = -\frac{\phi_2}{\phi_1 + \phi_3} > 0 \text{ and } c = -\frac{\phi_5}{\phi_1 + \phi_3} < 0 \tag{20}$$

Setting $-(\phi_3 + \phi_4) = \phi_1$ implies that to compensate for the effort diminishing effect of a 1 percent increase in the "reference level" of the real wage, as represented by the current average real wage and the past average real wage, the firm has to increase its own wage by the same percentage.

Equation (19) is a real wage Phillips Curve plus an "error correction term" represented by the log of the labour share. Empirical estimates of (19) (usually replacing

n_t with the unemployment rate) or variants thereof repeatedly find c=0 for the United states but $c < 0$ for European countries.[38] This will later provide a way to distinguish real wage rigidity between the United States and Europe. It has been argued by Blanchard and Katz (1999) that the presence of a labour share term is required for an effect of "any factor that decrease the wages firms can afford to pay [...] conditional on the level of technology" on unemployment.[39] Examples of those would be payroll taxes. Indeed we can reproduce here the simple textbook response of steady state employment to changes in payroll taxes and the mark-up as well as the result of Blanchard and Katz concerning the role of the parameter c. As we will assume imperfect competition later, in the steady state, marginal cost equal the inverse of the mark-up μ, i.e. $mc = \mu^{-1}$. From (13) , it is easy to see that in the steady state, with r^k and mc constant, real wages grow the same rate as total factor productivity, which we denote as g: (13) is essentially a textbook price setting function, giving the real wage (and its growth rate) consistent with firms realising their mark-up. Assuming that there is a tax τ on real wages, implying a net wage of $(1-\tau) w_t$, substituting (15) into (19) for w_{t-1}, and noting that in the steady state, $mc = \mu^{-1}$, we have

$$n_t = \frac{-c}{b} \log \left(\frac{(1-\alpha)(1-\tau)}{\mu} \right) + \frac{\log(1+g)}{b} - \frac{a}{b}$$

Clearly, an increase in payroll taxes and a reduction in product market competition (i.e. an increase in the mark-up) both decrease employment, while an increase in productivity growth increases employment as long as $c < 0$, but have no effect if c=0. c (as well as a and b) is not explicitly derived here but can be thought of as implicitly depending institutional variables. Thus the wage setting relationship resulting from the efficiency wage model used here coarsely incorporates the effect of labour market institutions on unemployment.

It remains to determine the size of the overhead labour force. Following Rotemberg and Woodford (1999), it is assumed that in the steady state, all profit generated by employing productive labour and capital goes to the overhead staff so that the firm ends up with zero profits.[40] This is justified because setting up production is impossible without overhead labour and the firms profit is thus essentially equal to the

[38]See Blanchard and Katz (1999), p.73, and Cahuc and Zylberberg (2004), p.484-486. Note that (19) differs from the empirical specification in that it is the private sector labour share, assuming that overhead workers are essentially the self employed. This is done to simplify calculations. Note that in (19) we can very easily replace the labour share term by $(1-\alpha) mc_{t-1}$. This manipulation would not be possible if we were using the labour share for the total economy, including the state sector (assuming that the value added of state employees would be measured with the wages they are paid, as is common practice in national accounts). However, it can be shown that the effect of an employment change on the labour share would be even greater if we included state employees. This would essentially make persistent reductions in real wage growth even harder and thus, which, as will become clear later, would be expected to enhance the effects we are interested in showing here.

[39]Blanchard and Katz (1999), p.72.

[40]See Rotemberg/ Woodford (2004), pp. 15-16.

collective marginal product of its overhead staff. We assume that the overhead staff splits this profit equally. As mentioned above, it is assumed that there is full employment among overhead workers and that the amount of overhead workers required and employed is such that the real wage for overhead and non-overhead workers 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

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

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

$$\frac{\mu - 1}{1 - \alpha} = \frac{\overline{n}}{n_t^p - \overline{n}} \equiv \overline{s}$$

which is the ratio of overhead labour to productive labour, which we call $\overline{s}$. Using $n_t^p = \overline{n} + (n_t^p - \overline{n})$, we arrive at

$$\begin{aligned} n_t^p - \overline{n} &= \frac{n_t^p}{1+\overline{s}} \\ \overline{n} &= \frac{\overline{s}}{1+\overline{s}} n_t^p \end{aligned} \qquad (21)$$

which gives the amount of productive and overhead labour as a function of employment.

5.3 Price Setting and Nominal Rigidities

Each firm produces one of the variants of the output good in the CES basket. Given that investment expenditure stretches over these variants in precisely the same way as consumption demand, we can write $y_{t+i}(j) = Y_{t+i}\left(\frac{p_{t+i}(j)}{P_{t+i}}\right)^{-\theta}$. It is assumed that the representative firm faces costs if it alters its individual price inflation from a reference level $\Pi - 1$, which would usually be the steady state level of inflation in the economy. These costs arise because deviating from the "standard" level of inflation requires the firm to engage in a re optimisation process which has to be carried out by high paid marketing professionals, while small price changes can be decided by lower paid "frontline" staff. Apart from that, customers dislike price volatility because it requires them to switch between products, which the firm has to compensate by extra marketing efforts, special offers etc. These costs are likely to increase in the firms output as well. Following Lubik/Marzo (2007), we assume the following functional form:

$$AC_{t+i}(j) = \frac{\varphi}{2}\left(\frac{p_{t+i}(j)}{p_{t+i-1}(j)} - \Pi\right)^2 y_{t+i}(j) \qquad (22)$$

Demand for the firm's product is as follows: $y_{t+i}(j) = Y_{t+i}\left(\frac{p_{t+i}(j)}{P_{t+i}}\right)^{-\theta}$.The firm j chooses its price $p_{t+i}(j)$ in order to maximise

$$\sum_{i=0}^{\infty} E_t\left[\rho_{t,t+i}\left[\frac{p_{t+i}(j)}{P_{t+i}}y_{t+i}(j) - mc_{t+i}y_{t+i}(j) - AC_{t+i}(j)\right]\right] \tag{23}$$

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 $\rho_{t,t+i} = \beta^i \frac{u'(C_{t+i})}{u'(C_t)}$. Differentiating with respect to $p_t(j)$ and noting that, as all firms are the same, $p_t(j) = P_t$ holds ex post yield

$$(1-\theta) + \theta mc_t - \varphi\left(\frac{P_t}{P_{t-1}} - \Pi\right)\frac{P_t}{P_{t-1}} + \theta\frac{\varphi}{2}\left(\frac{P_t}{P_{t-1}} - \Pi\right)^2$$
$$+E_t\left[\rho_{t,t+1}\varphi\frac{Y_{t+1}}{Y_t}\left(\frac{P_{t+1}}{P_t} - \Pi\right)\frac{P_{t+1}}{P_t}\right] = 0 \tag{24}$$

which is a nonlinear version of the standard New Keynesian Phillips curve, which relates current inflation to expected future inflation, and implies a steady state value for marginal cost (for $\frac{P_t}{P_{t-1}} = \frac{P_{t+1}}{P_t} = \Pi$) of $\frac{\theta-1}{\theta}$. It is, however, a consistent feature of empirical estimations of Phillips curves that specifications which include lagged inflation ("hybrid" Phillips curves") perform better than those which include only expected next period's inflation because inflation has inertia.[41] 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 but 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, and customers will get used to the different pace of price changes as well. Hence we have

$$(1-\theta) + \theta mc_t - \varphi\left(\frac{P_t}{P_{t-1}} - \frac{P_{t-1}}{P_{t-2}}\right)\frac{P_t}{P_{t-1}} + \theta\frac{\varphi}{2}\left(\frac{P_t}{P_{t-1}} - \frac{P_{t-1}}{P_{t-2}}\right)^2 \tag{25}$$
$$+E_t\left[\rho_{t,t+1}\varphi\frac{Y_{t+1}}{Y_t}\left(\frac{P_{t+1}}{P_t} - \frac{P_t}{P_{t-1}}\right)\frac{P_{t+1}}{P_t}\right] = 0 \tag{26}$$

As the simulation experiment which we aim to conduct is a disinflation, we have to introduce an inflationary shock, like for instance an oil price shock. We account for such a shock by adding a so called "cost-push shock" u_t to the Phillips curve equation. This shock increases current inflation, holding the values of past inflation

[41] See for instance Gali/Gertler (2000).

and marginal costs constant. This gives

$$(1-\theta)+\theta mc_t-\varphi\left(\left(\frac{P_t}{P_{t-1}}-u_t\right)-\frac{P_{t-1}}{P_{t-2}}\right)\left(\frac{P_t}{P_{t-1}}-u_t\right)+\theta\frac{\varphi}{2}(\left(\frac{P_t}{P_{t-1}}-u_t\right)-\frac{P_{t-1}}{P_{t-2}})^2 \tag{27}$$

$$+E_t\left[\rho_{t,t+1}\varphi\frac{Y_{t+1}}{Y_t}\left(\frac{P_{t+1}}{P_t}-\left(\frac{P_t}{P_{t-1}}-u_t\right)\right)\frac{P_{t+1}}{P_t}\right]=0 \tag{28}$$

While it would certainly be desirable to derive such a shock from first principles, like for instance explicitly including energy in the production function, the road taken here has the advantage of simplicity and is in line with the New-Keynesian literature as well.[42]

Although we will simulate a non-linearised version of the model below, it is still insightful to linearise the Phillips Curve for purpose of comparison with other specifications found in the literature and in empirical studies. This is all the more so as simulating a model with a linearised Phillips Curve does yield results which are pretty close to the model featuring the non-linearised Phillips Curve. Linearising 25 around the steady state gives

$$\pi_t=\frac{\pi_{t-1}}{1+(1+g)\overline{\rho}}+\frac{(\theta-1)\widehat{mc}_t}{\varphi\left(1+(1+g)\overline{\rho}\right)}+\frac{(1+g)\overline{\rho}}{1+(1+g)\overline{\rho}}E_t\pi_{t+1} \tag{29}$$

The steady state discount rate $\overline{\rho}$ can be replaced by $\beta\frac{u'(C_{t+1}-Hab_t)}{u'(C_t-Hab_{t-1})}$. Hence for the case of logarithmic utility $(u(C_t)=\ln(C_t-Hab_{t-1}))$ and as consumption, habit and output will all grow at the same rate in the steady state, we have

$$\pi_t=\frac{(\theta-1)}{\varphi}\widehat{mc}_t+\beta E_t\pi_{t+1} \tag{30}$$

and

$$\pi_t=\frac{\pi_{t-1}}{1+\beta}+\frac{(\theta-1)\widehat{mc}_t}{\varphi\left(1+\beta\right)}+\frac{\beta}{1+\beta}E_t\pi_{t+1} \tag{31}$$

for the hybrid Phillips Curve. Note that these equations resemble very closely specifications which are obtained by Woodford (2003) under the assumption of Calvo contracts but different degrees of indexing of the prices of those firms which can not re-optimise prices to past inflation. While equation 30 is a purely forward looking Phillips curve and corresponds to no indexing in the Calvo model, equation 31 corresponds to full indexing among those firms which are not able to re-optimise their prices. In fact, for both equations, the coefficients on expected future inflation and the coefficient on lagged inflation in the second equation exactly match Woodfords results.[43] In the simulations carried out below, we will use the (non linearised) hybrid

[42] See for instance Clarida et al (1999), pages 1665 and 1667.

[43] See Woodford (2003), p. 215.

Phillips curve because of the generally superior empirical performance of Phillips Curves featuring lagged inflation. Furthermore, implies that disinflation is always costly in terms of output and employment because as $\beta < 1$, the weight on lagged inflation exceeds 0.5.[44] Costliness is a feature of real world disinflations, and recent estimates the hybrid Phillips Curve by Jondeau and Bihan (2005) suggests that the coefficients on past and expected inflation exceed 0.5 in France, Germany and the Euro area as a whole and are in fact quantitatively close to the values in equation 31 for standard values of β.[45] Other evidence supporting the hypothesis of full indexation to past prices among non optimising firms has been provided by estimations of complete general equilibrium models with the goal of matching impulse response functions of monetary shocks. Examples of this are Woodford and Giannoni (2003) and Christiano, Eichenbaum and Evans (2005).[46] Furthermore, if disinflation were costless even in the short run, the persistent effects of monetary policy which are the subject of this paper could not arise.

It is instructive to add the cost push shock to 31 and solve forward, which yields

$$\pi_t - \pi_{t-1} = \frac{\theta - 1}{\varphi} \sum_{i=0}^{\infty} \left(E_t \widehat{mc}_{t+i} \right) + (1 + \beta) \sum_{i=0}^{\infty} E_t u_{t+i} \tag{32}$$

This shows that, up to a linear approximation, 27 is in fact 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 be constant, while it will accelerate or decelerate otherwise. This means that the model has a well defined NAIRU.

5.4 Monetary Policy

Monetary Policy will be assumed to follow a simple Taylor type nominal interest rate rule. The exact specification will vary across simulations, though all specifications will include a lagged dependent variable in order to account for the interest rate inertia observed in the data. The baseline rule will be a rule which reacts to current inflation and the lagged output gap:

$$i_t = (1 - \rho)\, \bar{i} + (1 - \rho)\, \psi_\pi \pi_t + (1 - \rho)\, \frac{\psi_Y}{4} gp_{t-1} + \rho i_{t-1} \tag{33}$$

where $\bar{i}$, ρ and gp_t denote the long-run real interest rate (recall that inflation is zero in the steady state), the degree of interest rate smoothing and the output gap,

[44] As was shown by Chadha et al (1992), this is a sufficient condition to prevent the path of disinflation from being completely costless. Intuitively, a reduction in expected inflation reduces inflation today, and a lower coefficient on expected inflation means that today's inflation will be reduced by less for any given output level. See Chadha et al (1992), p. 403.

[45] See Jondeau/ Bihan (2005), pp. 521-550.

[46] See Woodford (2003), p. 351 and Christiano, Eichenbaum and Evans (2005), pp. 30-32.

respectively, while ψ_π and ψ_Y denote the long run coefficients on inflation and the output gap. Hence the central bank responds to the lagged value of the output gap but current values of inflation, on the grounds that output data is usually available only with a lag while data on inflation arrives earlier.

The output gap is the percentage deviation from its natural level Y_t^n, which is the output level which would set marginal costs equal to its long run level μ^{-1}, given the capital stock, and the previous periods real wage. As can be obtained from equation (32), 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 (14) and the wage setting equation (19) into (13) and setting $mc_t = \mu^{-1}$.The natural levels of output and employment are then given by the values of Y_t^n and n_t^n solving

$$\mu^{-1} = \frac{\left(n_t^n - n^s - \overline{n}\right)^\alpha \left(w_{t-1} \exp(a + b\left(n_t^n - \overline{n}\right))\right)}{A\left(1-\alpha\right)\left(\phi_1 TFP_t\right)^{1-\alpha} K_t^\alpha} \tag{34}$$

$$Y_t^n = A{K_t}^\alpha (TFP_t \phi_1 \left(n_t^n - n^s - \overline{n}\right))^{1-\alpha} \tag{35}$$

Note that given the past real wage, the capital stock has a postive 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 through the factor price frontier, which tends to lower marginal costs and thus makes room for the higher real wage which is generated by higher employment through the wage setting equation.

