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MONETARY STABILISATION WITH NOMINAL ASYMMETRIES*

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Optimal monetary stabilisation in the standard New Keynesian framework usually assumes a policy loss function from outside the model. In this paper, in contrast, the objective arises directly from the model. Credit constraints and sticky nominal debt contracts imply that monetary stabilisation has asymmetric impacts depending on whether consumers are credit-constrained. The policy problem is to maximise some weighting of the expected utility of the different types of consumer. Features of optimal stabilisation are derived that do not appear to be far out of line with empirical evidence for many countries but that clearly conflict with standard loss function results.

In recent years there has been a considerable resurgence of interest in the analysis of monetary stabilisation of output and inflation, in the wake of earlier developments in developing 'New Keynesian' underpinnings for the long-unfashionable IS-LM/AS-AD model of the macroeconomy.[1] Although this literature has produced a range of both theoretical and analytical insights, it has arguably suffered from a rather deep inconsistency in its approach to monetary policy. Put simply, the literature struggles to explain, in its own terms, what monetary stabilisation is for.

There has been an understandable and laudable anxiety to show the optimising underpinnings of New Keynesian models. After an initial focus on the micro underpinnings of sticky prices, these models have developed into full-blown macro-models in which consumers are generally represented by a single representative agent. The Euler Equation of this single consumer becomes the 'optimising IS Curve'. But if the only rigidity in a New Keynesian economy is price stickiness, that affects all consumers symmetrically, it is hard to see why this should actually matter very much in terms of welfare. It is true that in the presence of price stickiness fluctuations in aggregate demand may induce greater fluctuations in output than if prices were flexible, but if the representative agent is an unconstrained permanent income consumer, with access to perfect capital markets (which must be assumed if the representation is to be legitimate), then the associated costs of such fluctuations in output are known to be small.[2] Without assu-

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[1] Clarida *et al.* (1999) provide an excellent survey of the New Keynesian monetary policy literature; McCallum and Nelson (1999) and Rotemberg and Woodford (1997) are both standard references for the New Keynesian version of the IS-LM model. Note that in general the 'Taylor Rule' (Taylor, 1993) has supplanted the textbook LM curve. This still slopes upwards in (r,y) space but implies a target for the inflation rate, rather than the price level.

[2] A commonly used benchmark estimate of the welfare cost of output fluctuations is Lucas's (1997) figure of less than one hundredth of one percent of consumption in perpetuity. Estimates of a similar order of magnitude have also been produced, in general equilibrium representative agent models, by Ireland (1997) and Carlstrom and Fuerst (1995).

ming additional rigidities, it is not clear whether variability in inflation should matter at all.

In such a framework, still the most common way to generate a problem for monetary policy to solve is to introduce an 'outside' objective – i.e., one that does not arise from the model itself – by resorting to an analytical tool that has survived into the New Keynesian era. but which is virtually unchanged from its earlier incarnation in the Old Keynesian era: the policy loss function in output and inflation deviations. A recent survey paper by Clarida *et al.* (1999) for example, still treats this as the consensus approach.

In contrast, this paper follows those relatively few papers that examine the impact of an 'inside objective', in which the monetary stabilisation problem has a basis in expected utility, and arises from the model itself. In contrast to models with a single representative agent, however, the policy problem here arises because sticky prices do not represent the only element of stickiness in the model: there are additional forms of nominal inertia that imply that monetary stabilisation has asymmetric impacts on different types of consumer.[3]

In the main part of the paper, these asymmetries arise from the combination of credit constraints and stickiness of nominal debt contracts (though a number of results are general to a wider class of asymmetries). While some consumers are unconstrained intertemporal optimisers, others are assumed to be subject to credit constraints. They are able to borrow, but only up to an amount consistent with an exogenously given level of collateral (they thus never fall below a zero net worth threshold). Since measurement of collateral is costly, financial institutions are assumed to set individual debt contracts only periodically, in nominal terms.[4]

In addition to the usual New Keynesian assumption of sticky product prices, therefore, there is an additional source of nominal inertia, in the aggregate value of the nominal debt of constrained consumers. As a result monetary stabilisation has distinctly asymmetric impacts. The policy problem is to maximise some weighting of the expected utilities of constrained and unconstrained consumers.

