The Real Effects of Money Growth in Dynamic General Equilibrium

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Abstract

Dynamic New Keynesian models generally ignore steady state money growth. Within a standard New Keynesian framework, we show that the interaction between staggered nominal contracts and money growth leads to a long-run trade-off between output and money growth that is significant, and remains so when the contract length is endogenised. We show that the existence of the tradeoff depends crucially on a phenomenon we call employment cycling: firms' substitution among different labor types over the course of the contract period. We discuss the plausibility of this phenomenon and show that when it is absent, money becomes super-neutral.

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1 Introduction

Although dynamic general equilibrium (DGE) models with nominal rigidities have become standard in the macroeconomic literature,[1] these models usually neglect money growth, as their dynamics are derived from linearizations around a steady state in which the money supply is constant. In practice, of course, the money supply in market economies is usually growing. Thus it is important to inquire whether the presence of money growth would change the properties of these models.

The central long-run issue is whether the classical dichotomy holds in the long run, i.e. whether real variables (such as output, employment or unemployment) are independent of the inflation rate in the long run. Most textbook models of the Phillips curve[2] presuppose this property, thereby making the Phillips curve consistent with a NAIRU or natural rate of unemployment. By contrast, the standard DGE models with nominal rigidities, commonly based on Calvo pricing, lead to a New Keynesian Phillips curve of the form $\pi_t = \beta E_t \pi_{t+1} + \gamma y_t + \varepsilon_t$, where π is inflation, y is output, β is the discount factor, ε_t is an error term, and E_t is the expectations operator. Although the long run inflation-output tradeoff implied by this Phillips curve is not vertical, the mainstream view is that it is negligibly close to vertical, since the discount factor is close to unity in practice.

This paper indicates that the tradeoff between inflation and real variables could be significant, depending on the calibration of the underlying DGE model.

This issue is of central importance to macroeconomics. There is a broad consensus in the current macroeconomic literature that real phenomena can be analyzed independently of nominal phenomena in the long run; and this helps explain the appeal of the New Neo-Classical Synthesis and the NAIRU hypothesis. The purpose of this paper is to examine whether this consensus rests on tenuous foundations.

As far as we are aware, the only studies which examine the influence of steady-state money growth in a DGE framework are Ascari (1998, 2000) and Devereux and Yetman (2002). Whereas they find that steady-state output and employment are indeed affected by money growth, they do not examine the microeconomic mechanisms leading to this result. This paper identifies the various channels whereby money growth affects the real economy in the long run, and explores the influence of each. This provides an intuitive understanding of the determinants of the long-run tradeoff between real variables and inflation.

In particular, we analyze a DGE model with staggered wage contracts (of the Taylor (1980a) type). An analogous analysis, with the similar qualitative conclusions, can be derived for Taylor price contracts and for Calvo wage and price contracts (see Graham

[1] Recent surveys include Goodfriend and King (1997), Roberts (1997), Estrella and Fuhrer (1998), Mankiw (2000), and Gali (2002).

[2] See, for example, Blanchard and Fischer (1989) and Romer (1996).

and Snower (2003)). Our results may be summarized as follows.

- First, we show that, for a given length of nominal wage contracts, real variables are not independent of inflation. This is so even though we make the standard assumptions that agents have rational expectations, there is no money illusion, and there are no permanent nominal rigidities.

- Second, the long-run relation between real variables and inflation does not disappear when the contract frequency is endogenous.

- Third, we show that, in the context of a standard DGE model with nominal rigidities, the relation between real variables and inflation depends on three basic phenomena: (i) "employment cycling:" firms' ability to substitute among different labor types over the contract period, (ii) "labor supply smoothing:" households' preference for stable employment paths (rather than ones that are intertemporally volatile), and (iii) time discounting: households have a positive rate of time preference. Time discounting generates a positive relation between output and inflation, whereas employment cycling and labor supply smoothing give rise to a negative relation.

- Fourth, we show that, for standard calibrations of the model's parameters, the time discounting effect is dominant at low inflation rates, but the employment cycling and labor supply smoothing effects come to dominate at higher inflation rates. Thus the employment-inflation relation is upward-sloping at low inflation rates and downward-sloping at high inflation rates. The same is true of the output-inflation tradeoff.

- Fifth, employment cycling plays a central role in generating the employment-inflation and output-inflation tradeoffs. In particular, we show that when this phenomenon is absent, real variables become independent of inflation. The plausibility of this phenomenon will be discussed below.

The intuition underlying our results is reasonably straightforward. In our model, households are differentiated by labor types, which are imperfect substitutes in firms' production functions, i.e. there are diminishing returns to each labor type. Thus each household faces a downward-sloping demand curve for its labor type. The households are divided into wage-setting cohorts. Different cohorts set their nominal wage at different times, and each cohort holds its nominal wage fixed over a given contract period. The wage is set so as to maximize the household's utility over the contract period, given its labor demand curve.

When the money supply grows, the aggregate price level rises through time. Since the nominal wage of each cohort is fixed, its real wage is relatively high at the beginning of the contract period (when the price level is relatively low) and relatively low at the end of that period (when the price level is relatively high). Since there are diminishing returns to each labor type, each firm has an incentive to demand relatively little of the household's labor at the beginning of the contract period, and relatively much at the end. Moreover, since the contract periods are staggered, cohorts with relatively high real wages (whose contracts have been set recently) are matched by cohorts with relatively low real wages (whose contracts have been set some time ago). Thus each firm keeps substituting among different labor types, in response to the swings in relative real wages. This is the employment cycling phenomenon.

In practice, employment cycling is of course much more likely to occur in form of hours variations than through hiring and firing. There is evidence that overtime work is sensitive to the wage, and thus it seems plausible that a limited degree of employment cycling may occur when a significant degree of inflation occurs over the contract period, so that significant variations in the real wage take place over this period. It is a well-known empirical regularity that, as the aggregate inflation rate rises, relative prices become more volatile, and this phenomenon is often taken to be the origin of a major real cost of inflation. The inefficiency of employment cycling could possibly be viewed as a simple analytical characterization of this cost.

The faster the money supply grows, the greater is the steady state inflation rate (since in the long run the two are equal we use the terms interchangeably). Thus the greater are the fluctuations of a cohort's real wage over a given contract period, and the more employment cycling the firms will do. Since the different labor types are imperfect substitutes, more employment cycling means lower average productivity of labor (i.e. a lower ratio of output to the total number of workers employed by the firm). On this account, higher inflation is associated with lower output and employment.

Next, observe that firms' employment cycling implies that households' supply of labor services is not constant through time. If a household's marginal disutility of labor rises with the amount of labor supplied, implying a preference for labor supply smoothing, then employment cycling makes the household worse off. To compensate the household for this welfare loss, it requires a higher wage. The faster the money supply grows (and thus the higher the inflation rate and greater the degree of employment cycling), the higher is the real wage that the household sets, for a given average supply of labor over the contract period. The higher the real wage, the lower is the firm's demand for the household's labor. Thus, once again, higher inflation is associated with lower employment, and thus lower output as well.

Finally, under staggered wage setting, the current contract wage depends on the current price level (which prevails at the beginning of the contract period) and the expected future price level (which prevails later in the contract period). If the households' rate of time preference is positive, then the contract wage is influenced more strongly by the current price level than the expected future price level. Thus, the faster the money supply grows, the more the contract wage lags behind the price level; consequently, the lower is the average real wage over the contract period. The lower the real wage, the more labor will firms demand. In this way, discounting generates a positive relation between inflation and employment (and the corresponding output).

The overall degree to which real variables depend on inflation clearly depends on the relative strengths of the employment cycling and labor supply smoothing effects (on the one hand) and the discounting effect (on the other). At low rates of inflation, there is little employment cycling and thus the supply of labor services is reasonably stable through time. Consequently the discounting effect is dominant, so that output is positively related to inflation in the long run. But at higher inflation rates, employment cycling becomes more pronounced and thus the supply of labor services becomes more volatile over the contract period. When these effects become dominant, output becomes negatively related to inflation in the long run.