5.5 Introducing Endogenous Growth

The basic idea in the knowledge spill over model is to start off with a standard neoclassical production function with labour augmenting technical progress just like the one used above, with the difference that labour augmenting technological progress might be firm specific:

$$Y_t(i) = F(K_t(i), TFP_t\,(i)\, n_t(i)) \tag{36}$$

Romer then makes two crucial assumptions:

- Increasing its 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.[47] However, the impact of the firms capital stock on the aggregate capital stock is so small that they can be neglected. Thus the production function of firm i becomes

[47] See Barro/ Sala-i-Martin (2004), pp.21-22.

$$Y_t(i) = F(K_t(i), K_t n_t(i)) \tag{37}$$

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, where the labour force is in elastically supplied and wages are perfectly flexible, this leads to an inefficiently low choice of the capital stock. In turn, this leads to a growth rate which is inefficiently low because saving is to low as the individual return on capital falls short of the social return on capital. Thus introducing endogenous growth in this fashion is equivalent to replacing TFP_t by K_t in the above equations.

Note that the steady state in the learning by doing model satisfies the famous five stylized facts of growth: Output per capita and capital per labour keep increasing, the capital output ratio is trend less, the real wage per unit of labour keeps increasing, the rate of profit is trend less and the share of GDP going to capital and labour are trend less as well. This will also be true for the model developed below. Thus from an empirical point of view, there is no reason rendering the neoclassical production function superior to the alternative employed here.

Thus we set $TFP_t = K_t$ in the above equations. This affects the production function and the marginal cost equation (13), which become

$$mc_t = \frac{\left(r_t^k\right)^\alpha w_t^{1-\alpha}}{A\alpha^\alpha(1-\alpha)^{1-\alpha}(\phi_1 K_t)^{1-\alpha}} \tag{38}$$

$$Y_t = AK_t(\phi_1 \left(n_t - n^s - \overline{n}\right))^{1-\alpha} \tag{39}$$

Obviously, the capital stock now has a stronger effect on both marginal costs and output than in the absence of endogenous growth. For a given capital rental (that means assuming that output expands at the same rate and employment stays constant) and a given real wage, an increase in the capital stock by 1% for a given capital rental reduces marginal costs by $(1-\alpha)\,\%$, while in the absence of endogenous growth, it only has an indirect effect through the capital rental. Indeed, we will see that the movement of the real wage to capital ratio is crucial for understanding the employment dynamics in the in the simulations of the economy with endogenous growth to be discussed later. Accordingly, the capital stock also has a greater effect on natural employment and the NAIRU: Equations (34) and (35) become

$$\mu^{-1} = \frac{\left(n_t^n - n^s - \overline{n}\right)^\alpha w_{t-1} \exp(a + b\left(n_t^n - \overline{n}\right))}{A(1-\alpha)(\phi_1)^{1-\alpha} K_t} \tag{40}$$

Clearly, a n increase in the capital stock now accommodates a larger increase in employment than in (35) .

5.6 The Aggregate Equations

This section summarises the models aggregate equations developed above for convenience of the reader and introduces explicit functional forms where that has not yet been done above. As many of the economies variables are growing in the steady state ($Y_{t,} C_t, I_t, w_t, K_t$), simulation of the model requires normalising those variables in a way which produces constant steady state values. It is very convenient from a technical point of view to normalise with respect to the capital stock. Just how that is done is shown in the appendix, as well as how the steady state values of the variables are calculated.

5.6.1 Aggregate Demand

Aggregate demand consists of consumption, investment and the amount of price adjustment costs:

$$Y_t = C_t + I_t + \frac{\varphi}{2}(\pi_t - \pi_{t-1})^2 Y_t \tag{41}$$

We will assume logarithmic utility so that the consumption Euler equation becomes

$$1/\left(C_t - hab_{t-1}\right) = \beta\left(1 + i_t\right) E_t\left[\frac{1}{\left(C_{t+1} - hab_t\right)\left(1 + \pi_{t+1}\right)}\right] \tag{42}$$

The level of habit is given by

$$hab_{t-1} = jC_{t-1}$$

Investment expenditures is governed by the following equations:

$$\lambda_t = \frac{1}{C_t - Hab_{t-1}} \tag{43}$$

$$\beta E_t\left(\lambda_{t+1} r^k_{t+1} + \lambda_{t+1} q_{t+1}\left(1 - \delta\right)\right) = \lambda_t q_t \tag{44}$$

$$\begin{aligned} \lambda_t q_t &\left[\left(1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - (1+g)\right)^2\right) - \frac{I_t}{I_{t-1}}\kappa\left(\frac{I_t}{I_{t-1}} - (1+g)\right)\right] \\ &+ \beta E_t\left[\lambda_{t+1} q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 \kappa\left(\frac{I_{t+1}}{I_t} - (1+g)\right)\right] = \lambda_t \end{aligned} \tag{45}$$

while the capital accumulation is given by

$$K_{t+1} = \left(1 - \delta\right) K_t + I_t\left(1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - (1+g)\right)^2\right) \tag{46}$$

The capital rental is given by

$$r_t^k = \alpha mc_t \frac{Y_t}{K_t} \tag{47}$$

Note that with endogenous growth, we can write r_t^k as a function of employment and marginal costs alone, namely

$$r_t^k = \alpha mc_t A(\phi_1 (n_t - n^s - \overline{n}))^{1-\alpha} \tag{48}$$

5.6.2 Aggregate Supply

What follows are the equations for marginal costs, wage setting and employment. In the absence of endogenous growth, we have

$$\frac{\left(r_t^k\right)^\alpha w_t^{1-\alpha}}{A\alpha^\alpha(1-\alpha)^{1-\alpha}(\phi_1 TFP_t)^{1-\alpha}} \tag{49}$$

while in the presence of endogenous growth this equations becomes

$$mc_t = \frac{\left(r_t^k\right)^\alpha w_t^{1-\alpha}}{A\alpha^\alpha(1-\alpha)^{1-\alpha}(\phi_1 K_t)^{1-\alpha}} \tag{50}$$

Wages are set according to equation (17):

$$\log w_t - \log w_{t-1} = a + b * (n_t - \overline{n}) + c \log\left(\frac{w_{t-1}(n_{t-1} - \overline{n} - n^s)}{Y_{t-1}}\right) \tag{51}$$

Output in the absence of endogenous growth is given by

$$Y_t = A{K_t}^\alpha (TFP_t \phi_1 (n_t - \overline{n} - n^s))^{1-\alpha} \tag{52}$$

while in the presence of endogenous growth, we have

$$Y_t = A_t K_t ((n_t - \overline{n} - n^s)\, \phi_1)^{1-\alpha}$$

The evolution of prices is determined by the Phillips Curve, where we replace the stochastic discount factor by its definition $\rho_{t,t+1} = \beta \frac{u'(C_{t+1} - hab_t)}{u'(C_t - hab_{t-1})} = \beta \frac{C_t - hab_{t-1}}{C_{t+1} - hab_t}$

$$(1-\theta) + \theta mc_t - \varphi\left(\left(\frac{P_t}{P_{t-1}} - u_t\right) - \frac{P_{t-1}}{P_{t-2}}\right)\left(\frac{P_t}{P_{t-1}} - u_t\right) + \theta\frac{\varphi}{2}(\left(\frac{P_t}{P_{t-1}} - u_t\right) - \frac{P_{t-1}}{P_{t-2}})^2 \tag{53}$$

$$+\beta E_t\left[\frac{C_t - hab_{t-1}}{C_{t+1} - hab_t}\varphi\frac{Y_{t+1}}{Y_t}\left(\frac{P_{t+1}}{P_t} - \left(\frac{P_t}{P_{t-1}} - u_t\right)\right)\frac{P_{t+1}}{P_t}\right] = 0 \tag{54}$$

where u_t is a cost push variable which is used to introduce the possibility of an inflationary shock (like an oil price shock). The linearised and forward solved version of this, which is helpful for interpretation of the simulation results, is then

$$\pi_t - \pi_{t-1} = \frac{\theta - 1}{\varphi} \sum_{i=0}^{\infty} \left(E_t \widehat{mc}_{t+i} \right) + (1 + \beta) \sum_{i=0}^{\infty} E_t u_{t+i} \tag{55}$$

[48] This equation is a forward looking version of the traditional accelerationist Phillips Curve and says that inflation will accelerate if the sum of current and expected future marginal costs and current and future shocks exceed zero.

Finally, policy is specified by equation 33

$$i_t = (1 - \rho)\, \bar{i} + (1 - \rho)\, \psi_\pi \pi_t + (1 - \rho)\, \frac{\psi_Y}{4} g p_{t-1} + \rho i_{t-1} \tag{56}$$

6 Simulation Setup and Calibration

We will present results from two types of simulations. In the first one, the model economy is hit by a deterministic cost push shock aimed at creating a scenario akin to the challenge faced 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 were annual inflation increases several percentage points above its target level for some time is then subsequently reduced. Therefore u_t is set equal to 0.03 for the first quarter and a forecast conditional on this being the case is computed for all the variables. To put it differently, we have a 3 percentage point increase in quarterly inflation given marginal costs, or 12 percentage point increase at an annualised rate. In the baseline simulation, this will give rise to a disinflation of a bit more than 4.6 percentage points over 5 years, which is at the lower end of disinflations experienced. 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 were inflation by 8.6, 10.8 and 13.7 percentage points over the same period. 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 employment beyond that point is endogenous. The models are solved employing a second order approximation to the policy function using the algorithm of Schmitdt-Grohe and Uribe (2004).[49] We consider the second order approximation appropriate because the model has multiple distortions (unemployment, imperfect competition, external effects of capital goods production). Therefore precautionary savings effects which would be lost if the policy function were approximated to first order might matter. The only source of uncertainty we consider arises from random

[48] The derivation is shown in the Appendix. For comparison see Woodford (2003), p. 215.

[49] See Schmitd-Grohe and Uribe (2004), pp.755 to 775.

draws of the cost push shock. The solution and the simulations are conducted using the software Dynare.[50]

The calibration of the model parameters for the experiment described above is presented in table 1. It was arrived at as follows. We can distinguish between four different types of parameters. The first set is calibrated according to standard values in the literature. It consists of the utility discount factor β, the output elasticity of capital α, the elasticity of substitution between varieties of goods θ (implying a mark-up of 1.2 and a share of overhead labour of 17.93%,the depreciation rate δ, the adjustment cost parameter φ and the share of government employees n^s. φ is calibrated as to generate marginal cost coefficient in the Phillips which would also be generated in a Calvo Phillips Curve with full backward indexing of unchanged prices if the probability of no re optimisation is 2/3. n^s is based on 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.[51] Employment in the German public sector has been shrinking for years and our estimate of it's share in total employment will therefore be rather conservative. The second set of parameters are the coefficients on employment and the labour share in the wage setting function, b and c, which are calibrated to be consistent with an estimate of that function, and the intercept a, which is calibrated to achieve a steady state unemployment rate of 4%, a procedure also used by Danthine and Kurman (2004).[52] We estimate (51) on Germany quarterly data on hourly labour costs, unemployment and the labour share ranging from 1970 to 2000 by two stage least squares to account for possible endogeneity of employment. Our calibration of b and c is consistent with this estimate, which is reported in the appendix.

The three "free" parameters A, γ and j the production function multiple, the parameter indexing adjustment costs and the degree of habit formation were calibrated to match second moments of a couple of variables in the New Growth Economy. We also apply this set of parameters to the JLN economy and report the resulting second moments as well. We generate the moments, by setting standard deviation of the cost push shock equal to 0.003, thus producing a sample of 200000 observations generated by random draws of the stochastic cost push shock. Since we are chiefly interested in

[50] The programme and useful recourses on how to use it can be downloaded from http://www.cepremap.cnrs.fr/dynare/.

[51] The number of full time equivalents is calculated by adding up employees where each employee is weighted with the fraction of the 40 hour working week he or she is working. This gives a number of 4.6 million full time equivalents in 2006, see Statistisches Bundesamt 2007, table 2.3.4. This does not include employment in incorporated government owned companies. Assuming an average yearly holiday of a month, this gives an estimate of 8794.76 mio. hours (=40*4.6*365/7*11/12). The total number of hours by non-self-employed workers for that year was 56001 mio., see Statistisches Bundesamt (2007), table 2.7. With a calibrated unemployment rate of 4%, we then get a share of government employment in the total labour force of 15.26%. Assuming that about 3% of the labour force are employed in government owned firms, we arrive at our calibrated share of government employees of 18%.

[52] See Danthine and Kurmann (2004), p.120.

relative measures, the absolute size of the cost push shock is of little importance. We choose it so that the standard deviation of employment is close to it's value on the data. j was then calibrated primarily to match the persistence of the consumption capital ratio (all trended variables are normalised with the capital stock) as measured by the autocorrelation coefficient up to fifth order, while A and γ were calibrated to approximate the standard deviation of the investment output ratio relative to the output capital ratio.

Table 1: Calibration of non-policy parameters

α	β	j	A	θ	δ	ϕ_1	φ	a	b	c	γ	u_1	$\overline{n}$
0.33	0.99	0.4	0.38	6	0.025	0.452	30	-0.0307	0.08	0.01	0.65	0.03	0.1793

n^s	$\overline{i}$	g_{TFP}	σ
0.18	0.0181	0.0079	0.003

Finally, there is the monetary policy rule. The baseline calibration of the policy rule is taken from Clausen and Meier (2003), who estimate a Bundesbank policy rule over the period from 1973 to 1998 for quarterly data using a real time measure of the output gap in order to account for the fact that the central banks information set does not include future levels of GDP. Thus they argue that the estimate of potential output underlying the output gap measure should be based only on GDP levels known up to the quarter when the decision on the interest rate is made.[53] An important additional benefit of this procedure with respect to the model at hand lies in the fact that the potential output estimate will evolve in a manner depending more strongly on past values of actual output than in a procedure which uses the full sample of output values. This is what we would expect to be the case in our endogenous growth/ sticky price model, where changes in output via changes in investment have a much stronger effect on productive capacity than in a model with a neoclassical production function and fixed total factor productivity growth.

Clausen and Meier's best performing procedure for estimating potential output, a linear trend, yields the statistically significant coefficients on output, inflation and the lagged interest 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.[54] This is of particular interest for the coefficient on the output gap, because the Bundesbank was often perceived as paying much less attention to output than the Fed, which was also borne out by estimates of the Taylor rule.[55] Because this paper aims to explain long swings in Europe's big economies by the response of monetary policy to an inflationary shock, wee deem it a conservative approach to use as baseline coefficients for the policy rule the least hawkish ones in the literature of Bundesbank

[53]See Clausen/ Meier (2003), p. 2. Note that because Taylor rules are usually estimated using annualised inflation and interest rate data, the coefficient on the output gap has to be divided by 4 to adapt it to quarterly frequency.