These results hinge crucially on employment cycling because, as noted, when this phenomenon is absent, it can be shown that there is no long-run relation between real variables and inflation.

The remainder of this paper is organized as follows. Section 2 presents our underlying DGE model with staggered wage setting under an exogenously given contract period. Section 3 derives results and discusses in detail the intuition behind them. In section 4 we allow the wage contract period to be determined endogenously, and show that a long-term relationship between real and nominal variables continues to exist. To explore the central role of employment cycling in our analysis, Section 5 examines the relation between real variables and inflation in the absence of such cycling (e.g. because employment adjustment costs are sufficiently high to discourage firms from varying employment over the contract period). Section 6 concludes.

2 The model

The model consists of three types of agent. First, there is a continuum of households supplying differentiated labor. Second, a large number of identical firms produce a homogeneous output by means of labor, as described by a production function in which the households' labor types are imperfect substitutes. Third, a government prints money and real bonds, and rebates the seigniorage proceeds to households as a lump sum.

Each household makes its wage and employment decisions in a decentralized way, facing a downward-sloping labor demand curve for its services. The households are grouped into N wage-setting cohorts, and each cohort sets a nominal wage contract for N periods. Wage setting is staggered, with different cohorts setting wages at different periods, spread uniformly through time.

2.1 Firms

Firms produce a homogeneous output and there is perfect competition in the product market. Each firm uses all labor types in a CES production function:[3]

$$y_t = n_t = \left[\int_{h'=0}^{1} n_t \left(h'\right)^{\frac{\theta_n - 1}{\theta_n}} dh' \right]^{\frac{\theta_n}{\theta_n - 1}} \tag{1}$$

where y_t is output, $n_t(h)$ is the amount of labor chosen from household h and θ_n is the elasticity of substitution between different labor types. This production function is linear in composite labor n_t. Since all firms are identical, we normalize the number of firms to one (the representative firm).

The representative firm's cost-minimization leads to a downward-sloping demand curve for each household's labor (see Dixit and Stiglitz (1977)):

$$n_{t+i}(h) = \left(\frac{\mathsf{W}_t(h)}{\mathsf{W}_{t+i}} \right)^{-\theta_n} y_{t+i} \tag{2}$$

where $\mathsf{W}_t(h)$ is the wage set by household h. The corresponding aggregate wage index is W_{t+i} is a wage index defined as

$$\mathsf{W}_t = \left[\int_{h'=0}^{1} \mathsf{W}_t \left(h'\right)^{1-\theta_n} dh' \right]^{\frac{1}{\theta_n - 1}} \tag{3}$$

2.2 Households

Suppose that at time $t = 0$ household h resets its nominal wage, to be held constant for N periods. Let c_t be its consumption of goods, W_t its nominal wage, M_t its nominal money holding, P_t the aggregate price index, R_t the gross nominal interest rate on its bond holdings B_t, T_t its net lump-sum transfers from government, and Π_t its profit income. It

[3] We use the following notational convention:

	nominal	real
trended	X_t	x_t
detrended	X_t	x_t
steady state	X	x
linearized	$\hat{X}_t$	$\hat{x}_t$

x_t refers to an aggregate variable, $x_t(f)$ and $x_t(h)$ to the value of that variable for a specific firm or household.

faces the following problem

$$\max_{\{c_{t+i},\mathsf{W}_t(h),B_{t+i},\mathsf{M}_{t+i}\}} E_t \sum_{i=0}^{N-1} \beta^i U\left(c_{t+i}(h), n_{t+i}(h), \frac{\mathsf{M}_{t+i}(h)}{\mathsf{P}_{t+i}}\right) \tag{4}$$

subject to series of budget constraints

$$\underbrace{\mathsf{P}_{t+i}c_{t+i}(h) + \mathsf{B}_{t+i+1}(h) + \mathsf{M}_{t+i+1}(h)}_{\text{expenditure}} = \tag{5}$$
$$\underbrace{\mathsf{W}_t(h)\, n_{t+i}(h) + R_{t+i}\mathsf{B}_{t+i}(h) + \mathsf{M}_{t+i}(h) + \mathsf{T}_{t+i}(h) + \Pi_{t+i}(h)}_{\text{income}}$$

and the downward-sloping demand curve for the household's labor

$$n_{t+i} = \left(\frac{\mathsf{W}_t(h)}{\mathsf{W}_{t+i}}\right)^{-\theta_n} y_{t+i} \tag{6}$$

We choose a utility function that has desirable long-run properties (see King, Plosser and Rebelo (1988))[4]

$$U\left(c_t, n_t, \frac{\mathsf{M}_t}{\mathsf{P}_t}\right) = \log c_t(h) + \varsigma \frac{(1 - n_t(h))^{1-\eta}}{1-\eta} + V\left(\frac{\mathsf{M}_t(h)}{\mathsf{P}_t}\right) \tag{7}$$

Deriving first order conditions and rearranging gives an expression for the household's optimal wage

$$\mathsf{W}_t^*(h) = \frac{\varsigma\theta_n}{\theta_n - 1} \frac{E_t \sum_{i=0}^{N-1} \beta^i (1 - n_{t+i}(h))^{-\eta} n_{t+i}(h)}{E_t \sum_{i=0}^{N-1} \beta^i \frac{n_{t+i}(h)}{c_{t+i}(h)\mathsf{P}_{t+i}}} \tag{8}$$

Thus the optimal contract wage is equal the marginal disutility of labor supplied as a result of setting a particular wage, weighted by the average marginal utility of consumption over the period the wage is chosen for.

The government's budget constraint is

$$\mathsf{B}_{t+i+1} + \mathsf{M}_{t+i+1} = R_{t+i}\mathsf{B}_{t+i} + \mathsf{M}_{t+i} + \mathsf{T}_{t+i}$$

where B, M, and T are the aggregate amounts of bonds, money, and net transfers.

We let households smooth consumption over the contract period.[5] We focus on behav-

[4] This is a special case of the more general utility function proposed by King, Plosser, and Rebelo (1988), with a coefficient of relative risk aversion of unity. While this assumption is not innocuus in general (see Graham (2003)) it does not affect our results significantly, but greatly simplifies the presentation

[5] This could be rationalized through perfect credit markets or, equivalently, by assuming that households mutually insure one another by exchanging bonds.

ior in the steady state, where profits are zero ($\Pi_{t+i}(h) = 0$, due to perfect competition in the product market) and $B_{t+i+1}(h) + M_{t+i+1}(h) = R_{t+i}B_{t+i}(h) + M_{t+i}(h) + T_{t+i}(h)$. Thus the household's smoothed consumption $\overline{c}_t(h)$ per period is equal to average real wage income per period:

$$\overline{c}_t(h) = \frac{1}{N} E_t \sum_{i=0}^{N-1} \beta^i \frac{W_t^*}{P_{t+i}} n_{t+i}(h) \tag{9}$$

Substituting this into the contract wage (8) and assuming a symmetric equilibrium in which all households resetting their wage at time t make identical decisions we obtain:

$$E_t \sum_{i=0}^{N-1} \beta^i (1 - n_{t+i})^{-\eta} n_{t+i} = \frac{N(\theta_n - 1)}{\varsigma\theta_n} \tag{10}$$

Intuitively, the optimal contract wage sets the present value of the marginal disutility of labor (the left side of this equation) equal to the corresponding present value of the marginal utility of consumption (the right side of the equation). Since households smooth consumption but not employment, the present value of the marginal disutility of labor depends on time discounting, but the present value of the marginal utility of consumption does not. In fact, the latter present value is constant. Thus, the optimal contract wage is set so that the present value of the marginal disutility of labor over the contract period remains constant through time.

2.3 The steady state

Since we are concerned with the long run relation between real variables and inflation, we let the steady-state growth rate of money be a constant,

$$\mu = \frac{M_{t+1}}{M_t} \tag{11}$$

so that different steady-state values of money growth identify different points on the real variable-inflation tradeoff.