[54]See Clausen/ Meier (2003), pp. 11-12 and p. 22.

[55]See for instance Clarida et. al (1998), p. 1045, who estimate a statistically insignificant coefficient on the output gap of 0.25/4.

Taylor rule estimates.

Table 2: Baseline calibration of the policy rule: Clausen and Meier (2003)[56]

ψ_π	ψ_Y	ρ
1.5	0.52	0.75

However, it is well known to that estimating potential output, and in particular obtaining output gap measure consistent with the underlying theoretical model are a tricky business.[57] Furthermore, some would argue that the central bank reacts to forecasts of inflation rather than current values. To check the robustness of our results both with respect to the specification of the interest rate rule, potential output measurements and estimation methodology, we perform both the deterministic simulations and the moment comparison also for an alternative forward looking interest rate rule estimated by Clarida, Gali and Gertler (1998) for the Bundesbank. Their rule is estimated using monthly data. A quarterly data version of their specification which we can be used in the models suggested here amounts to

$$i_t = (1-\rho)\,\bar{i} + (1-\rho)\,\psi_\pi E_t\left(\frac{\pi_{t+1}+\pi_{t+2}+\pi_{t+3}+\pi_{t+4}}{4}\right) + (1-\rho)\,\frac{\psi_Y}{4} gp_t + \rho i_{t-1} \tag{57}$$

Hence the central bank responds to a one year forecast of inflation, the current output gap and the lagged interest rate.[58] They measure potential output using a quadratic trend of a western German industrial production index and their data set stretches from 1979 to 1993 and estimate the policy rule using the general method of moments.[59] 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, Gali and Gertler (1998)[60]

ψ_π	ψ_Y	ρ
1.31	0.25	0.91

7 Some Moment Comparison

We now report the results of comparing the second moments generated by stochastic simulations of the model economy to the corresponding empirical moments for German data. The moment comparison formed an important exercise in the calibration of the model: the three free parameters γ, A and j where calibrated with an eye on

[56] See Clausen and Meier (2003), p. 22.
[57] See Gali (2001), p. 12 and Gali and Gertler (1999), pp. 200-205.
[58] See Clarida, Gali and Gertler (1998), p. 10439 and 1042.
[59] See Clarida, Gali and Gertler (1999), p. 1040.
[60] See Clarida, Gali and Gertler (1998), p. 1045.

the empirical standard deviation of the investment/capital ratio to the output capital ratio, the persistence of employment and consumption, both as measured by the first to fifth order autocorrelation. We report some selected second moments of other important variables to give an idea how the model in the chosen calibration matches the data. We carry out the same comparison for the JLN economy, and for both the Baseline policy reaction function and the Clarida Gali Gertler estimate.

We consider the following variables: The ratios of output, consumption, investment and real wages to capital, denoted as F_t, D_t, R_t and H_t respectively (recall that we have to normalise all the trended variables with the capital stock to stationarise them) and employment n_t (measured as linearly detrended log hours), the nominal interest rate i_t, inflation π_t (measured as the change in the GDP deflator), productivity growth p_t (measured as change in real GDP per hour worked), capital stock growth g_t, and the investment/ savings rate I/Y. From those, we compute the following moments: The coefficient of variation for output, the relative standard deviations of D_t and R_t to GDP, the standard deviations of employment, the savings rate and capital stock growth , the cross-correlation of all variables with F_t and the autocorrelation of each variable up to the fifth order. We conduct the moment comparison for both the baseline case and the reaction function estimated by Clarida, Gali and Gertler.

The construction of the data for F_t, D_t, R_t and H_t are discussed in the Appendix. The raw data was obtained from the Statistisches Bundesamt, except for the nominal interest rate data which was obtained from the "International Financial Statistics" CD-ROM. The data set ranges 1970:Q1 to only 1990:Q4 because reunification is associated with a big drop in F_t, D_t and R_t, which would distort moments. Furthermore, except for employment, inflation and the nominal interest rate, there are strong theoretical reasons to believe that all of the remaining variables are stationary, which is why we do not detrend or filter them. However if we adjust the sample if stationarity is not confirmed by either an ADF test (by rejecting the null of a unit root) or a KPSS test (by not rejecting the null of stationarity).

The null of stationarity is rejected at the 5% level level for D_t and F_t.After removing the years 70 to 73, we are not rejecting the null of stationarity anymore at the 10% level for these variables. However, stationarity is rejected for H_t in the reduced sample. However the larger sample indicates that H_t is stationary (the null of stationarity is not rejected at the 5% level).For R_t, the unit root can be rejected over the entire sample at the 5% level, as is the case for g_t and the savings rate. The same holds for the nominal interest rate, and so we do not detrend this variable either, while we do detrend the inflation rate, because the null of stationarity is rejected for this variable over the full as well as the reduced sample. Thus we employ the reduced sample to compute the cross-correlations and relative standard deviations listed above.

Table 4 reports the various standard deviations, relative standard deviations and cross-correlations with the output capital ratio F_t listed above. Column 1 contains the data, while column 2 and 3 refer to the baseline policy reaction function. The standard deviation of employment for the New Growth economy is on the mark because we have calibrated the standard deviation of the cost push to achieve this goal. The resulting coefficient of variation of F_t for the New Growth Model (NGM) is smaller than in the data. It is in fact almost equal to the standard deviation of employment, which is in fact also true for the JLN economy. The relative standard deviation of D_t in the New Growth model is very closer to the data, while the in the JLN economy, it is far too low. The relative standard deviation of R_t with respect to F_t is close to the data in both models but closer in the New Growth economy. The standard deviations of capital stock growth very close to the data in the New Growth economy, and such is the standard deviation of capital stock growth relative to the standard deviation of employment (0.0766 as opposed to 0.0714 in the data) This is important because changes in the capital stock growth rates drive the results (and in particular employment) in the New Growth economy discussed in the next section. We would not want the model to produce a standard deviation of capital stock growth relative to employment that exceeds the data very much, which is the situation in the JLN economy.

Turning to the cross-correlations, what is most striking is that for the neoclassical model, $corr(i_t, F_t)$, $corr(\pi_t, F_t), corr(p_t, F_t)$ are wrongly signed, being negative where they should be positive. The New Growth model produces wrong signs for $corr(\pi_t, F_t)$, though the absolute value is much smaller than for the JLN Economy, and $corr(H_t, F_t)$. The magnitudes of $corr(D_t, F_t)$ and $corr(R_t, F_t)$ are not too far away from the data for both models, while for $corr(n_t, F_t)$, both models produce considerably too high values. It is particularly interesting that the New Growth model manages to produce a positive correlation between the output capital ratio and the nominal interest rate. Correctly matching the correlation of output with inflation and the nominal interest rate is generally perceived as a difficulty in New Keynesian models if demand shocks are absent.[61]

[61] See for instance Nolan and Thoenissen (2005), p. 25-26.

Table 4: Relative Standard Deviations and Cross correlations

Moments	**Data**	JLN	NGM	CGG: JLN	CGG: NGM
$sd.F_t/meanF_t$	**0.0262**	0.0115	0.0192	0.0077	0.0215
$sd.D_t/sd.F_t$	**0.6216**	0.4447	0.5936	0.4619	0.5910
$sd.R_t/sd.F_t$	**0.4989**	0.5783	0.4540	0.6072	0.4812
$sd.n_t$	**0.0196**	0.0112	0.0209	0.0074	0.0235
$sd.I_t/Y_t$	**0.0092**	0.0048	0.0053	0.0035	0.0061
$sd.g_t$	0.0014	0.0012	0.0016	0.0009	0.0018
$corr(D_t, F_t)$	**0.8601**	0.95	0.9923	0.8863	0.9906
$corr(R_t, F_t)$	0.9001	0.9317	0.9953	0.8898	0.9948
$corr(n_t, F_t)$	**0.6083**	0.950	0.9990	0.8001	0.9991
$corr(i_t, F_t)$	**0.1521**	-0.6772	0.0830	0.0188	0.8804
$corr(\pi_t, F_t)$	**0.3252**	-0.5071	-0.0901	0.1471	0.2263
$corr(p_t, F_t)$	**0.2689**	-0.1966	0.7587	-0.2452	0.8262
$corr(H_t, F_t)$	**0.4454**	0.4476	-0.6729	0.4468	-0.7258

Table 5 reports the autocorrelation up to the fifth order for the data and the baseline case. For those variables which we do not reject the null of stationarity over the full sample we use the dataset starting in 1970 rather than the reduced dataset starting in 1974 in order not to unnecessarily sacrifice information. When the i-th order autocorrelation of a variable is within $\pm 0.1$of the corresponding autocorrelation in the sample, it is printed in bold, while a number in italics means that the value is closer to the data than the i-th order autocorrelation of the same variable in the competing model. Concerning the variables F_t, D_t,and n_t, we observe that the New Growth economy is matching the persistence the data quite closely, while R_t, g_t, i_t and I_t/Y_t are considerably less persistent in the New Growth model than in the data. Conversely, all these variables show far too little persistence in the JLN economy (and everywhere less than in the New Growth economy): The autocorrelations are dying off too quickly.

For π_t,both models produce very similar autocorrelations: The first order autocorrelations are a bit too high, the second and third ones are almost matched while the fourth and fifth one is wrongly signed. For p_t, both models produce incorrectly signed first, and second order autocorrelations. The JLN economy then does match the sign of the third order autocorrelation but produces wrong signs for the remainder. The New Growth economy produces a wrong sign for the third order autocorrelation but almost matches the fourth and matches the sign of the fifth. For the real wage to capital ratio H_t, both models match the first to third order autocorrelation but the from then onwards the autocorrelations in the New Growth model are too high, while the Neoclassical model produces on the mark autocorrelations. Thus the New Growth model does mostly better than the neoclassical at matching the data's second moments for the baseline central bank reaction function, with very few exceptions.

Table 5: Autocorrelations: Baseline

Order of Autocorrelation	Data	NCM	NGM	Data	NCM	NGM
	F_t	F_t	F_t	i_t	i_t	i_t
1	**0.85**	**0.89**	**0.93**	**0.9**	**0.8**	**0.84**
2	**0.74**	0.65	**0.82**	**0.75**	0.49	*0.58*
3	**0.64**	0.4	**0.71**	**0.58**	0.22	*0.38*
4	**0.55**	0.22	**0.63**	**0.39**	0.06	*0.25*
5	**0.46**	0.08	*0.58*	**0.23**	-0.00	**0.2**
	D_t	D_t	D_t	π_t	π_t	π_t
1	**0.93**	**0.88**	**0.94**	**0.25**	0.45	*0.42*
2	**0.89**	0.65	**0.85**	**0.05**	**0.1**	**0.07**
3	**0.84**	0.4	**0.76**	**-0.03**	**-0.07**	**-0.09**
4	**0.79**	0.22	**0.71**	**0.2**	-0.11	-0.11
5	**0.72**	0.11	**0.68**	**0.09**	-0.08	-0.07
	R_t	R_t	R_t	p_t	p_t	p_t
1	**0.96**	**0.9**	**0.94**	**-0.03**	0.53	0.84
2	**0.91**	0.68	**0.82**	**-0.18**	0.07	0.67
3	**0.86**	0.45	*0.7*	**-0.02**	*-0.21*	0.53
4	**0.81**	0.24	*0.6*	**0.37**	-0.31	**0.47**
5	**0.74**	0.1	*0.54*	**0.04**	-0.27	*0.42*
	n_t	n_t	n_t	H_t	H_t	H_t
1	**0.93**	**0.88**	**0.94**	**0.91**	**0.99**	**0.99**
2	**0.84**	0.65	**0.84**	**0.88**	**0.95**	**0.97**
3	**0.73**	0.34	**0.74**	**0.84**	**0.9**	**0.94**
4	**0.62**	0.20	**0.66**	**0.80**	**0.84**	0.92
5	**0.51**	0.08	*0.62*	**0.76**	**0.78**	0.89

Order of Autocorrelation	Data	NCM	NG	Data	NCM	NG
	g	g	g	I/Y	I/Y	I/Y
1	**0.97**	**0.9**	**0.94**	**0.95**	**0.91**	**0.94**
2	**0.92**	0.68	**0.82**	**0.91**	0.71	**0.82**
3	**0.88**	0.45	*0.7*	**0.87**	0.49	*0.69*
4	**0.83**	0.24	*0.6*	**0.82**	0.3	*0.58*
5	**0.78**	0.1	*0.54*	**0.75**	0.15	*0.51*

We now turn to the Clarida, Gali and Gertler reaction function. The relative standard deviations and cross correlations can be obtained from columns 4 and 5 of table 4. Again the standard deviations of F_t and n_t are quite close to each other for both models, unlike in the data. The New Growth economy still closely matches the relative standard deviation of D_t and R_t (the later even better than before) while the JLN economy the relative standard deviation of D_t is still a good deal too low and the relative standard deviation of R_t is too high. $corr(D_t, F_t)$ and $corr(R_t, F_t)$ are almost equal while $corr(n_t, F_t)$ is considerably reduced (and thus brought closer to the data) for the JLN economy. $corr(H_t, F_t)$ and $corr(p_t, F_t)$ also show some change in magnitude but not in signs. By contrast, $corr(\pi_t, F_t)$ becomes positive in both models, with the New Growth model coming very close to the data, while $corr(i_t, F_t)$ becomes positive in the New Growth model. Concerning the autocorrelations, which are reported in Table 6, note that they generally increase somewhat in the New Growth model, much so in case of i_t, but decrease in the neoclassical model, with the exception of i_t and π_t. Thus we conclude that the New Growth model is still better at matching the second moments discussed here, in particularly the persistence in the data, than the JLN economy.

Table 6: Autocorrelations: Clarida, Gali Gertler Reaction Function

Order of Autocorrelation	Data	NCM	NGM	Data	NCM	NGM
	F_t	F_t	F_t	i_t	i_t	i_t
1	**0.85**	**0.84**	0.96	**0.9**	**0.91**	**0.99**
2	**0.74**	0.57	*0.87*	**0.75**	**0.73**	0.98
3	**0.64**	0.30	*0.77*	**0.58**	**0.55**	0.96
4	**0.55**	0.10	*0.69*	**0.39**	**0.42**	0.93
5	**0.46**	-0.01	*0.64*	**0.23**	**0.34**	0.91
	D_t	D_t	D_t	π_t	π_t	π_t
1	**0.93**	0.77	**0.96**	**0.25**	0.66	*0.49*
2	**0.89**	0.46	**0.90**	**0.05**	0.36	**0.14**
3	**0.84**	0.23	**0.83**	**-0.03**	0.12	**-0.06**
4	**0.79**	0.13	**0.78**	**0.2**	-0.03	-0.13
5	**0.72**	0.12	**0.74**	**0.09**	-0.1	-0.11
	R_t	R_t	R_t	p_t	p_t	p_t
1	**0.96**	**0.92**	**0.96**	**-0.03**	0.34	0.9
2	**0.91**	0.72	**0.86**	**-0.18**	*-0.00*	0.76
3	**0.86**	0.48	*0.75*	**-0.02**	*-0.20*	0.64
4	**0.81**	0.26	*0.65*	**0.37**	-0.26	*0.55*
5	**0.74**	0.08	*0.58*	**0.04**	-0.23	*0.49*
	n_t	n_t	n_t	H_t	H_t	H_t
1	**0.93**	**0.82**	**0.96**	**0.91**	**0.99**	**0.99**
2	**0.84**	0.53	**0.88**	**0.88**	**0.95**	**0.98**
3	**0.73**	0.24	**0.8**	**0.84**	**0.91**	0.95
4	**0.62**	0.03	*0.73*	**0.80**	**0.85**	0.93
5	**0.51**	-0.1	*0.68*	**0.76**	**0.8**	0.90

Order of Autocorrelation	Data	NCM	NG	Data	NCM	NG
	g	g	g	I/Y	I/Y	I/Y
1	**0.97**	**0.92**	**0.96**	**0.95**	**0.94**	**0.95**
2	**0.92**	0.72	**0.86**	**0.91**	0.78	**0.85**
3	**0.88**	0.48	*0.75*	**0.87**	0.58	*0.73*
4	**0.83**	0.26	*0.65*	**0.82**	0.37	*0.62*
5	**0.78**	0.08	*0.58*	**0.75**	0.19	*0.54*

8 Simulation Results

We can now turn towards discussing the results of some simulations. In discussing the results we will focus on the dynamics of employment and the NAIRU, Inflation, marginal costs and the capital stock.

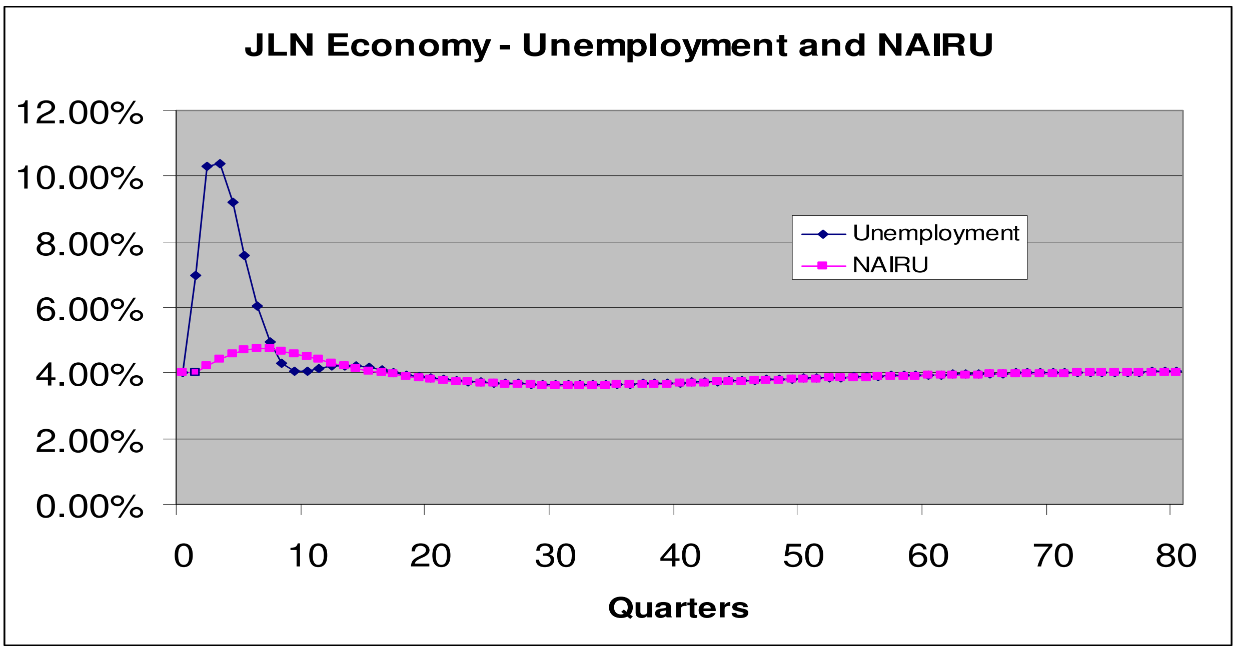

Figure 2

We will discuss the results from the JLN economy first. Figure 3 plots the response of actual unemployment (blue diamond) and the NAIRU (the pink square). In all figures, the period zero value will be the steady state value of the respective variable. Unemployment increases by about 3 percentage points on impact but starts recovering after rising to 10.4 percentage points above its steady state value. It then quickly recovers and in quarter 8 practically returns to its steady state value. 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 the policy rule 33. As consumers and investors are forward looking, this causes a contraction of aggregate demand on impact. Figure 2 plots the inflation rate, which peaks in quarter 1 at a value of 3.8% and then quickly declines back to zero.

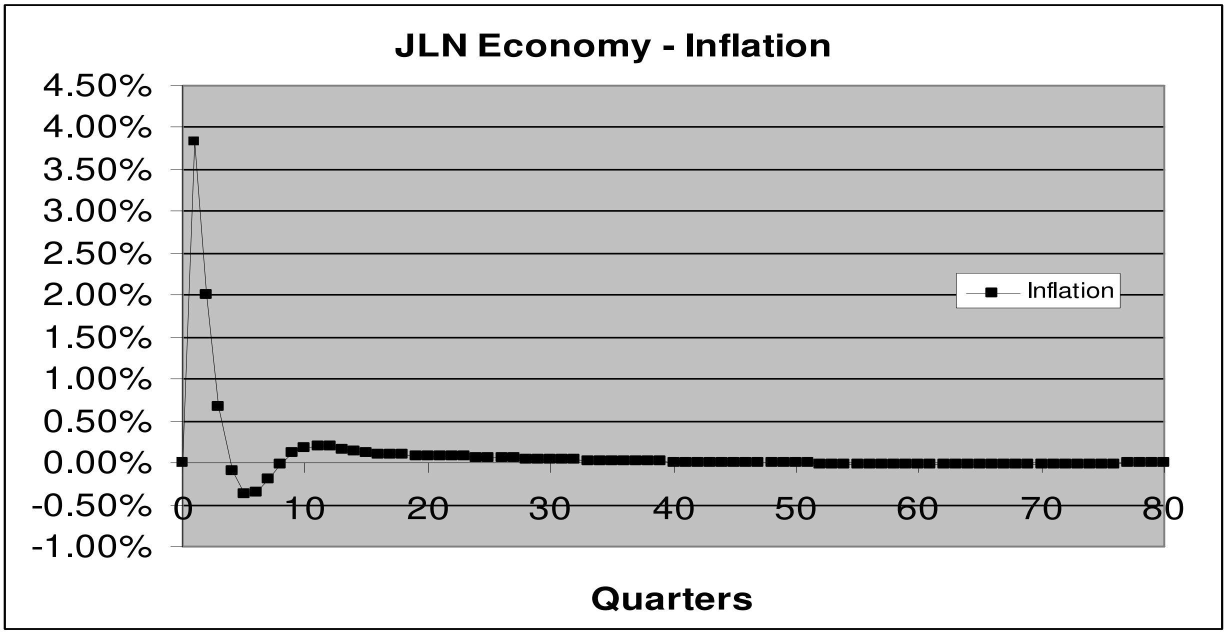

Figure 3

There is then some overshooting in employment, because after employment has recovered, the effective labour ratio ($\frac{K_t}{n_t TFP_t}$) has decreased as capital stock growth has slowed down during the recession. The resulting increase in the marginal product of capital increases capital stock growth above trend, which can be obtained from figure 4. This increases the demand for labour. The path of natural employment shows that this overshooting can be accommodated without an acceleration in inflation. Natural employment increases in line with actual employment because the real wage declines relative to total factor productivity during the recession (see (**??**)). The higher level of employment does then imply higher real wage growth. However, the fact that capital stock growth is above trend puts downward pressure on r_t^k which works to lower marginal costs (see equation (49)) and thus counters the inflationary effect of above trend real wage growth

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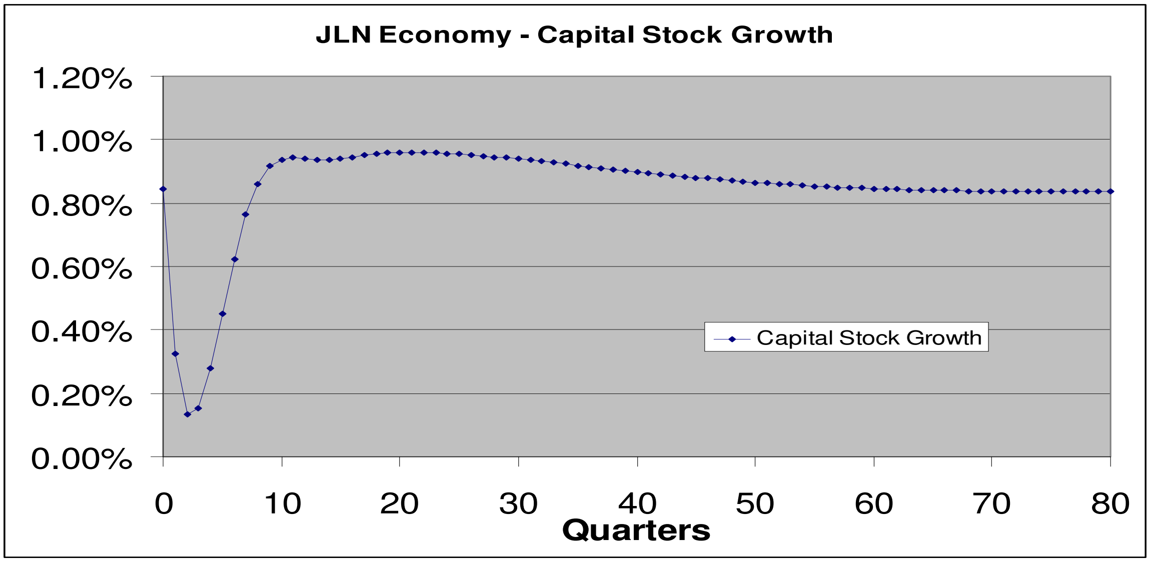

Figure 4

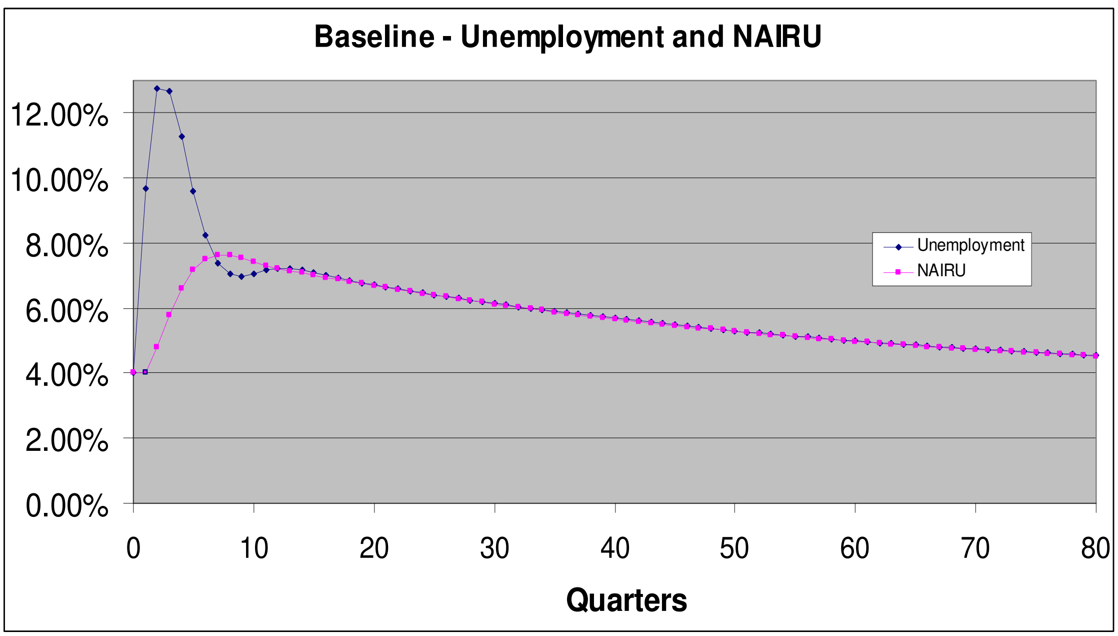

Figure 5

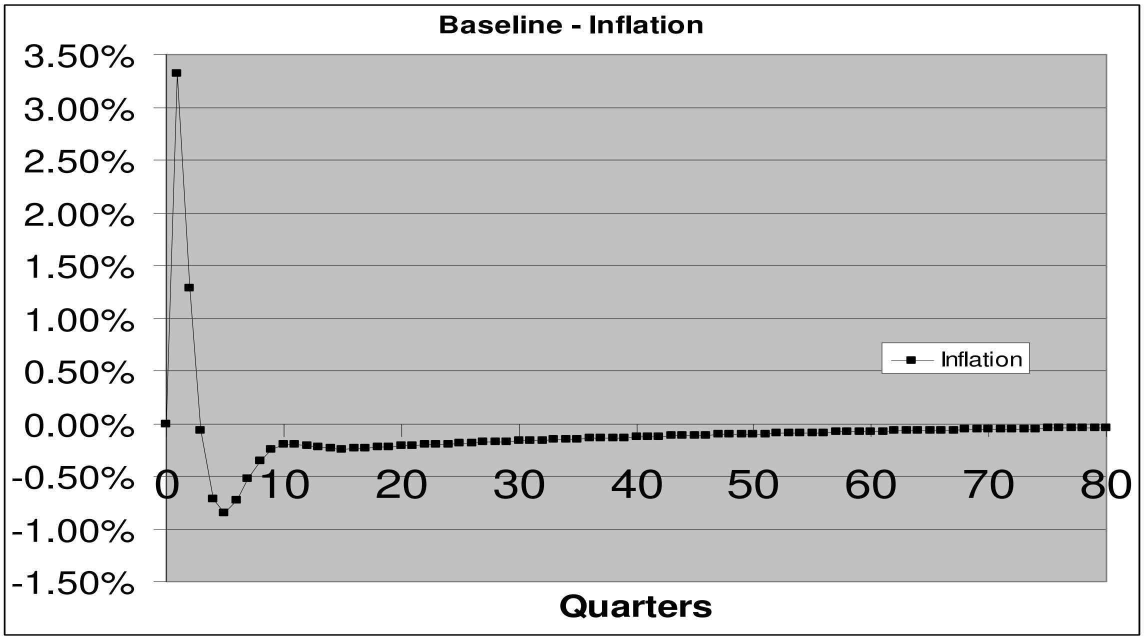

Figure 6

We now turn towards the New Growth economy. Figure 5 plots unemployment and the NAIRU for quarter zero to quarter 80. Unemployment increases by 5.7 percentage points on impact. This is a bit strong, however big on impact jumps are common problem in forward looking models whose solution lies beyond the scope of this paper. It is clear that the shock has far more persistent effect on employment than in the neoclassical model. 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 soon comes to a halt: quarterly increases are now in the order of magnitude 0.06 percentage points per quarter or less. As can be obtained from table 7, after 40 quarters, or 10 years unemployment is still about 1.7 percentage points above its steady state value, while after 60 Quarters (15 years) the difference is still about 1 percentage point. 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 rises above the NAIRU, which gradually increases during and after the recession. A glance at Figure 6 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 equation 55 and the definition of the NAIRU in this model.