To derive the influence of money growth on real variables, it is convenient to detrend all nominal variables with respect to the money supply. (This detrending process is familiar from the real business cycle literature (King, Plosser and Rebelo (1988)), although of course the trend being removed there is one of technology growth.) For example, the wage index W_{t+i} detrended to time t is

$$W_{t+i} = \frac{W_{t+i}}{M_t} = \frac{W_{t+i}}{M_{t+i}} \frac{M_{t+i}}{M_t} = W_{t+i}\mu_t^{t+i} \tag{12}$$

where μ_t^{t+i} is expected money growth between time t and time $t + i$, W_{t+i} is the detrended wage, and W_{t+i} is its trended counterpart. In the steady state this becomes

$$\frac{\mathsf{W}_{t+i}}{\mathsf{M}_t} = \mathsf{W}_{t+i}\mu^i \tag{13}$$

Consequently the detrended wage index (3) is

$$W_t = \left(\frac{1}{N}\sum_{i=0}^{N-1}\left(W^*_{t-i}\mu^{-i}\right)^{1-\theta_n}\right)^{\frac{1}{1-\theta_n}}$$

Thus, in the steady state, the ratio of the contract wage to the aggregate wage is

$$\frac{W^*}{W} = \left(\frac{1}{N}\frac{1-\mu^{N(\theta_n-1)}}{1-\mu^{\theta_n-1}}\right)^{\frac{1}{\theta_n-1}} \tag{14}$$

Observe that steady-state money growth uniquely determines the ratio of the contract wage to the aggregate wage (given the parameters of the model).

The household's labor supply function (10) determines steady-state household labor supply. Given this labor supply and the wage ratio (14), we obtain aggregate steady-state output y from the labor demand function (6). In short, (6), (10) and (14) comprise a system of three equations in the three unknowns $(n\,(h),\frac{W^*}{W},y)$ which define the steady state of the system. We solve this system numerically.[6]

3 Results

We calibrate our model with standard values: the annual real interest rate is 4%; the elasticity of labor substitution is $\theta_n = 5$; the contract period is one year. There are 52 wage-setting cohorts,[7] so that each week one cohort sets its nominal wage and then keeps it fixed for a year. Furthermore, we let households' preferences over leisure be linear, $\eta = 0$ meaning that households are indifferent to the path of labour supplied . Although there is little doubt that the marginal disutility of labor rises with the amount of labor provided per working day, it seems doubtful that most people have strong preferences in favor of labor smoothing over their wage contract period. On the contrary, many people prefer to bunch their overtime work, in order to make room for free time (shopping days, holidays). The intertemporal substitution of labor relevant to our analysis is that which occurs over the contract period, and in this context there may be little preference for labor smoothing[8].In any case, our results under positive values of η are given in the next section.

[6] Details of the solution method are available from the authors on request

[7] The results are quite insensitive to the number of cohorts.

[8] In the real business cycle literature, $\eta = 0$ in the indivisible labor case. This is straightforwardly reconcilable with our argument that employment cycling takes place primarily in terms of hours variations. After all, a one-year wage contract period is sufficiently long to permit workers to bunch their labor services

Figure 1 shows aggregate steady-state employment and output (on the vertical axis) for different values of steady-state money growth (on the horizontal axis). Observe that employment increases monotonically with money growth. Thus if we define unemployment as the difference between total available labor time and employment, we obtain a downward-sloping Phillips curve in inflation-unemployment space. Note, however, that output is positively related to steady-state inflation (money growth) at low inflation rates, but negatively related at higher inflation rates. In other words, the output-inflation tradeoff is backward-bending.

[Figure 1 here]

3.1 Intuition

To gain an intuitive understanding of these relations, consider the simple case in which there are just two wage-setting cohorts ($N = 2$) and each nominal wage is set for two periods. Let cohort 0 set its wage at time t while cohort 1 sets its wage at time $t + 1$. Suppose that steady-state money growth - and thus steady-state inflation - is positive. Since the price level rises from period to period whereas each cohort's nominal wage is readjusted every second period, it follows that each cohort's real wage is high at the beginning of its contract period and low at the end of it. Specifically, at time t, the real wage of cohort 0 is high and that of cohort 1 is low, and vice versa at time $t + 1$.

The firm at time t has a relatively low demand for cohort 0 and relatively high demand for cohort 1, and vice versa at time $t + 1$. This substitution towards labor types with low real wages (and away from labor types with high real wages) is the essence of what we have called *employment cycling.*

Since different labor types are imperfectly substitutable, employment cycling is inefficient in the sense that, for given aggregate employment n, more employment cycling is associated with lower aggregate output. The greater is steady-state inflation rate, the more employment cycling firms do, and thus the lower the average productivity of labor. In this way, the employment cycling effect leads to a negative relation between output and inflation.

To see this formally, note that since aggregate output y is linear in aggregate employment n, the aggregate wage W is equal to the aggregate price level P. Thus, by the wage ratio (14), the real contract wage of the cohort that sets its wage in period t (namely, cohort 0) is

$$\frac{W_t^*(0)}{P_t} = \left(\frac{1 + \mu^{\theta_n - 1}}{2}\right)^{\frac{1}{\theta_n - 1}} \tag{15}$$

over the contract period even though these services may come in discrete units.

Substituting this into the labor demand function (6), we obtain

$$n_t(0) = \left(\frac{1+\mu^{\theta_n - 1}}{2}\right)^{\frac{-\theta_n}{\theta_n - 1}} y_t \tag{16}$$

For a given employment level $n_t(0)$, we can see that the higher the rate of money growth μ (and thus the higher the inflation rate), the lower will be the corresponding level of aggregate output y_t. This is the employment cycling effect.

The other determinant of the relation between real variables and inflation curve is the *time discounting effect.*[9] By (8), observe that, for a two-period contract, the optimal contract wage $W_t^*(h)$ is a weighted average of the current price level P_t and the future price level P_{t+1}. The lower the discount factor β (i.e. the higher the discount rate), the smaller the weight on the future price relative to the present one. Thus, the faster the money supply grows, the more the contract wage lags behind the average price level over the contract period, i.e. the lower the average real contract wage over the contract period. As a result, the firm employs more labor and produces more output over the contract period, *ceteris paribus.*

Another view of discounting effect emerges from the labor supply function (10). Recall that this implies that the household sets its contract wage so that the present value of the marginal disutility of labor is a constant. Thus, the lower the discount factor β, the more labor it supplies over the contract period. Formally, note that whereas cohort A's real contract wage and employment at time t are given by (15) and (16), respectively, its real contract wage and employment at time $t+1$ are

$$\frac{W_{t+1}^*(A)}{P_{t+1}} = \frac{1}{\mu}\left(\frac{1+\mu^{\theta_n - 1}}{2}\right)^{\frac{1}{\theta_n - 1}} \tag{17}$$

and

$$n_{t+1}(A) = \mu^{\theta_n}\left(\frac{1+\mu^{\theta_n - 1}}{2}\right)^{\frac{-\theta_n}{\theta_n - 1}} y_{t+1} \tag{18}$$

Substituting the employment equations (16) and (18) into the labor supply function (10) and recalling that steady-state output is constant, we obtain

$$n_t(A)\left(1+\beta\mu^{\theta_n}\right) = k \tag{19}$$

Thus aggregate employment is

$$n = n_t(A) + n_t(B) = n_t(A) + n_{t+1}(A) = \frac{k\left(1+\mu^{\theta_n}\right)}{1+\beta\mu^{\theta_n}} \tag{20}$$

[9] Note that since households' preferences over leisure are linear, there is no labor supply smoothing effect

For positive real interest rates ($\beta < 1$) this expression is increasing in μ so steady state employment increases with money growth.

Putting the employment cycling and discounting effects together, we find that as money growth (and steady-state inflation) increases, employment rises (due to the discounting effect) but output for any given level of employment falls (due to employment cycling). At low inflation rates, there is little employment cycling, and thus the discounting effect dominates. As result, there is a positive long-run relation between output and inflation. However, at higher inflation rates, firms engage in lots of employment cycling, and once this cycling effect dominates, the long-run relation between output and inflation turns negative.