Table 7: Baseline -
Unemployment increase with respect to the steady state for selected Quarters

10	20	30	40	50	60	70	80
3.1	2.7	2.2	1.7	1.3	1	0.7	0.5

We know from equation (51) 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 7 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 which 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. Therefore this variable matters a lot for marginal cost, which is also borne out by equation (50). Figure 8, 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.

By contrast, in the neoclassical model, the effect of the capital stock on marginal costs is much weaker. The major determinant of marginal costs apart from real wages, TFP_t, 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. Furthermore, the neoclassical model has an in-built stabilisation mechanism for investment, because unlike in the New Growth economy the marginal product of capital increases in the labour-capital ratio. This is not the case in the New Growth economy, where at the economy wide level, the capital rental depends on employment alone, as can be obtained from equation (49).

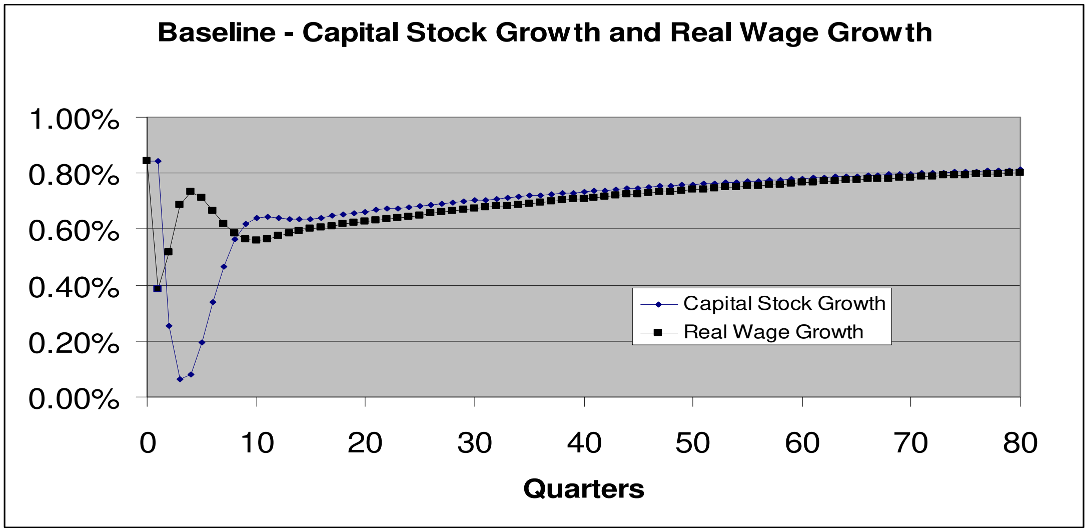

Figure 7

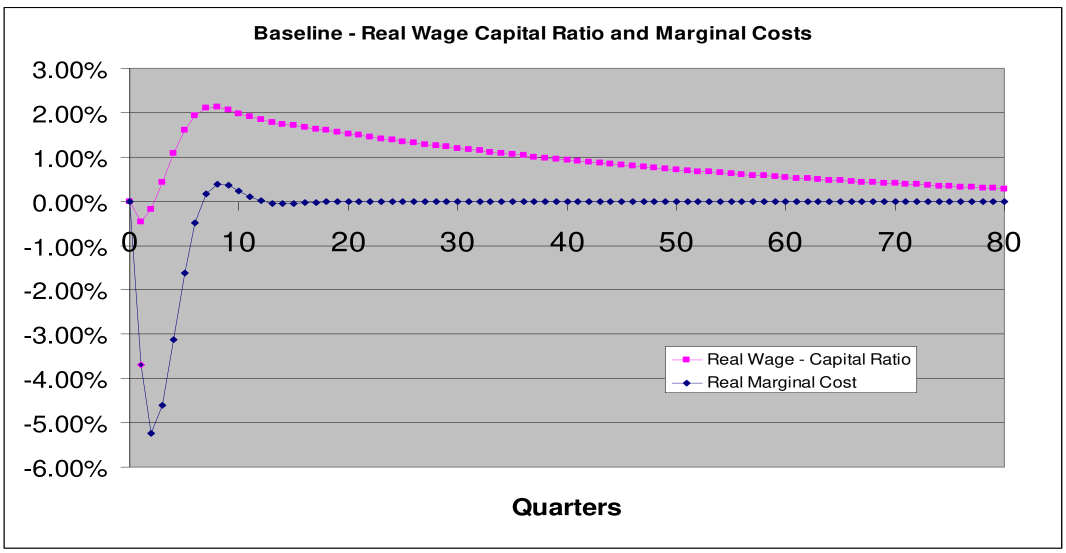

Figure 8

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 would push real wage growth above the growth rate of the capital stock and thus push 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 actual unemployment and inflation starts to pick up. To put it differently, the central bank does not have a reason to boost employment by aggressively lowering interest because although inflation is somewhat below target, the output gap is closed as marginal cost equals its steady state value. Figure 9 shows that the central bank stops lowering the real interest rate (i.e. $E_t(i_t - \pi_{t+1})$) after 8 quarters, when it is 0.45 percentage points (about 0.56 percentage points at an annualised rate) below the steady state value, and begins to tighten again. This is not very expansionary because the capital rental is depressed and expected to remain so, too. Figure 10 summarises the benefits from investing by plotting the present discounted value of an additional unit of capital, q_t (this meaning of q_t can be picked up from equation (43), where the relevant discount factor is the stochastic discount factor of households $\beta\frac{u'(C_{t+1}-Hab_t)}{u'(C_t-Hab_{t-1})}$). Tobin's Q recovers quickly after the shock has passed and reaches its steady state value of one after 5 quarters, then exceeds it's steady state level for . However, this is not sufficiently high to move up the capital stock growth rate quickly because of the presence of investment adjustment costs: The investment first order conditions (43) determine 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 (46), which has declined during the recession and the 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 a higher q_t which in turn would require a lower real interest rate.

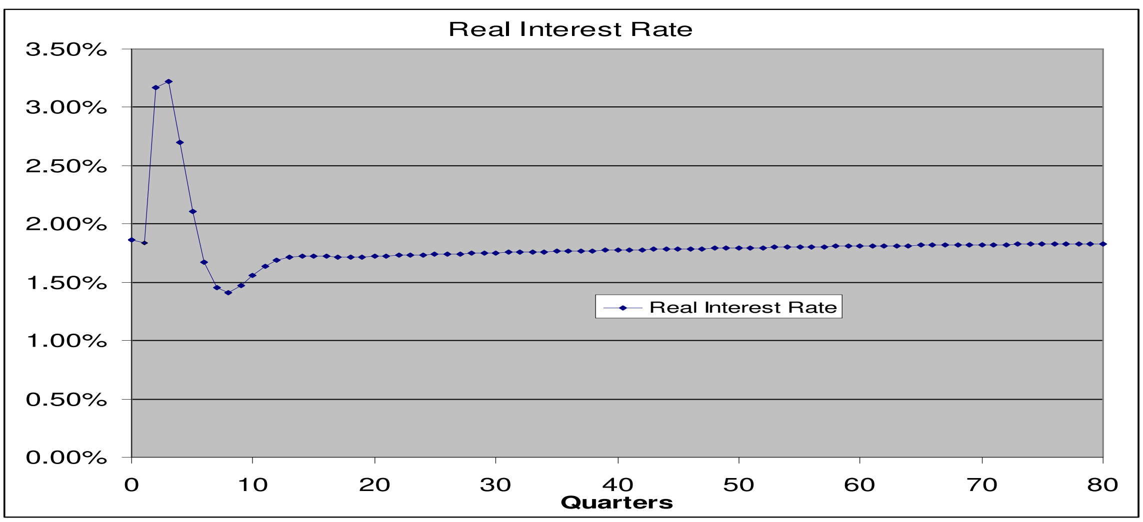

Figure 9

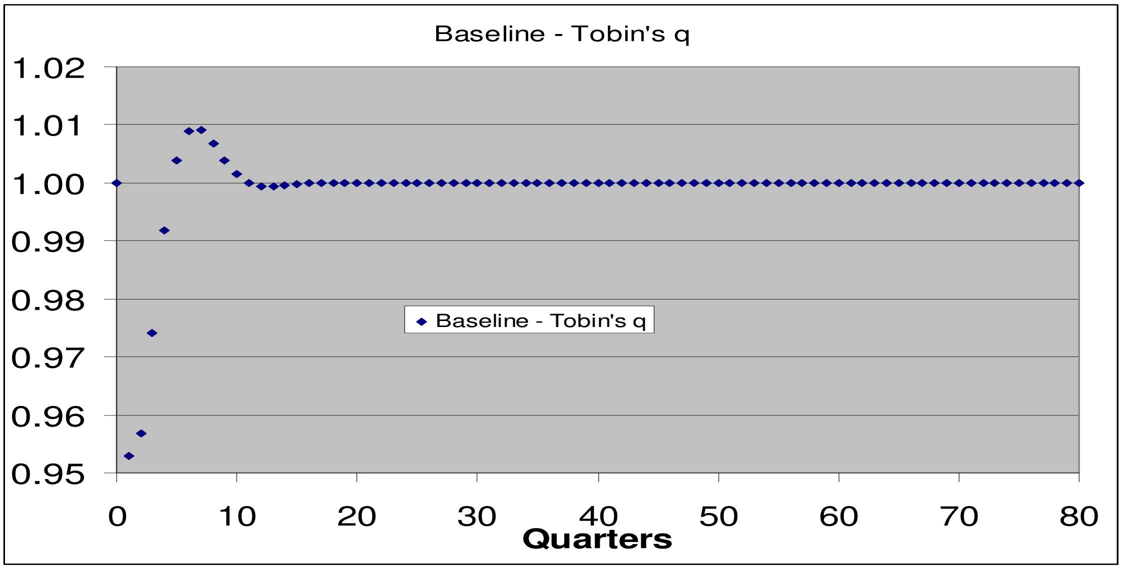

Figure 10

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 very slightly faster than real wages. This causes a slow decline in the wage-capital ratio, as can be obtained from figure 8, and allows for a slow reduction in unemployment because 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.

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, or $\widehat{mc}_t = 0$, has increased. Just as found by Ball, a successful disinflation during which the economy goes into a recession is followed by an increase in the NAIRU. Furthermore, there is also a persistent slowdown in labour productivity growth. It is easily shown that labour productivity growth p_t in the New Growth model can be written as $p_t = \left(\frac{n_{t-1}-\overline{n}-n^s}{n_t-\overline{n}-n^s}\right)^{\alpha}\left(1+\frac{K_t}{K_{t-1}}\right)-1$. Hence if quarterly employment changes are negligible, productivity growth is essentially equal to capital stock growth, implying that, from about quarter 9 onwards, quarterly labour productivity growth can be obtained from figure 6. At this point it falls short of its steady state value by about 0.23% per quarter or 0.92% at an annualised rate, while 40 quarters after the shock it is still about 0.11% lower than in the steady state (0.44% at an annualised rate).

These results provoke the question how changes to the central banks reaction function affects the long-run paths of employment and inflation. Intuition would expect 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 because investment would be squeezed less, implying a smaller decline in capital stock growth which could accommodate higher of non-inflationary employment after the recovery from the recession. Therefore we increase the coefficient on the output gap, ψ_Y, to 5, leaving all other parameters the same. The corresponding evolution of unemployment can be obtained from figure 11. Indeed unemployment not only increases considerably less in the short run (in fact it decreases on impact), but after 40 quarters, it is still about 0.8 percentage point lower than in the Baseline case, as can be obtained from table 8. Hence a less hawkish monetary policy has indeed very long-lasting benign effects on employment. Figure 12 shows that capital stock growth declines less than in the baseline case and that its post-shock plateau value exceeds the corresponding baseline value (in quarter 9) by about 0.05%, or about 0.2% at an annualised rate, and also recovers faster subsequently.

Table 8: $\psi_Y = 5$ - percentage point deviation of unemployment from its Steady State for selected Quarters