3.2 Linearizations

Since we are working in the familiar framework of Taylor contracts, it is instructive to obtain a wage setting equation which we can compared with that in Taylor (1980a). To do this, consider a simplified case where there are just two cohorts i.e. $N = 2$. Substituting (6) into (10) and linearizing gives a wage-setting equation:

$$k_0 \hat{W}_t^* = \frac{1}{1+\beta} k_1 \hat{W}_{t-1}^* + \frac{\beta}{1+\beta} \left(1 - k_1\right) \hat{W}_{t+1}^* - k_2 \hat{\mu}_t - k_3 \hat{\mu}_{t+1} + k_3 \left(\hat{y}_t + \beta \hat{y}_{t+1}\right) \tag{21}$$

where

$$k_1 = \frac{\mu^{\theta_n - 1}}{1 + \mu^{\theta_n - 1}} \tag{22}$$

$$k_0 = \frac{1-\beta}{1+\beta} k_1 + \frac{\beta}{1+\beta} \tag{23}$$

$$k_2 = \frac{1}{1+\beta} k_1 \tag{24}$$

$$k_3 = \frac{1}{\theta_n \left(1+\beta\right)} \left(1 - k_1\right) \tag{25}$$

This is a microfounded analogue of Taylor (1980a) wage-setting equation.

Consider first the case of $\mu = 1$, i.e. we are linearizing around a steady state money growth of zero. Then the wage setting equation becomes

$$\hat{W}_t^* = \alpha \hat{W}_{t-1}^* + \left(1 - \alpha\right) \hat{W}_{t+1}^* - \left(2\alpha - 1\right) \hat{\mu}_t + \frac{1}{\theta_n} \left(\hat{y}_t + \beta \hat{y}_{t+1}\right) \tag{26}$$

where

$$\alpha = \frac{1}{1+\beta} \tag{27}$$

In the long-run steady state, $\hat{W}_t^* = \hat{W}_{t-1}^* = \hat{W}_{t+1}^*$, $\hat{\mu}_t = \hat{\mu}_{t+1} = \hat{\mu}$ and $\hat{y}_t = \hat{y}_{t+1} = \hat{y}$ so the equation simplifies to a long-run relation between output and money growth:

$$\hat{y} = \theta_n \frac{1-\beta}{1+\beta}\hat{\mu} \tag{28}$$

and since $\beta < 1$ output is positively related to money growth. This is the case examined in Graham and Snower (2002). It isolates the discounting effect, because in the absence of inflation there is no employment cycling.

Now consider the general case in which money growth need not be zero. Then, given that steady-state inflation is equal to money growth ($\widehat{\pi} = \widehat{\mu}$), the long-run relation between output and inflation is

$$\hat{y} = 2\theta_n \left(\frac{\mu^{\theta_n - 1}}{1 + \mu^{\theta_n - 1}} - \frac{\beta\mu^{\theta_n}}{1 + \beta\mu^{\theta_n}} \right) \widehat{\pi} \tag{29}$$

Note that the term $\frac{\beta\mu^{\theta_n}}{1+\beta\mu^{\theta_n}}$ increases faster with μ than does the first term $\frac{\mu^{\theta_n-1}}{1+\mu^{\theta_n-1}}$, so that the output-inflation relation is positive at low inflation rates, but negative at high inflation rates. For $\beta = 0.98$ (corresponding to a real interest rate of 4% per year), the change-over occurs at a steady-state inflation rate of 6%.

3.3 Sensitivities

The key parameters of the model are (a) the discount factor, $\beta = \frac{1}{1+r}$, where r is the real interest rate, (b) the elasticity of substitution between different labor types, θ_n, and (c) the elasticity of labor supply, η. Let us consider the sensitivities of the relation between real variables and inflation to each of these parameters in turn.

3.3.1 The Interest Rate

Figure 2 shows the sensitivity to the real interest rate r for the indivisible labor case. The greater is r, the stronger is the time discounting effect. Thus, for any positive money growth rate, the more the contract wage lags behind the average price level over the contract period, and this leads the firms to employ more labor and produce more output. In Figure 3, consequently, increases in the real interest rate move the employment-inflation and output-inflation curves upwards.

[Figure 2 here.]

3.3.2 The Intertemporal Substitution

Consider a more general utility function in which the elasticity of utility with respect to leisure may be greater than unity: $\eta > 0$. In that case, households have a preference for smoothing their labor through time. Figures 3a and 3b show how steady-state employment and output vary with money growth for several illustrative values of η. Observe that increases in the elasticity η shift the steady-state employment-inflation and output-inflation curves downwards. Even raising η from zero to 0.2 significantly reduces the range over which employment and output rise with money growth and the output-inflation relation turns negative at a lower inflation rate.

[Figures 3 here]

The reason is what we have called the *labor-supply smoothing effect.* Due to employment cycling, individual households cannot provide a constant stream of labor services through time. Since the marginal disutility of labor rises with labor, these fluctuations in hours worked makes them worse off. In response, they set their contract wage so as to ensure that they supply less labor, on average, over the contract period. Greater money growth leads to greater employment cycling, and thus lower average labor supply and, via the production function, lower output. In this way, the labor-supply smoothing effect imparts a negative relation to the steady-state employment-inflation tradeoff and, via the production function, to the output-inflation tradeoff.

To see the intuition underlying this result, consider the case of two wage-setting cohorts ($N = 2$) and set $\beta = 1$ to eliminate the discounting effect. Then the labor supply function (10) becomes

$$(1 - n_t)^{-\eta} n_t + (1 - n_{t+1})^{-\eta} n_{t+1} = k \tag{30}$$

Note that the present value of the marginal disutility of labor (the right side of this equation) is convex in labor, so the household prefers to smooth its labor through time. Equation (30) indicates that the greater the difference between n_{t+1} and n_t (i.e. the greater the degree of employment cycling), the lower the average level of employment over the contract period. Thus, in the absence of the discounting effect, the employment-inflation relation is always negative, on account of the labor-supply smoothing effect.

Furthermore, output falls faster than employment as money growth increases, since the effect of money growth on output depends not only on the labor-supply smoothing effect, but also on employment cycling.

There is always a region around zero money growth where discounting effects dominates leading to an increase in labor and output with money growth, but this region is tiny for the standard calibrations.

3.3.3 Elasticity of Substitution in Production

Figure 4 shows sensitivity to the elasticity of substitution in production, θ_n. Increasing θ_n has two effects. First, different labor types become closer substitutes and thus a given amount of employment cycling is associated with higher output. In other words, holding the degree of employment cycling constant (i.e. constant variation of employment over the contract period), an increase in θ_n raises output.

[Figure 4 here]

Second, an increase in θ_n induces the firm to raise employment cycling, since it is now less costly to substitute among labor types over the contract period. For a given degree of labor substitutability in production, an increase in employment cycling leads to a fall in output, since different labor types are imperfect substitutes.

For the above calibrations of the other parameters, it turns out that for all but very low rates of inflation, the second effect dominates the first. Thus in Figure 4 the output-inflation curve is shifted downwards.

Moreover, the employment-inflation curve shifts upwards, because the greater is the degree of cycling, the stronger is the time discounting effect.

3.3.4 The Contract Multiplier

Our analysis indicates that the contract multiplier has a negligible influence on the long-run response of real variables to money growth. In other words, changing the number of wage-setting cohorts, while holding the length of the contract period constant, has little effect on the long-run employment-inflation and output-inflation relations.[10] What matters for the long-run relation between real and monetary variables, as we will see in the following section, is the length of the contract period, rather than the degree of staggering.

3.3.5 The Influence on Unemployment

Table 1 shows the percentage change in the long-run unemployment rate when money growth is raised from zero to 4 percent, for different values of the interest rate (r) and the elasticity of substitution in production (θ_n). For this purpose, the steady-state unemployment rate was taken to be 5 percent. The low values of θ_n (up to 10) correspond to the usual microeconomic parameterizations, whereas the high values (over 10) correspond to parameter values backed out from standard macro estimates of Taylor wage equations (e.g. Taylor (1980b) and Sachs (1980)).

[Table 1 here]

As we can see, the interest rate and the elasticity of substitution in production are complementary in their effect on the unemployment rate[11].

[10] In a related area, Chari, Kehoe and McGrattan (1996) show that the contract multiplier has a negligible effect on the persistence of real effects from temporary monetary shocks. Note, of course, that this persistence is a different phenomenon from the slope of the long-run relation between real and nominal variables, investigagted here.

[11] Note that the values in this table apply approximately for endogenous N

4 Endogenising the Frequency of Nominal Adjustments

Thus far we have assumed that the frequency of nominal adjustments (the length of the wage contract period) remains constant regardless of the rate of money growth. In this regard, our analysis is susceptible to a version of the Lucas critique, since agents may have an incentive to set wages more frequently as the rate of money growth rises. We now consider the following question: When the frequency of nominal adjustments is endogenised, does the long-run tradeoff between inflation and real variables disappear, so that a NAIRU or natural rate (of output, employment, etc.) is restored? Our answer, perhaps surprisingly, is no.

Intuitively, our analysis generates a tradeoff between real variables and inflation on account of a nominal rigidity (wage staggering). But if an increase in inflation leads agents to adjust wages more frequently, then the nominal rigidity falls as inflation rises. If the nominal rigidity were to fall sufficiently wages would become fully flexible and the tradeoff between real and nominal variables would be eliminated. We will show, however, that this does not happen unless inflation is extremely high. In the absence of hyper-inflation, the real and monetary sides of the economy remain inextricably interdependent.

To model the frequency of nominal adjustments, we now allow households to choose the length of their wage contract period (N), assuming there is a fixed cost F to changing wages. In practice, this fixed costs generally involves much more than a negotiation cost (e.g. the cost of the time spent negotiating, the expected cost of a breakdown in negotiations, etc.), since wage adjustment are typically accompanied by performance and salary reviews. Formally, the household's problem is to choose N so as to maximize its discounted stream of utility, subject to its constraints:[12]

$$\max_N \sum_{j=0}^{\infty} \sum_{i=Nj}^{(N-1)(j+1)} \beta^i \left[\log c_{t+i} + \varsigma \frac{(1-n_{t+i})^{1-\eta}}{1-\eta} - F \right] \tag{31}$$

subject to the budget constraints (5) and the labor demand functions (6).

Note that in the steady state this becomes an infinite sum of identical N period problems, so it can be rewritten as:

$$\max_N \frac{1}{1-\beta^N} \left[\sum_{i=0}^{N-1} \beta^i \left(\log c_{t+i} + \varsigma \frac{(1-n_{t+i})^{1-\eta}}{1-\eta} \right) - F \right] \tag{32}$$

[12] In this problem, the household splits the future into a series of N-period problems. The first N-period problem is $\sum_{i=0}^{N-1} \beta^i \left[\log c_{t+i} + \varsigma \frac{(1-n_{t+i})^{1-\eta}}{1-\eta} - F \right]$, the second problem is $\sum_{i=N}^{2(N-1)} \beta^i \left[\log c_{t+i} + \varsigma \frac{(1-n_{t+i})^{1-\eta}}{1-\eta} - F \right]$, and so on, to the infinite future. The household then choose the size of the partition N so as to maximize the present value of its utility. See Devereux and Yetman (2002) for an analogous problem.

which can be solved numerically.

We calibrate the fixed cost by assuming that at a steady state inflation rate of 4%, wages are set for one year. This is roughly in line with the evidence given by Backus (1984), Benabou and Bismut (1987), Levin (1991), and Taylor (1993, 1998).[13]

Solving the model for an elasticity of labor supply $\eta = 0$, we obtain Figure 5a. These results are striking and may be summarized as follows.

[Figure 5a here]

First, that *the endogenisation of the contract period has not eliminated the long-run relation between inflation and real variables.* The reason is that changing wages is costly, in real terms. Specifically, the higher the rate of money growth (and the higher the associated rate of steady-state inflation), the more employment cycling firms do and the lower the average employment over the contract period for any given contract wage. The household can reduce employment cycling and raise average employment over the contract period (for any given contract wage) by reducing the contract length. This is the household's benefit from reducing the contract length N in response to an increase in steady-state inflation. However, reducing N means expending the fixed cost F more frequently. Consequently, when steady-state inflation rises, the contract period does not fall by enough to eliminate the tradeoff between inflation and real variables.

[Figure 5b here]

Figure 5b shows the effect of endogenising N for a wider range of inflation. At sufficiently high rates of inflation, the output-inflation and employment-inflation relations eventually bend backward so that a further increase in money growth *reduces* employment. At money growth rates that are substantially higher, the benefits of wage adjustment become so large relative to the costs that wages and prices become perfectly flexible, and there is no longer a trade off between real variables and inflation. However, this outcome only obtains under extreme hyper-inflations.

Second, *when the contract period is endogenous, a rise in steady-state inflation rate leads to shorter contracts and, as a result, the employment-inflation relation becomes weaker (closer to the horizontal axis) than when the contract period remains constant.*

[13]Much of this evidence is indirect, in the sense that it is inferred from autocorrelation functions of aggregate wage data. Direct evidence on the union sector in the US, presented in Taylor (1983) and Cecchetti (1984), suggest longer average contract periods. However, much more work needs to be done in exploring the frequency of wage and price change.

When the frequency of nominal adjustments is endogenized, the labor supply decision needs to be recalibrated for each frequency. Specifically, as inflation rises, the frequency of wage adjustments rises and thus the contract length falls. The households wage setting decision (10) sets the present value of the marginal disutility of labor equal to the associated present value of the marginal utility of consumption. The shorter the contract length, N, the lower is the present value of thej marginal utility of consumption, *ceteris paribus*.

To explain this result intuitively, we show that shorter contracts dampen the time-discounting effect, and thus employment is lower at any given level of inflation. As we have seen, the current contract wage depends on the current price level and all the expected future price levels over the span of the contract. The shorter the contract, the shorter is the range of expected future price levels on which the current contract wage depends. If households have a positive rate of time discount, then the less heavily will future price levels be discounted. Thus, for any given rate of money growth (steady-state inflation) the current contract wage will lag less far behind the price level and, by implication, the higher is the average real wage over the contract period and thus the lower is employment.

To see why this is so, consider two adjacent wage-setting cohorts, i.e. two cohorts who set their wages in immediate succession: for example, one in time period $t-1$ and the other in period $t-2$, and let the wage contract be more than two periods long. The ratio of period-t employment across these cohorts depends on the difference in their real wages. In steady state, the real wage of cohort A in period $t-2$ is the same as the real wage of cohort B in period $t-1$. Under positive inflation, the real wage of each cohort falls through time. Thus, since cohort A set its wage before cohort B, the real wage of A at time t is lower than the real wage of B at time t. The greater the inflation rate, the lower is A's real wage relative to that of B. The ratio of employment across these cohorts depends on this divergence in real wages.

Formally, rewrite the labor demand function (6) in terms of detrended wages: $n_{t+i}(h) = \left(\frac{W_t^*}{W_{t+i}}\mu_t^{-i}\right)^{-\theta_w} y_{t+i}$. Thus, in the steady state, $n_{+i} = \left(\frac{W^*}{W}(N)\,\mu^{-i}\right)^{-\theta_w} y$, where n_{+i} is steady-state employment i periods after the wage is reset. Now consider two adjacent cohorts in the steady state: $n_{+1} = \left(\frac{W}{W_{t+i}}\mu^{-1}\right)^{-\theta_w} y$ and $n_{+2} = \left(\frac{W}{W_{t+i}}\mu^{-2}\right)^{-\theta_w} y$. Then the ratio of employment across adjacent cohorts depends only on the inflation rate (which determines their relative real wages):

$$\frac{n_{+1}}{n_{+2}} = \mu^{-\theta_w} \tag{33}$$

Thus, the steady-state employment of the various cohorts at a particular time may be depicted by the sequence $(n_{+1}, n_{+2}, ..., n_{+N})$, which is a rising geometric series. If change in the contract period N would lead to a mean-preserving spread on cohort employment, then aggregate employment would remain unchanged. Specifically, suppose that contract period falls from 5 to 3, so that the employment vector contracts from $\left(n'_{+1}, n'_{+2}, n'_{+3}, n'_{+4}, n'_{+5}\right)$ to (n_{+1}, n_{+2}, n_{+3}). Then, in a mean-preserving spread, the fall in the size of the largest cohort (from n'_{+5} to n_{+3}) would be equal to the rise in the size of the smallest cohort (from n_{+1} to n'_{+1}).