10	20	30	40	50	60	70	80
1.8	1.4	1.1	0.8	0.7	0.5	0.4	0.29

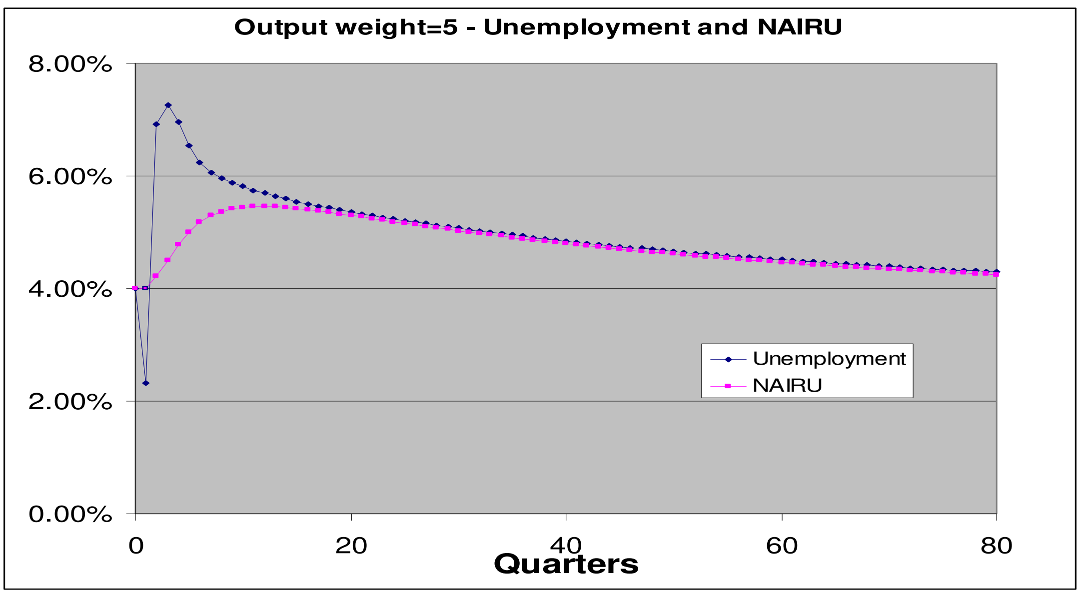

Figure 11

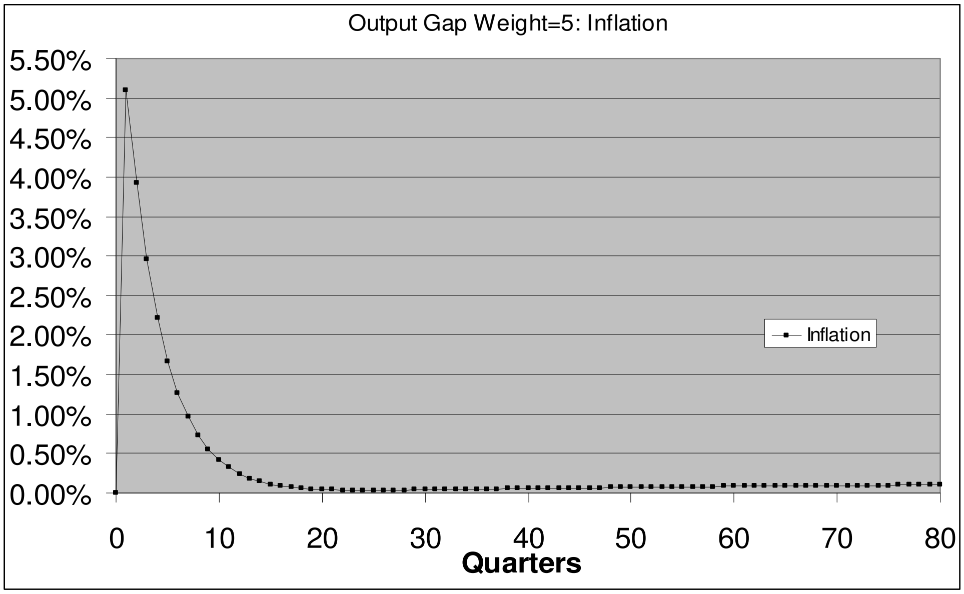

Figure 12

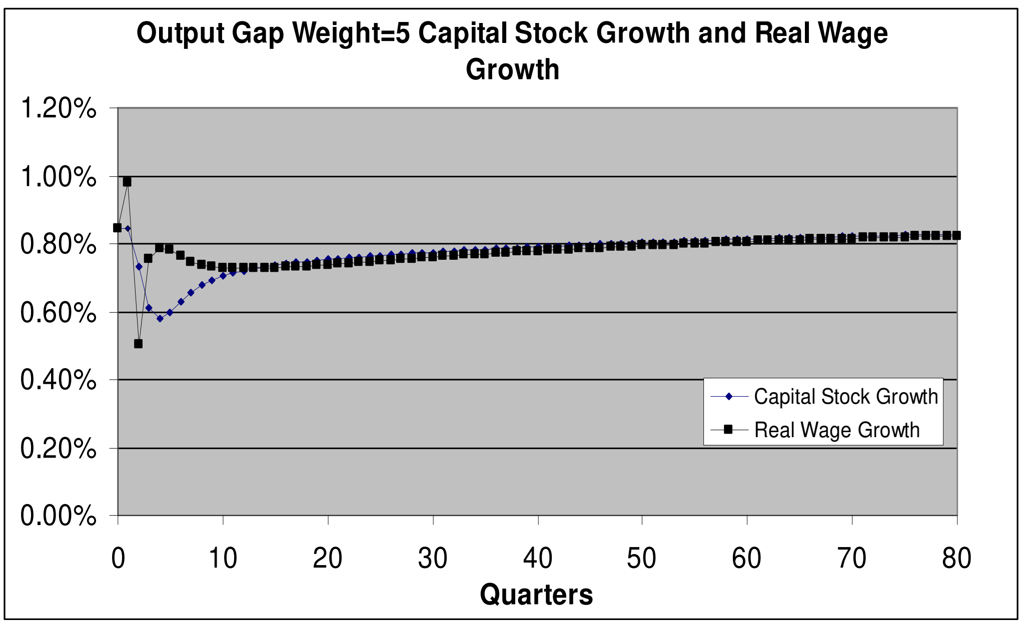

Figure 13

The lower increase in unemployment comes at the cost of a considerably stronger inflation surge during the lifetime of the cost-push shock. While in the baseline simulation, inflation peaks a (quarterly) rate of 3.3%, it now increases as high as 5.1% in the first quarter, as can be obtained from figure 12, 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, while the gain in employment is of more long-run nature. Whether this is desirable or not would require a welfare analysis which is beyond the scope of this paper. However, it is illustrative to summarise the long-run trade-offs policymakers are facing by continuing to vary the output gap coefficient and to plot the resulting average annualised inflation rates against the corresponding average unemployment and natural unemployment rates. This done in Figure 14 over 60 quarters, for values of ψ_Y between 0.3 and 5. Both curves are clearly downward sloping. As with traditional Phillips Curves, both curves become steeper as unemployment becomes lower. The unemployment Phillips Curve is always flatter than the NAIRU-Phillips Curve because monetary policy affects the path of actual unemployment in the short run more strongly than the NAIRU: its slope varies from -0.77 to -2.7 as unemployment falls while the slope of the NAIRU Phillips curve varies from -0.9 to -3.3. Over the range of policy rules considered here, a 1.5 percentage point reduction in the average NAIRU is associated with a 2.4 percentage point increase in inflation. Hence we have, very much contracting conventional wisdom, a trade-off between inflation and unemployment over an extended period of time. By contrast, similar experiments with the neoclassical version only produced the short run trade-off between the variation of inflation and the variation of employment familiar from New Keynesian models. From an empirical point of view, 5 is arguably not a reasonable value for ψ_Y, however we will see in the next section when we turn to the cross country dimension that the effect of an increase in the output gap coefficient depends very much on the form of the policy reaction function. We will use the estimates of Clarida Gali and Gertler (1998) of the policy rule mentioned above for the Bundesbank and the Fed to explore to which the estimated differences in the reaction function coefficients can help to explain the difference in the evolution of unemployment.

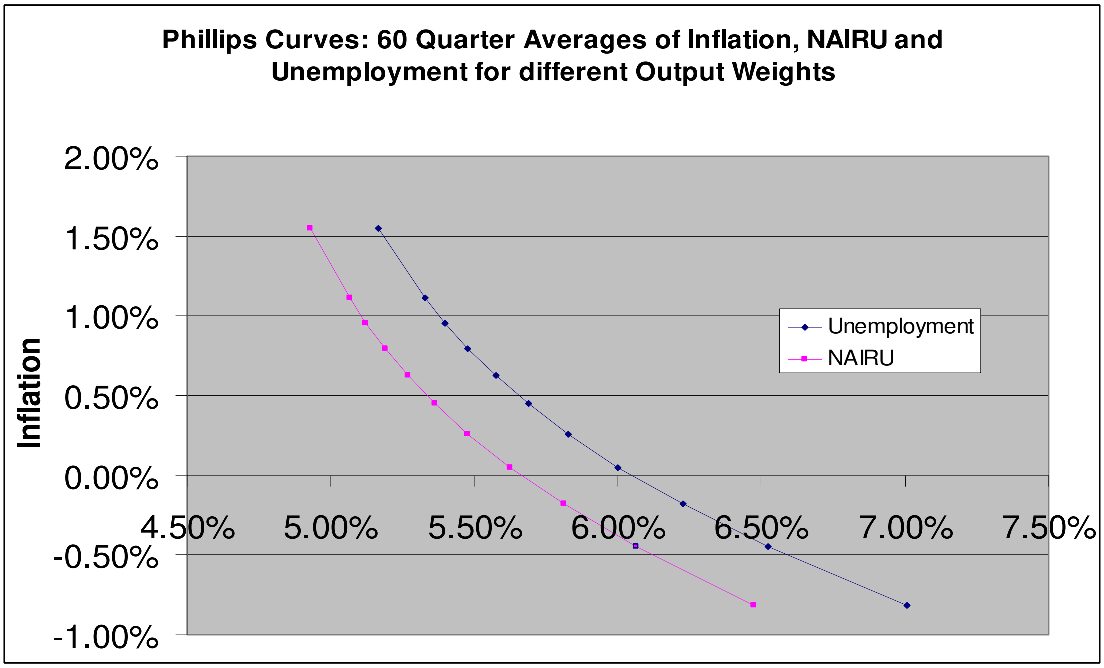

Figure 14

We will next consider how these results change if real wages are less flexible. Intuition would suggest that more flexible wages would cause a less persistent response of unemployment, because any given increase in unemployment leads to a smaller reduction in real wage growth than before, which will mitigate the drop of the capital stock growth rate relative to the real wage growth rate. Hence only a higher rate of unemployment can be accommodated without triggering an acceleration of inflation. Higher unemployment in turn reduces the marginal product of capital, implying less investment, reducing capital stock growth and thus limiting the room for employment expansion.

To investigate the quantitative implications of these mechanisms, we reduce e the slope of the real wage growth function b to 0.07. Figure 15 shows that both actual unemployment and the NAIRU fall much slower than in the baseline case. The maximum NAIRU is about 0.6 percentage points higher than the maximum in the baseline simulation, thus reducing the room for an immediate non-inflationary recovery. As a result, after 40 quarters, as can be obtained from table 9 the deviation from the steady state is 2.5 percentage points as opposed to 1.7 percentage points in the baseline case. Viewing this and the previous results in conjunction clearly lend support to the view that as suggested by Blanchard, it is both "shocks and institutions" which are at the heart of explaining the evolution of unemployment, to the extent that labour market institutions affect real wage flexibility. To the extent that real wage growth is found to be more flexible in the United States than in continental Europe, this results offers an explanation why the increase in American unemployment during the disinflation in the early 1980s has not been sustained. However, as mentioned above, it seems that a robust observable intercontinental difference in real wage rigidity lies in the value of c, the coefficient on the labour share, rather than in the value of b.[62] We will examine the consequences of setting c equal to zero in the following section

Table 9: $b = 0.06$ **- Percentage point Deviation of unemployment from its Steady State for selected Quarters**

10	20	30	40	50	60	70	80
3.6	3.4	2.9	2.5	2.1	1.7	1.4	1.2

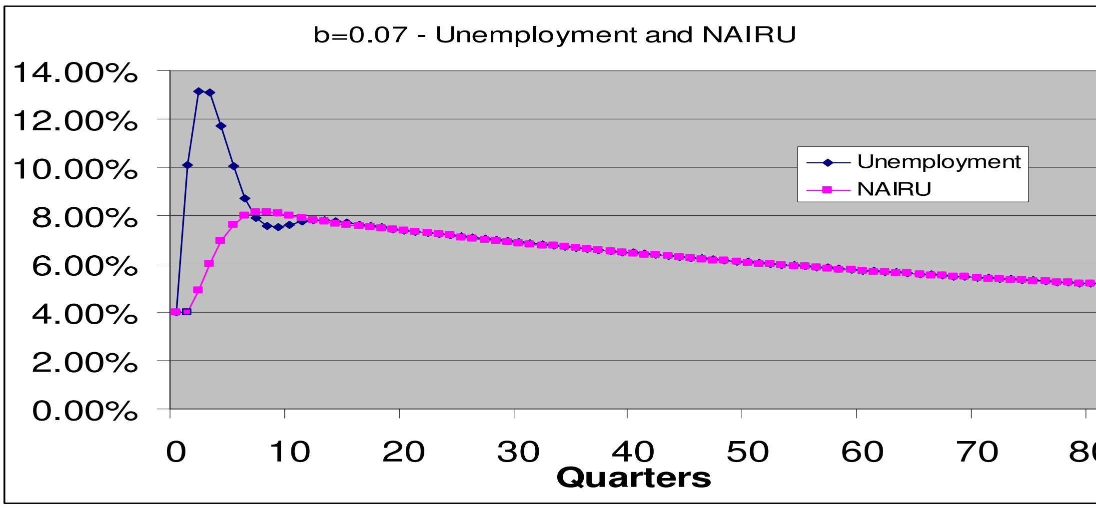

Figure 15

As a final robustness experiment, we change the slope of the adjustment cost function by reducing γ. It is clear and can also be verified from equation (43) that if adjustment cost react slower to $\frac{I_t}{I_{t-1}}$, investment will be less affected by changes in the present value of an additional unit of capital and thus will decrease more in response to a fall in q_t and an increase in the real interest rate, which in turn implies that reductions in employment will have a bigger effect on capital accumulation, too. This would be expected to increase unemployment in the short as well as in the long run. On the other hand, lower adjustment costs also imply that investment growth will by more when interest rates fall and employment recovers. This would be expected to speed up the recovery of employment. Reducing γ from 0.65 to 0.4 generates the employment path displayed in figure 16. As expected, both actual and natural employment decrease by less than in the baseline case and recover more quickly. Accordingly, unemployment increases by more both in the short and in the medium run, as can be obtained from table 10.

[62] See Blanchard and Katz (1999), p.73, and Cahuc and Zylberberg (2004), p.484-486.

Table 10: $\gamma = 0.4$ **- Percentage point Deviation of unemployment from its Steady State for selected Quarters**

10	20	30	40	50	60	70	80
3.8	3.2	2.5	2.0	1.5	1.2	0.9	0.6

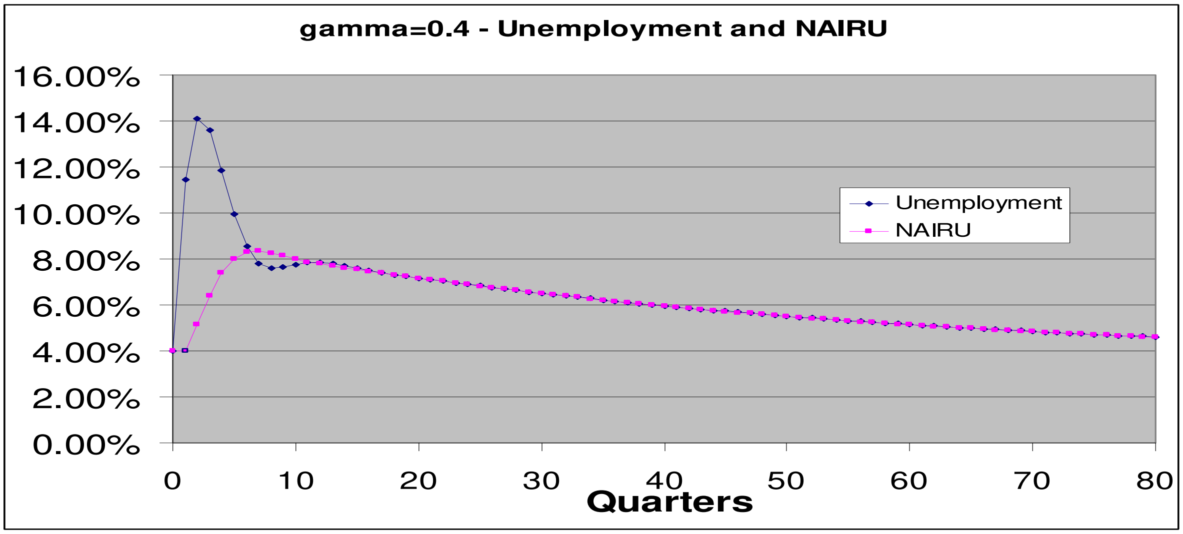

Figure 16

9 Cross Country Aspects

The previous section showed 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 use our model also to (coarsely) replicate differences in unemployment evolutions across countries. We address this issue in three different ways in this section. We take a look at differences in the size of the disinflation across the OECD, the policy reaction function coefficients between the Bundesbank and the Federal Reserve and real wage rigidity.