So, when the contract period N shortens in response to a rise in inflation, will households adjust their wages so as to induce a mean-preserving spread in cohort employment?

The answer is no, on account of the discounting effect. When the contract period shortens, households have less opportunity to discount the future, and thus the wages it receives are valued more highly. On this account, households set their contract wage higher than the wage that would yield a mean-preserving spread in cohort employment. From the time the contract wage is set, their real wage falls over the contract period, raising employment (with an elasticity greater than unity) and consumption as the contract period progresses. Due to the curvature of the households' utility function, the households' disutility of labor will rise relative to the utility of consumption. Moreover, since the shortening of the contract periods leads households to discount the future less heavily, households' attach more importance to the increase in the disutility of labor relative to the utility of consumption. Thus, they set their wage higher, and induce lower employment.

In short, the firm's employment decisions depend on the real wages of different cohorts at the *same point in time*, whereas the household's wage setting decisions depend on the real wages they receive *through time*. And since households discount the future, a shortening of the contract period leads them to adjust their wages so as to sacrifice some present utility for the sake of future utility. Thus aggregate employment falls.

Formally, for the simple case in which $\eta = 0$, the labor supply relation (10) is

$$\sum_{i=0}^{N-1} \beta^i n_{t+i} = \frac{N(\theta_w - 1)}{\varsigma \theta_w} \tag{34}$$

and in the steady state, this may be expressed as

$$\sum_{i=0}^{N-1} \left(1 + \beta\mu^{\theta_w} + ... + \beta\mu^{N\theta_w}\right) n_{+0} = \frac{N(\theta_w - 1)}{\varsigma \theta_w} = \sum_{i=0}^{N-1} \left(\beta\mu^{\theta_w}\right)^i n_{+0} \tag{35}$$

Moreover, aggregate employment is

$$n = \frac{1}{N}\sum_{i=0}^{N-1} n_{+i} = \frac{1}{N}\left(1 + \mu^{\theta_w} + ... + \mu^{N\theta_w}\right) n_{+0} \tag{36}$$

$$= \frac{\left(1 - \mu^{N\theta_w}\right)\left(1 - \beta\mu^{\theta_w}\right)}{\left(1 - \mu^{\theta_w}\right)\left(1 - \left(\beta\mu^{\theta_w}\right)^N\right)} \frac{(\theta_w - 1)}{\varsigma \theta_w} \tag{37}$$

Thus, aggregate employment is increasing in N when there is a discounting effect (i.e. when $\beta < 1$).

Third, *the output-inflation relation is weaker (closer to the horizontal axis) under endogenous contract length than when the contract period remains constant.* When inflation increases, and the contract period shortens as result, there are two effects on output: (a) As noted above, employment falls (for any given level of inflation). Thus, for any given degree of employment cycling, aggregate output falls. (b) As the contract period shortens, the degree of employment cycling falls. Since different types of labor are imperfect substitutes, less employment cycling means more output. As shown in Figure 5, the second effect dominates.[14] Intuitively, it is clear that the second effect must dominate when inflation is sufficiently high, because eventually gives wage setters have the incentive to set wage flexibly ($N = 1$). Then money superneutrality is reestablished and the output-inflation curve coincides with the horizontal axis.

5 Adjustment costs

How do these results change if we eliminate the effects of labor cycling in the steady state? To answer this question we assume that firms face sufficiently large hiring and firing costs that they choose to hire a constant amount of each labor type across the contract period. For simplicity, we do not model these costs explicitly, but assume instead that they manifest themselves as a constraint that labor employed from each cohort is constant across the contract period. The firm's profit maximization problem is then:

$$\max_{n_t(0)} \sum_{i=0}^{\infty} \beta^i y_{t+i} - \left(\sum_{i=0}^{N-1} \beta^i \frac{W_t(0)}{P_{t+i}} \right) n_t(0) - C\left(\{W_{t+j}(j), n_{t+j}(j)\}_{j=1}^{N-1} \right) \tag{38}$$

where cohorts[15] are labelled such that cohort 0 changes its wage at time t, cohort 1 at time $t+1$ etc and C is a function giving the total costs relating to all cohorts other than 0. Output is defined as

$$y_{t+j} = \left[\frac{1}{N} \left(\sum_{i=0}^{j} [n_{t+i}(i)]^{\frac{\theta-1}{\theta}} + \sum_{i=j}^{N-1} [n_{t-i}(i)]^{\frac{\theta-1}{\theta}} \right) \right]^{\frac{\theta}{\theta-1}} \tag{39}$$

[14] Formally, the production function may be expressed as follows:

$$\begin{aligned} y &= \left(\frac{1}{N} \sum_{i=0}^{N-1} n_{+i}^{\frac{\theta_w-1}{\theta_w}} \right)^{\frac{\theta_w}{\theta_w-1}} \\ &= n_{+0} \left(\frac{1}{N} \sum_{i=0}^{N-1} \mu^{\theta_w-1} \right)^{\frac{\theta_w}{\theta_w-1}} \\ &= n_{+0} \left(\frac{1}{N} \frac{1-\mu^{N(\theta_w-1)}}{1-\mu^{\theta_w-1}} \right)^{\frac{\theta_w}{\theta_w-1}} \end{aligned}$$

Thus, aggregate output rises less fast than aggregate employment with the contract period N.

[15] Note we assume households behave symmetrically so we can abstract away from individual households and just consider the cohort's behaviour

Deriving the first order conditions gives the smoothed demand for cohort 0's labor

$$n_t(0) = \left[N\sum_{i=0}^{N-1}\beta^i\frac{\mathsf{W}_t(0)}{\mathsf{P}_{t+i}}\right]^{-\theta}\left(\sum_{i=0}^{N-1}\beta^i y_{t+i}^{\frac{1}{\theta}}\right)^{\theta} \tag{40}$$

As would be expected, this depends on an average of the real wage over the two periods, weighted by an average of the output. In the steady state $y_{t+i} = y\ \forall i, n_t(i) = n\ \forall i$, $y = n$ and $\mathsf{W}_t(i) = \mathsf{W}^*\ \forall i$ so

$$\frac{W^*}{P} = \frac{\sum_{i=0}^{N-1}\beta^i}{N\sum_{i=0}^{N-1}\left(\frac{\beta}{\mu}\right)^i} \tag{41}$$

The labor demand curve is flat which we would expect given the linear production function.

Define the wage index as the cost of producing one unit of output. Given (39) the firm has to hire one unit of each of the cohort's labor to produce one more unit of output so the steady state wage index W is given by

$$W = W^*\sum_{i=0}^{N-1}\left(\frac{1}{\mu}\right)^i \tag{42}$$

This implies that the markup set by firms is

$$\frac{P}{W} = \frac{N\sum_{i=0}^{N-1}\left(\frac{\beta}{\mu}\right)^i}{\sum_{i=0}^{N-1}\beta^i\sum_{i=0}^{N-1}\left(\frac{1}{\mu}\right)^i} \tag{43}$$

which is increasing in money growth. Here the discounting effect is manifested in the firm's behaviour - if $\beta = 1$ the markup is independent of money growth.

A household h that can reset its wage at time t chooses faces the following problem:

$$\max\sum_{i=0}^{N-1}\beta^i\log c_{t+i} + \frac{\varsigma}{1-\beta}\frac{(1-n_t(h))^{1-\eta}}{1-\eta} \tag{44}$$

subject to a series of budget constraints

$$\mathsf{P}_{t+i}c_{t+i}(h) + \mathsf{B}_{t+i+1}(h) + \mathsf{M}_{t+i+1}(h) = \tag{45}$$

$$\mathsf{W}_t(h)\,n_t(h) + R_{t+i}\mathsf{B}_{t+i}(h) + \mathsf{M}_{t+i}(h) + \mathsf{T}_{t+i}(h) + \Pi_{t+i}(h) \tag{46}$$

and to the demand for the household's labor (40). Deriving first order conditions gives :

$$\theta \frac{\varsigma}{1-\beta}\left(1-n_t^0\right)^{-\eta} = (\theta-1)\left(\sum_{i=0}^{N-1}\beta^i\lambda_{t+i}\right)W_t^0 \tag{47}$$

where λ_t is the Lagrange multiplier on the budget constraint at time t. With the assumption of consumption smoothing this reduces to:

$$\left(1-n_t^0\right)^{-\eta} n_t^0 = \frac{2\left(1-\frac{1}{\theta}\right)(1-\beta)}{\varsigma} \tag{48}$$

This means that labor supplied is constant and independent of the rate of money growth, and therefore, by the production function, so too will output. Money is not superneutral in the sense that it changes the real wage via (43) but it has no effect on employment or output.

6 Conclusion

This paper has investigated how the long-run employment-inflation and output-inflation tradeoffs depend on microeconomic behavior patterns. In particular, we have shown that these tradeoffs are the outcome of three interrelated influences: (i) The greater the degree of time discounting, the more the contract wage depends on current rather than future prices, and thus the more the contract wage lags behind the price level when there is inflation. (ii) Staggered wage contracts in an inflationary environment lead to employment cycling, i.e. firms substitute among different labor types in responses to their relative real wage movements. Since different labor types are imperfect substitutes, the greater the degree of employment cycling, the lower will be the level of output (*ceteris paribus*). (iii) Households prefer stable employment paths to those that vary over time. Thus greater the degree of employment cycling, the greater will be the average real wage that workers will require. The first influence imparts a positive relation to the employment-inflation and output-inflation tradeoffs, whereas the latter two influences impart a negative relation to these tradeoffs. The relative strength of the three influences, of course, depends on the relative magnitudes of the underlying microeconomic parameters: the rate of time discount, the elasticity of substitution between different labor types, and the elasticity of labor supply.

We have shown that when the contract length is endogenised, the long-run levels of output and employment may be sensitive to changes in money growth (and thus inflation) at low levels of inflation, but at higher levels of inflation real variables become independent of inflation. This is so even at contract periods of significant length, i.e. the relation between real variables and inflation disappears before inflation becomes so high that wages and prices become fully flexible.

Our analysis indicates the employment cycling plays a central role in making real variables responsive to changes in money growth over the long run. In particular, when we assume that employment adjustment costs are sufficiently high to eliminate employment cycling, the super-neutrality of money is restored. We have suggested, however, that in practice firms may well engage in a limited amount of employment cycling, in the form of hours variations over the contract period.

Our overall conclusion is that real variables are in general affected by money growth, even in the long run. But the nature of these relations depend on the properties of production technologies and preferences.

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Figure 1 : Output, employment and money growth

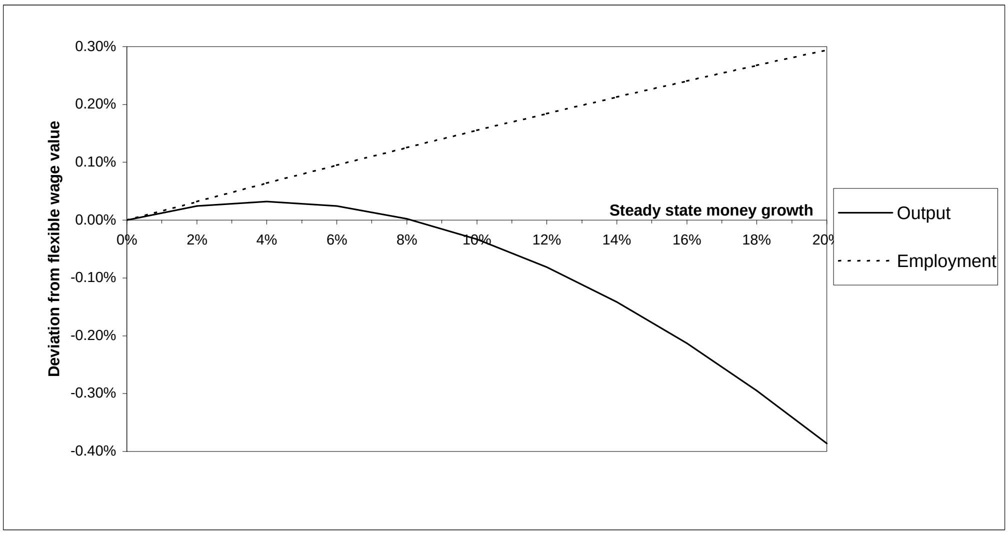

Figure 2 : Sensitivity to the real interest rate

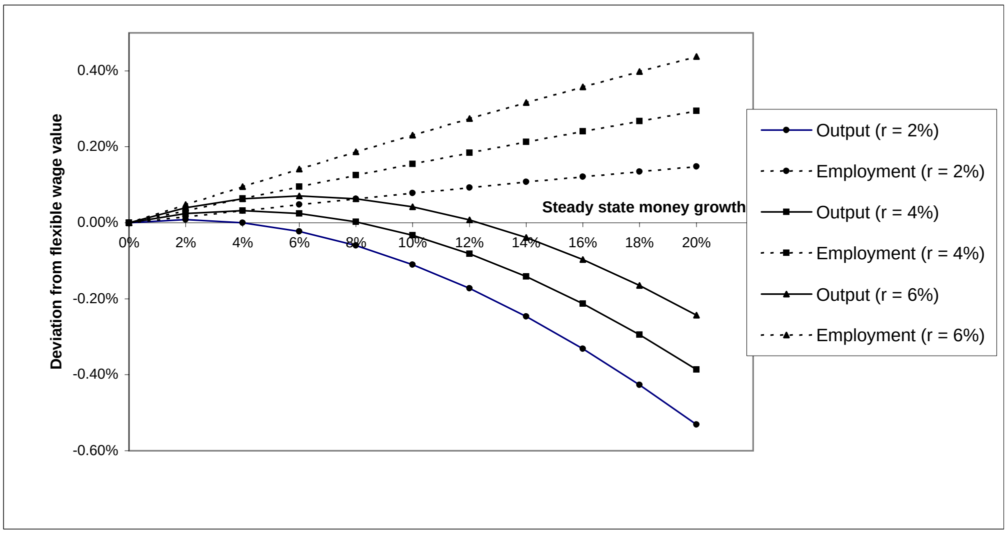

Figure 3a : Sensitivity to the elasticity of labour supply (eta)

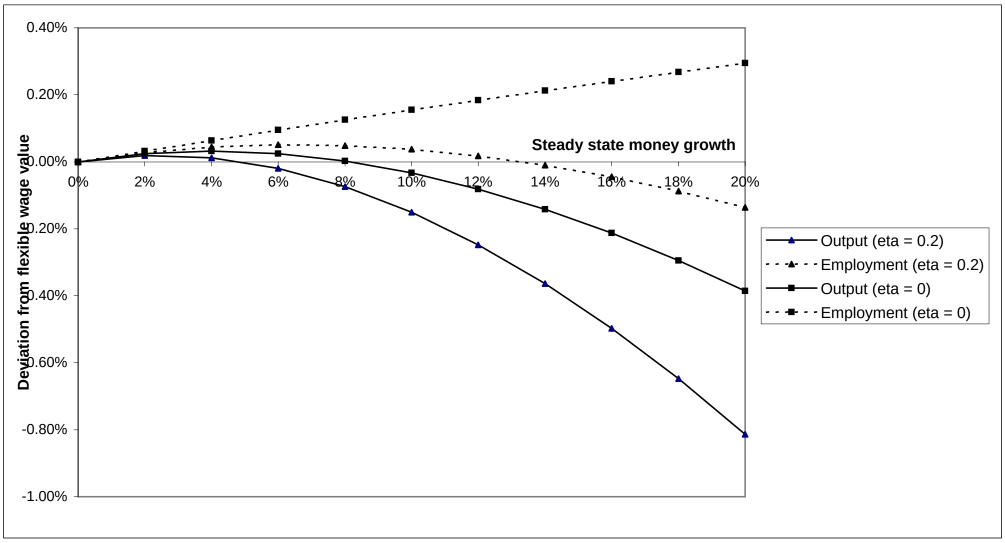

Figure 3b : Sensitivity to the elasticity of labour supply (eta)