We have mentioned before that there is an apparent, if not perfect, negative correlation between the change in inflation and the change in the NAIRU. Ball (1996) investigated this for the 1980s and we plotted it earlier over to decades and across 21 OECD countries. We will now vary the size of the disinflation over 10 years, or 40 quarters, in the most simple fashion, namely by varying the size of the cost push shock. Cross country differences in the size of the cost push shock used in our model can be interpreted as differences in the responsiveness to global supply shocks (for instance differences in the dependence on oil in case of an oil price shock), differences in the past record of monetary policy (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), differences in the choice of how much to disinflate (a central bank might just be willing to accept a higher inflation rate) and differently sized exchange rate shocks, or some combination of all of these factors. We are being deliberately unspecific about what exactly creates the difference between the inflation target of the central bank and the actual inflation rate. To generate observations, we vary the size of the cost push shock from 0.01 to 0.05, leaving all other parameters unchanged, and calculate the change from year 1 to year 10 of the inflation rate during those years and the NAIRU during the first quarter of those years, and plot the later against the former in figure 17.[63] There is obviously a clear negative correlation. The slope of the line varies between -0.41 and -0.56, which not too far away from the simple regression coefficient of -0.33 (or -0.36 if like Ball we do not consider Greece) resulting from a regression of the change in the NAIRU on the change in inflation using the OECD data presented earlier.

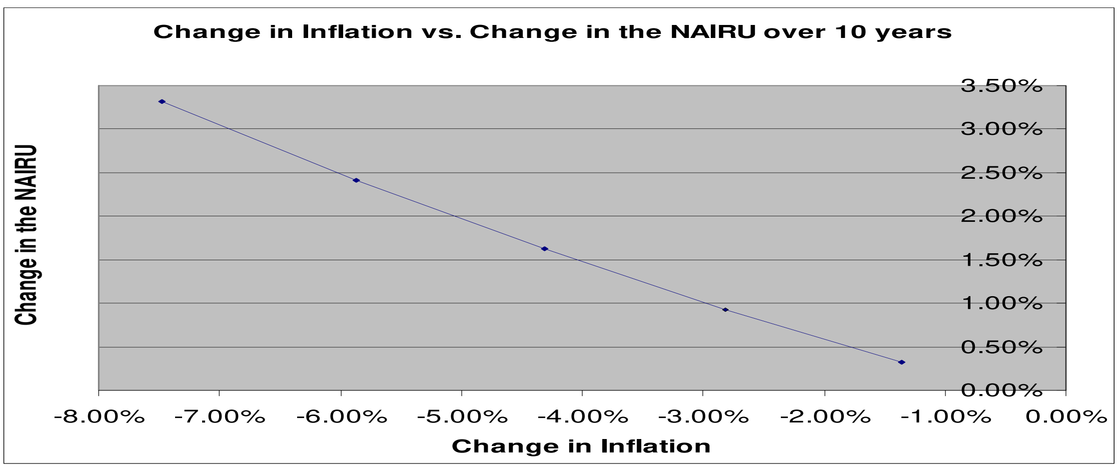

Figure 17

Let us now take a look at the effect of empirical differences in the Policy rule. To get a proper idea of the effects of these it is obviously important to have comparable estimates. Therefore we make use of the fact that Clarida, Gali and Gertler (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 for the reasons given above but to our knowledge, internationally comparable estimates of this kind do not exist. The coefficient estimates of Clarida,

[63]We take the difference of the first quarter of both years since the NAIRU moves up very fast during the first four quarters. Differencing 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.

Gali and Gertler of equation (57) for the Federal Reserve are reproduced in table 11. 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 10 shows the deviation of unemployment from is 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 Gali, and Gertler 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 and estimating 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 40 quarters, or 10 years, unemployment and the NAIRU are about 0.7 percentage points higher under the Bundesbank Rule than under the Federal Reserve rule. It is, however, informative to have a look at the standard errors associated with Clarida, Gali and Gertler's estimate. For instance, the standard error associated with the coefficient on the lagged interest rate ρ has as standard error of 0.03. Thus a value for ρ of 0.06 is still consistent (at a 5% level of confidence) with Clarida, Gali and Gertler's estimate. The third row of table 11 shows the implied evolution of unemployment if we set $\rho = 0.91$. The resulting unemployment trajectory is substantially lower than with the point estimate. After 40 quarters, the unemployment and the NAIRU are now 1.3 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 ψ_Y, which equals 0.16. Increasing ψ_Y to 0.88 yields the employment trajectory shown in the final row of Table 11, which is again lower than with the point estimate: after 40 quarters, unemployment is and the NAIRU are about 1.3 percentage points lower than under the Bundesbank policy rule. Thus in the New Growth model, differences in policy function parameters consistent with the Clarida Gali and Gertler evidence can contribute to explaining the different evolutions of the unemployment rate in Germany as compared to the United States.

Table 10: Coefficient estimates of Clarida, Gali and Gertler for the Federal Reserve.[64]

ψ_π	ψ_Y	ρ
1.83	0.56	0.97

Table 11: Clarida, Gali and Gertler policy rule: Deviation of unemployment from its Steady State

Quarter	10	20	30	40	50	60	70	80
Bundesbank	4.2	4.1	3.2	2.6	2.0	1.6	1.2	0.9
Federal Reserve	3.0	3.1	2.5	1.9	1.5	1.1	0.8	0.6
Federal Reserve, $\rho = 0.91$	2.2	2.1	1.6	1.3	1.0	0.8	0.6	0.4
Federal Reserve, $\psi_Y = 0.88$	2.4	2.4	1.9	1.5	1.1	0.9	0.6	0.5

Finally, we explore the effects of the observed cross continental differences in the nature of real wage rigidity, namely the impact of the labour share term in the wage setting function. Estimating (51) on U.S. data confirms the finding of other researchers that $c = 0$, while the U.S. estimate of b is not significantly different from the value we employed so far (0.08). 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, including the policy rule and its calibration. The resulting deviation of unemployment from its steady state can be obtained from table 12. Clearly, the increase in unemployment is persistently lower: After 40 quarters, unemployment is only 0.6 percentage points higher than in the steady state as compared to 1.7 percentage points in the Baseline. Thus, to the extent that the presence of the labour share term is due to institutional characteristics of the German labour market not explicitly modelled in this paper, our result is in line with Blanchard and Wolfers (2000) finding that both shocks and institutions affect unemployment in the medium run.

The differences in reaction function coefficients and the differences in real rigidity examined here also contribute to explaining why some points in figure 14 are "off the regression line". The three coefficient vectors for the federal reserve investigated here all imply lower NAIRU increases than under the Bundesbank rule but larger disinflations for an equally sized cost push shock, as can be obtained from the first four rows of table 13. Similarly, if we remove the labour share term from the wage setting function in the baseline calibration, the increase in the NAIRU drops but the size of the disinflation over ten years does not.

[64] See Clarida, Gali and Gertler (1998), p. 1045.

Table 12: $c = 0$ **- Percentage point Deviation of unemployment from its Steady State for selected Quarters**

10	20	30	40	50	60	70	80
0.9	1.0	0.8	0.6	0.4	0.3	0.2	0.1

Table 13: Change in the NAIRU vs. change in inflation for various scenarios

	$\Delta\pi_t^{annual}$	$\Delta NAIRU$
CGG, Bundesbank	-0.6	2.50
CGG, Federal Reserve	-3	1.9
CGG, Federal Reserve, $\rho = 0.91$	-9.1	1.2
CGG, Federal Reserve, $\psi_Y = 0.88$	-6.3	1.4
Baseline, $c = 0$	-5.2	0.5

10 Conclusion

This paper is a first pass at overcoming the traditional separation between the short and the long run in modern macroeconomics by integrating a New Growth production technology into a New Keynesian model with unemployment. We first incorporate a model embodying consensus features with respect to the short and medium run effect of a disinflation on unemployment. We then incorporate endogenous growth in this model. We show that within such a framework, what is commonly referred to as the natural rate of unemployment, or the NAIRU, is affected by the interaction of a one quarter cost push shock and monetary policy over a relevant horizon. Within this framework shows a temporary, two year inflationary shock ("cost push shock"), combined with an interest rate rule of the central bank calibrated to an estimate of a Bundesbank reaction function, can cause substantial and very persistent effects on unemployment, without any changes to labour market institutions. Under the baseline calibration, unemployment will still be about 1.7 percentage points above its pre-shock value after about 40 quarters, or 10 years. At the same time, inflation stops declining soon after the cost push shock has vanished. Thus the increase in unemployment represents an increase in the NAIRU.

The increase in the NAIRU is brought about by the decline in investment during the recession required to disinflate the economy. The capital stock, in this endogenous growth economy, has a much stronger effect on marginal costs than in models with a neoclassical production function. Thus, although wage growth declines as employment contracts, marginal cost returns back to their steady state level soon after the shock has vanished, which 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, which is constant, and the output gap, defined as the deviation of output from the level consistent with constant inflation, which is zero.

The model also shows that the central bank faces a trade-off between preventing a strong acceleration of inflation and quickly bringing inflation back to target on the one hand and preventing a persistent increase in unemployment on the other. A higher coefficient on the output gap has substantial and lasting benign effects on the path of employment. We also show that varying the output gap coefficient and plotting the resulting average unemployment rates and NAIRUs against the associated average inflation rates creates a downward sloping Phillips Curves.

Apart from generating a persistent increase in unemployment, the to some extent the model proposed here can also replicate cross country differences. 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 the relationship observed in the data. Using policy rule estimates of Clarida, Gali and Gertler for the Bundesbank and the Federal Reserves suggests a reason for the differences in unemployment performance in these countries. 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 if the function is estimated for U.S. data, helps with that as well: Lower real wage rigidity generates a lower increase in the NAIRU. Thus the paper lends support to the view that, as suggested by Blanchard, it is both "shocks and institutions" which are at the heart of explaining the evolution of unemployment across time and the observed differences across countries.

In addition, a comparison of second moments of the model with German data ranging from 1970 to 1990 shows that the New Growth sticky price model is matching the data of that time period much better than a sticky price model with an identical calibration but with a standard neoclassical production function. In particular, the New Growth sticky price model is much better at matching the observed persistence in important macroeconomic variables like employment, output and consumption, and other second moments as well.

Thus the model can contribute to explaining the evolution of European unemployment during the 1980s and beyond. Rising NAIRUs would be the consequence of the disinflations engineered as a response to the inflationary shocks of the late 1970s, as would be part of the slowdown in productivity growth. It would also explain why, as found by Ball, countries which disinflated less and pursued a more expansionary monetary policy once the economy was on the disinflationary track like the United States experienced smaller or no increases in the NAIRU. To the extent that real wages are more flexible in the United States, this would contribute to reducing the increase in the NAIRU as well.

An obvious extension of the analysis presented here would be to introduce a government and non Ricardian consumers or distortionary taxation to allow for expansionary effects of debt-financed government expenditure. While disinflation was somewhat less an issue in Europe during the 1990s than during the 80s, the "road towards Maastricht" forced those EU countries aiming to adopt the Euro in 1998 to pursue an austere fiscal policy which entailed both reducing budget deficits and the public debt-GDP ratio. By contrast, the Reagan administration hugely increased public debt. While this policy is commonly accepted to have affected employment in the short run, it would be interesting to analyse their potential long run effects within a suitably modified version of the model proposed here.

11 Appendix A - Forward Solution of the Phillips curve

The Hybrid Phillips Curve of this model is

$$\pi_t = \frac{\pi_{t-1}}{1+\beta} + \frac{(\theta-1)\widehat{mc}_t}{\varphi(1+\beta)} + \frac{\beta}{1+\beta} E_t \pi_{t+1} + u_t$$

This can be rearranged to get

$$\pi_t - \pi_{t-1} = \frac{(\theta-1)\widehat{mc}_t}{\varphi} + (1+\beta) u_t + \beta (E_t \pi_{t+1} - \pi_t)$$

Defining $\pi_t - \pi_{t-1} \equiv S_t$, we have a forward looking first order difference equation. Using the forward operator F, which is defined such that $FX_t = X_{t+1}$ we can write

$$(1-\beta F) S_t = \frac{(\theta-1)\widehat{mc}_t}{\varphi} + (1+\beta) u_t{}^{65}$$

Using the fact that $\frac{X_t}{1-\lambda F} = \sum_{i=0}^{\infty} (\lambda^i X_{t+i})$ if $\lambda < 1$, we arrive at

$$\pi_t - \pi_{t-1} = \frac{\theta-1}{\varphi} \sum_{i=0}^{\infty} (\widehat{mc}_{t+i}) + (1+\beta) \sum_{i=0}^{\infty} u_{t+i}$$

12 Appendix B - Normalised Version of the Model

In this appendix we show how the normalisation of C_t, Y_t, I_t and w_t by the capital stock change the aggregate equations of the model. The resulting equations are those which have been simulated. We define $\frac{C_t}{K_t}$, $\frac{hab_{t-1}}{K_t}$ $\frac{Y_t}{K_t}$, $\frac{I_t}{K_t}$ and $\frac{w_t}{K_t}$ as D_t, Hab_{t-1}, F_t, R_t and H_t, while the gross capital stock growth rate $\frac{K_{t+1}}{K_t}$ is defined as $1 + g^k_{t+1}$.

[65] See Leslie (1993), pp.94-95.