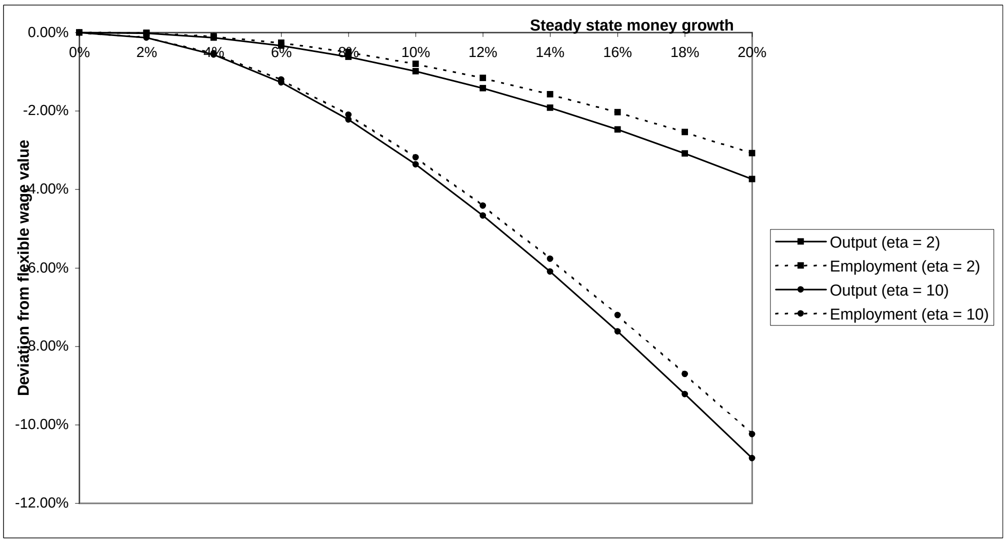

Figure 4 : Sensitivity to the elasticity of substitution between labour types (theta)

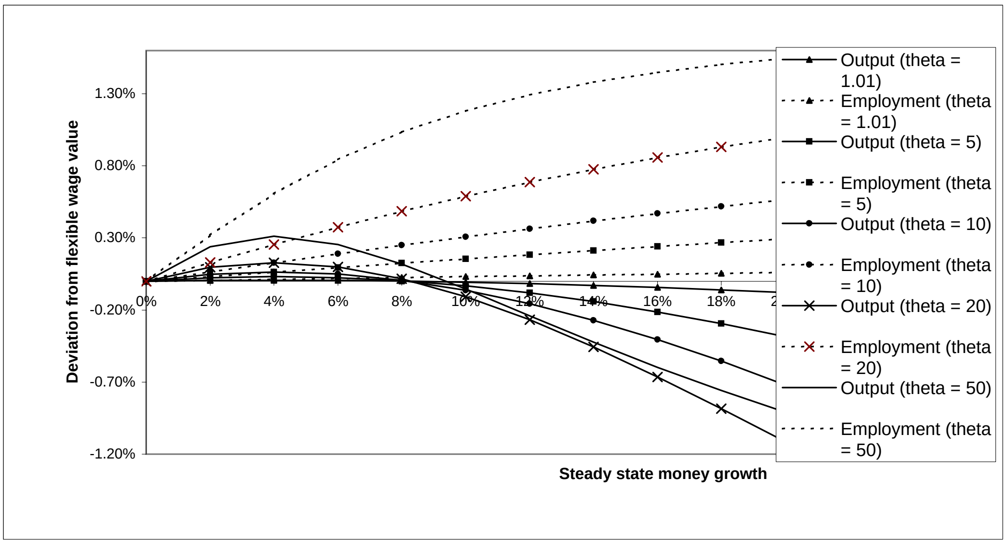

Figure 5a : Endogenising N : 0% - 20% inflation

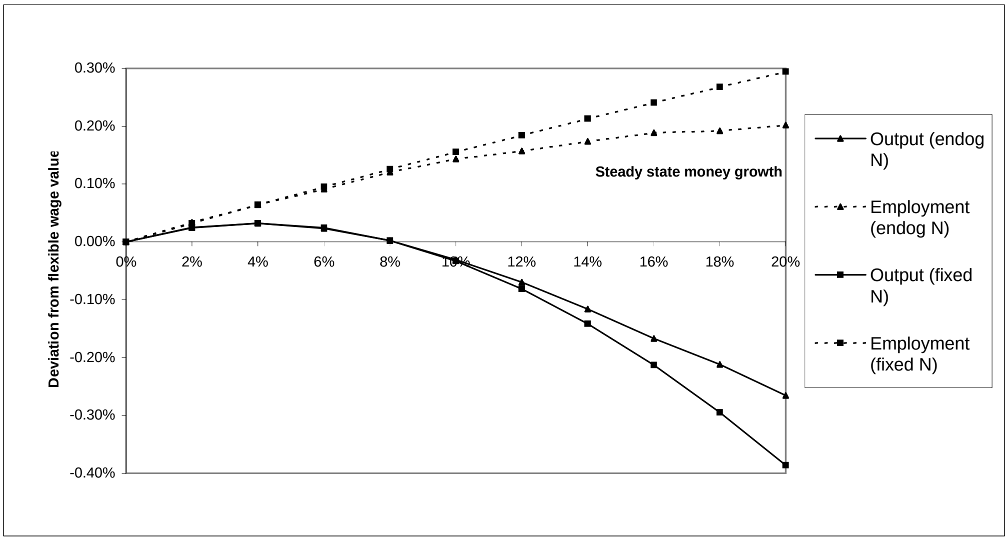

Figure 5b : Endogenising N : 0% - 80% inflation

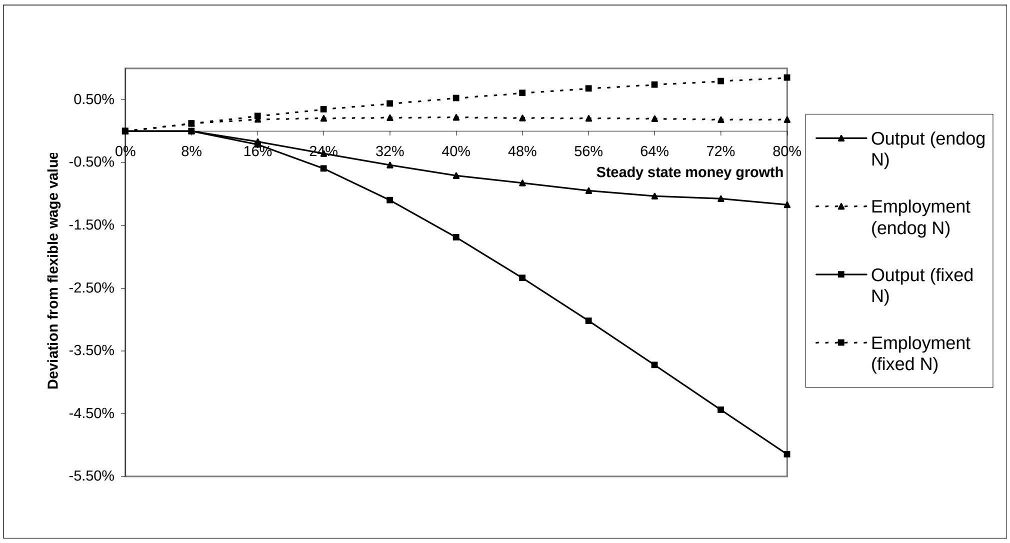

Table 1: How unemployment changes as money growth rises from 0% to 4%

	Theta				
Interest rate	1.01	5	10	20	50
2.00%	0.12%	0.61%	1.23%	2.44%	5.80%
4.00%	0.25%	1.22%	2.43%	4.83%	11.51%
6.00%	0.37%	1.81%	3.61%	7.18%	17.14%