12.1 Aggregate demand

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

$$F_t = D_t + R_t + \frac{\varphi}{2}(\pi_t - \pi_{t-1})^2 F_t \tag{58}$$

Consumption

$$\begin{aligned} 1/\left(D_t - Hab_{t-1}\right) &= \beta E_t \left[(1+i_t) / \left((1+\pi_{t+1}) D_{t+1} \left(1+g_{t+1}^k\right)\right)\right] && (59) \\ Hab_{t-1} &= j \frac{D_t}{1+g_{t+1}^K} && (60) \end{aligned}$$

Investment:

$$\beta E_t \left(\frac{1}{\left(D_{t+1} - Hab_t\right)\left(1+g_{t+1}^K\right)} \left(r_{t+1}^k + q_{t+1}(1-\delta)\right) \right) = \frac{1}{D_t - Hab_{t-1}} q \tag{61}$$

$$\frac{1}{D_t - Hab_{t-1}} q_t \left[\left(1 - \frac{\kappa}{2} \left(\frac{R_t}{R_{t-1}} \left(1+g_t^K\right) - (1+g) \right)^2 \right) - \frac{R_t}{R_{t-1}} \kappa \left(\frac{R_t}{R_{t-1}} \left(1+g_t^K\right) - (1+g) \right) \right] \tag{62}$$

$$+\beta E_t \left[\frac{1}{D_{t+1} - Hab_t} q_{t+1} \left(\frac{R_{t+1}}{R_t} \left(1+g_{t+1}^K\right) \right)^2 \kappa \left(\frac{R_{t+1}}{R_t} \left(1+g_{t+1}^K\right) - (1+g) \right) \right] = \frac{1}{D_t - Hab_{t-1}} \tag{63}$$

$$g_{t+1}^K = -\delta + R_t \left[1 - \frac{\kappa}{2} \left(\frac{R_t}{R_{t-1}} \left(1+g_t^K\right) - (1+g) \right)^2 \right] \tag{64}$$

The rental on capital:

$$r_t^k = \alpha mc_t A_t ((n_t - n^s - \overline{n}) \phi_1)^{1-\alpha} \tag{65}$$

12.2 Aggregate supply

Multiplying (49) $\frac{K_t^{\frac{\alpha}{1-\alpha}}}{K_t^{\frac{\alpha}{1-\alpha}}}$

$$mc_t = \frac{F_t^{\frac{\alpha}{1-\alpha}} H_t}{X} \tag{66}$$

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

Wage Setting: $\ln w_t = \ln w_{t-1} + a + b(n_t - \overline{n}) + c\log\left(\frac{w_{t-1}(n_{t-1}-\overline{n}-n^s)}{Y_{t-1}}\right)$ can be rewritten as $\ln H_t = a + b(n_t - \overline{n}) + \left(\frac{w_{t-1}}{K_{t-1}(1+g_t^k)}\right) + c\log((1-\alpha)mc_{t-1}) = a + b(n_t - \overline{n}) + \ln\left(\frac{H_{t-1}}{(1+g_t^k)}\right) + c\log((1-\alpha)mc_{t-1})$

$$H_t = \exp(a + b(n_t - \overline{n}))\frac{H_{t-1}}{(1+g_t^k)}((1-\alpha)mc_{t-1})^c \tag{67}$$

Employment: from $Y_t = A_t K_t((n_t - \overline{n} - n^s)\phi_1)^{1-\alpha}$, we have

$$n_t = \frac{1}{\phi_1 A_t^{\frac{1}{1-\alpha}}} F_t^{\frac{1}{1-\alpha}} + \overline{n} + n^s \tag{68}$$

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. $\rho_{t,t+1} = \beta\frac{u'(C_{t+1}-Hab_t)}{u'(Hab_{t-1})} = \beta\frac{C_t-Hab_{t-1}}{C_{t+1}-Hab_t}$, which gives

$$(1-\theta) + \theta mc_t - \varphi\left(\left(\frac{P_t}{P_{t-1}} - u_t\right) - \frac{P_{t-1}}{P_{t-2}}\right)\left(\frac{P_t}{P_{t-1}} - u_t\right) + \theta\frac{\varphi}{2}(\left(\frac{P_t}{P_{t-1}} - u_t\right) - \frac{P_{t-1}}{P_{t-2}})^2 \tag{69}$$

$$+\beta\frac{D_t - Hab_{t-1}}{F_t}\varphi E_t\left[\frac{F_{t+1}}{D_{t+1} - Hab_t}\left(\frac{P_{t+1}}{P_t} - \left(\frac{P_t}{P_{t-1}} - u_t\right)\right)\frac{P_{t+1}}{P_t}\right] = 0 \tag{70}$$

Replacing $\frac{P_t+i}{P_{t-1}+i} = 1 + \pi_{t+i}$ gives

$$(1-\theta) + \theta mc_t - \varphi((\pi_t - u_t) - \pi_{t-1})(1 + \pi_t - u_t) + \theta\frac{\varphi}{2}((\pi_t - u_t) - \pi_{t-1})^2 \tag{71}$$

$$+\beta\frac{D_t - Hab_{t-1}}{F_t}\varphi E_t\left[\frac{F_{t+1}}{D_{t+1} - Hab_t}(\pi_{t+1} - (\pi_t - u_t))(1 + \pi_{t+1})\right] = 0 \tag{72}$$

Natural output in the two equations determining natural employment and natural output has to be normalised as well. F_t^n, and "natural" employment nn_t,

$$\begin{aligned} \mu^{-1} &= \frac{(F_t^n)^{\frac{\alpha}{1-\alpha}}\exp(a + b(nn_t - \overline{n}))\frac{H_{t-1}}{(1+g_t^k)}}{X_t} \\ F_t^n &= A_t((n_t^n - \overline{n} - n^s)\phi_1)^{1-\alpha} \end{aligned} \tag{73}$$

given last periods wage/ capital ratio H_{t-1} and this periods capital stock growth rate rate g_t^k (which was also determined in the t-1 by the then investment decision). As can be obtained from the equations, both nF_t and natural employment can change over time. In particular, an increase in g_t^k will increase natural employment and nF_t , as it is no possible for firms to accommodate stronger real wage increases. The output gap gp_t is then calculated as

$$gp_t = \frac{Y_t - Y_t^n}{Y_t^n}\left(\frac{K_t}{K_t}\right) = \frac{F_t - F_t^n}{F_t^n} \tag{74}$$

13 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 we make use of the properties of the adjustment cost function and its derivatives in the steady state and apply these to the third of the equations in (43) , which yields $q = 1$.We plug this into the second equation of (43), use log utility assumption and notice that in the steady state all trended variables (including the level of habit and consumption) grow at the same rate g to get

$$\beta\left(r_{t+1}^k + (1-\delta)\right) = (1+g) \tag{75}$$

In the New Growth economy, we now replace the capital rental with equation (48), noting that in the steady state we have $mc = \mu^{-1}$, to arrive at

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

Clearly, g is increasing in n.

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 concave in employment. It is straightforward to show that the real wage implied by the desired mark-up grows at the same rate as output and the capital stock by using $mc_t = \mu^{-1}$ on 50. This yields

$$\begin{aligned} w_t &= K_t\phi_1\left(\frac{\mu^{-1}A\alpha^\alpha(1-\alpha)^{1-\alpha}}{\left(r^k\right)^\alpha}\right)^{1/(1-\alpha)} && (76) \\ \Delta\ln w_t &= \Delta\ln K_t = g && (77) \end{aligned}$$

Hence in the steady state, the real wage has to grow at the same rate as the capital stock. This means that equation 76 is in effect 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 its 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 76 with the wage setting function 19, making againg use of the fact that $mc = \mu^{-1}$. In practice, as was mentioned above, 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 α and $\overline{n}$.

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

$$F = A((n - \overline{n} - n^s)\,\phi_1)^{1-\alpha} \tag{78}$$

from the production function. For R_t, we have from the capital accumulation equation in (43)

$$R = g + \delta \tag{79}$$

D can then be determined as a residual via

$$D = F - R \tag{80}$$

H is computed using the cost-minimisation first order condition for labour (15)

$$H = (1-\alpha)\mu^{-1}\frac{F}{n - \overline{n} - n^s} \tag{81}$$

r^k is computed via

$$r^k = \alpha\mu^{-1}A((n - \overline{n} - n^s)\,\phi_1)^{1-\alpha} \tag{82}$$

The steady state value of i_t is computed from 42 (noting that in the steady state we have zero inflation and that both habit and consumption grow at the steady state growth rate)

$$i = \frac{1+g}{\beta} - 1 \tag{83}$$

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

14 Appendix D: Normalised Version of the Neoclassical Model

Most of the equations from Appendix B just carry over to the neoclassical model. However, there are a few changes related to the production function and the marginal cost equation. The aggregate production function is now $Y_t = AK_t^{\alpha}\left(TFP_t\phi_1\left(n_t - \overline{n} - n^s\right)\right)^{1-\alpha}$. Dividing both sides by K_t gives

$$F_t = \left(l_t\phi_1\left(n_t - \overline{n} - n^s\right)\right)^{1-\alpha} \tag{84}$$

where l_t is defined as $\frac{TFP_t}{K_t}$. This variable evolves according to

$$l_t = \frac{1 + g_{TFP}}{1 + g_t^K} l_{t-1} \tag{85}$$

In the neoclassical model, it 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 neoclassical model. Denoting $\frac{w_t}{TFP_t}$ as H_t^{nc}, we have from (49), after making use of (47)

$$mc_t = \frac{F_t^{(\alpha/(1-\alpha))} H_t^{nc}}{A^{1/(1-\alpha)} (1-\alpha) \phi_1} \tag{86}$$

Concerning the capital rental, we employ the neoclassical expression for F_t to have

$$r_t^k = \alpha m c_t A l_t^{1-\alpha} \left((n_t - \overline{n} - n^s) \phi_1 \right)^{1-\alpha} \tag{87}$$

Finally, the normalised wage setting becomes

$$H_t^{nc} = \exp(a + b (n_t - \overline{n})) \frac{H_{t-1}^{nc}}{(1 + g_{TFP})} \left((1-\alpha) m c_{t-1} \right)^c \tag{88}$$

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 83, while we compute r^k from 75. From 88, we have the steady state employment rate. Setting $mc_t = \mu^{-1}$in 87 then gives the steady state value for l_t as

$$l = \frac{1}{(n_t - \overline{n} - n^s) \phi_1} \left(\frac{r^k \mu}{\alpha A} \right)^{1/(1-\alpha)} \tag{89}$$

which allows us to compute F from 84. Rearranging 86 then gives H^{nc}.

15 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 from then on data for the unified country. All data is taken from a publication of the German "Statistisches Bundesamt", all of which has been seasonally adjusted.[66] When

[66] See Statistisches Bundesamt (2006) and Statistisches Bundesamt (2007a).

estimating the function, we replace the employment rate with one minus the unemployment rate. As a measure for labour costs, we the "Arbeitnehmerentgeld" per hour worked, which is employee compensation including the full tax wedge. This is deflated using the GDP price index. To construct the labour share we use We then estimate $\Delta \log w_t = a + b * Unemploymentrate_t + c \log (LS_{t-1}) + d92Q1$, where LS_{t-1} denotes the previous periods labour share in GDP, that means total nominal compensation (i.e. total "Arbeitnehmerentgeld") divided by total nominal GDP. $d92Q1$ denotes an intercept dummy equalling one in 1992Q1 and zero everywhere else. The later is again to account for reunification. We tried a slope dummy as well but it was not significant. We use two stage least squares to account for the possible endogeneity of employment. As instruments, we choose $\Delta \log \text{real}\, wage_{t-1}, unemploymentrate_{t-1}$ (following again Danthine/Kurman (2004)), c and $d92Q1$.[67]

As was already mentioned above, we exclude the period from 1970q1 to 1974Q4 because this was a time of extreme union militancy. During this period, there are five observations for real wage growth exceeding 2%, which are much higher than in the remainder of the sample. Fit (as measured by the adjusted R^2) strongly improves when we exclude those observations, and the result also becomes more efficient as the standard error strongly decreases. 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, U denotes the unemployment rate.

[67] See Danthine/ Kurman (2004), p. 121.

Table E1
Dependent Variable: WG
Method: Two-Stage Least Squares
Date: 06/03/08 Time: 12:27
Sample (adjusted): 1970Q3 2000Q4
Included observations: 122 after adjustments
Newey-West HAC Standard Errors & Covariance (lag truncation=4)
Instrument list: WG(-1) C U(-1) LOG(LS(-2)) D92Q1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.042273	0.018893	-2.237531	0.0271
U	-0.120587	0.046582	-2.588689	0.0108
LOG(LS(-1))	-0.089599	0.032530	-2.754342	0.0068
D92Q1	-0.112300	0.002188	-51.33630	0.0000

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. Note that this 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, implying a very high steady state risk less rate. Furthermore, a reduction in hours worked, which is the variable in the model is in reality not reflected one for one in an increase in unemployment. Regressing unemployment on log hours for the time period of 1970 to 1991q4 yields a coefficient of around 0.5. However, using detrended logarithmised hours to estimate the wage setting function does not yield significant results. 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 falls short of the calibrated coefficient is due to the fact that we have experimented with different computations of the labour share in GDP, i.e. one based on nominal values, which is the one used in the table and one based on real values. The later computations methods generated a value slightly higher than the 0.1 we had used in the simulations. However robustness checks show that a reduction of c by 0.01 has only a small effect and therefore we do not feel it necessary to redo all simulations discussed in the paper.

For the United States, we estimate the wage setting equation using the BLS series on real hourly compensation, BLS series PRS85006153, to calculate $\Delta \log w_t$, the seasonally adjusted unemployment rate, series LNS14000000Q, nominal GDP from the BEA NIPA table 1.1.5 and total nominal employee compensation from the BEA NIPA table 2.1. In order to get a significant coefficient on the unemployment rate, we were forced to include five years more than in our estimate for Germany, and we thus started in 1965. The result can be obtained from Table E2. As expected, the LS is not significant, which was result robust to adding and excluding observations. Re estimating the equation after dropping $\log(LS_{t-1})$ leads to an almost unchanged estimate of the coefficient on the unemployment rate. Note that the coefficients on the unemployment rate in Germany is not statistically different from the coefficient estimated for the U.S. at any reasonable level of confidence.

Table E2
Dependent Variable: WG
Method: Least Squares
Date: 06/03/08 Time: 16:03
Sample: 1965Q1 2000Q4
Included observations: 144
Newey-West HAC Standard Errors & Covariance (lag truncation=4)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005364	0.033562	0.159838	0.8732
U	-0.066995	0.033021	-2.028888	0.0444
LS	0.003206	0.059322	0.054043	0.9570

R-squared	0.030102	Mean dependent var	0.003202
Adjusted R-squared	0.016345	S.D. dependent var	0.006138
S.E. of regression	0.006088	Akaike info criterion	-7.344412
Sum squared resid	0.005226	Schwarz criterion	-7.282541
Log likelihood	531.7977	F-statistic	2.188064
Durbin-Watson stat	1.642216	Prob(F-statistic)	0.115927

Table 13
Dependent Variable: WG
Method: Two-Stage Least Squares
Date: 06/03/08 Time: 13:15
Sample: 1965Q1 2000Q4
Included observations: 144
Instrument list: WG(-1) C U(-1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
U	-0.067605	0.032425	-2.084951	0.0389
C	0.007253	0.002008	3.612856	0.0004

R-squared	0.030069	Mean dependent var	0.003202
Adjusted R-squared	0.023238	S.D. dependent var	0.006138
S.E. of regression	0.006067	Sum squared resid	0.005226
F-statistic	4.347020	Durbin-Watson stat	1.643279
Prob(F-statistic)	0.038864		

16 Appendix F: Construction of the Dataset used in the Moment Comparison

This appendix explains the construction of the dataset for F_t, D_t, R_t and H_t. The German federal statistical office ("Statistisches Bundesamt") supplies annual data for the capital stock in constant prices of the year 2000.[68] Thus we had to construct quarterly observations for the capital stock. We decided on the following method. We first calculated the annual change. Than we allocated the total changed to the four quarters according to the share these quarters had in real gross fixed investment.

Our data on real output, consumption and investment expenditure was preferably also to be in prices of 2000. However, the Statistisches Bundesamt only supplies chained indices for these variables.[69] We therefore used nominal GDP, consumption and investment 2000 to recursively calculate our series in absolute numbers. As the indices for post and pre reunification years have different bases, we used the ratio of unified Germany to Western Germany from 1991 to downscale the index for each variable. Furthermore, as the total labour force in our model is normalised to one, Output, consumption and investment are essentially expressed in per capita terms in our model. As a measure of the size of the labour force we use a linear trend which we fit to total hours. Our empirical measure of F_t is then given by output/(capital*trend hours), and analogously for D_t and R_t. H_t is computed using the real wage data also employed in the previous section (now expressed in prices of 2000).

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