Apart from this additional element of nominal asymmetry, the model analysed in this paper is straight out of the New Keynesian stable, and deliberately follows closely the consensus analytical framework set out in Clarida *et al.* (1999). Inflation is modelled as a standard hybrid backward- and forward-looking Phillips Curve (introducing a crucial element of structural inflation stickiness). Monetary policy is implemented via a simple interest rate reaction function. But the combination of credit constraints and sticky nominal debt contracts gives the model some features that are distinctly Old Keynesian. Constrained consumers behave in a way very similar to the textbook Keynesian model. Their consumption responds to

[3] It therefore contrasts with most other papers that have moved away from the loss function approach – Rotemberg and Woodford (1997), Ireland (1996, 1997), Carlstrom and Fuerst (1995), Aiyagari and Braun (1998) being prime examples – all of which assume perfect financial markets, and therefore use an objective function that is derived directly from the preferences of the single representative agent.

[4] The underlying model of debt contracts, (a slightly amended, discrete time version of Calvo's (1983) contract model) is derived in Graham and Wright (2003).

fluctuations in aggregate output and in the nominal as well as real interest rate (with the extent of the separate nominal interest rate effect depending on the stickiness of nominal debt contracts). This feature means that inflationary shocks, once combined with the response of systematic monetary policy in raising nominal interest rates, will typically have a contractionary impact on constrained consumers in the short term.[5]

Faced with demand shocks, and cost-push shocks to inflation, monetary policy cannot avoid these shocks inducing variability in the consumption of at least one of these groups, and in general both, with an implied impact on expected utility. As a result, a clear policy choice arises from within the model: how optimally to allocate the consumption variance that such shocks induce. A number of general features of optimal monetary stabilisation are derived, some of which contrast markedly with standard results in the loss function literature.

The paper is structured as follows. Section 1 sets out a model of consumption in which some consumers are subject to exogenous credit constraints, with sticky nominal debt contracts. Section 2 derives a 'semi-optimising IS Curve' that aggregates the consumption of the two types of consumer, and an exogenous demand shock. Section 3 defines the nature of systematic monetary stabilisation. Section 4 shows the impact of monetary stabilisation on the properties of inflation. Section 5 derives the implied interest rate rule consistent with any given degree of monetary stabilisation. Section 6 examines optimal monetary stabilisation. Section 7 discusses the impact of other forms of nominal asymmetries and of allowing for the impact of labour supply variability on expected utility.[6] Section 8 discusses a number of empirical patterns that have generally been regarded as puzzling in a loss function framework but that appear consistent with the analysis of this paper. Section 9 concludes the paper.

1. The Consumption Problem with Sticky Nominal Debt Contracts

1.1. *Credit Constraints and Sticky Nominal Debt Contracts*

The nature of nominal asymmetries in the main part of this paper (Section 7 discusses the basis for other possible asymmetries) can be justified with reference to four empirical features:

1. Nominal debt contracts (almost invariably backed up by some form of collateral – of which residential housing is quantitatively the most important element) are the norm in most countries with reasonably stable inflation;

[5] This may seem counter–intuitive, since an inflationary shock raises the net worth of constained consumers by lowering the real value of their debt. But constrained consumers, by definition, do not consume on the basis of their wealth but out of their disposable income (which is depressed by rises in nominal interest rates) and out of any new lending that banks may offer. In the longer term there will be an offsetting boost to constrained consumers as banks restore real debt levels towards the underlying collateral. But Graham and Wright (2003) show that at cyclical frequencies this effect is usually swamped by the contractionary impact of systematic monetary policy.

[6] This Section also includes a comparison with the results of Rotemberg and Woodford (1997), whose utility-based analysis of monetary stabilisation yields results closer to the loss function approach.

2. Adjustments to such contracts are relatively costly, and hence relatively infrequent – hence nominal debt contracts are 'sticky';
3. Interest payments on such contracts are typically reasonably closely related to the short-term interest rate used to implement monetary policy;
4. A significant fraction of consumers appear to face binding or near-binding credit constraints in the short-term, even when they may have significant positive net worth.

It is perhaps surprising that the combined impact of the first two features on nominal inertia has thus far played little or no role in mainstream macro analysis,[7] despite the enormous literature dealing with various aspects of product price stickiness. One well-known criticism of the standard sticky price model is that the 'menu costs' that ultimately must generate product product price stickiness are unlikely to be large. In the case of debt contracts, in contrast, the costs of adjustment may well be distinctly larger, since typically this will involve re-assessment of collateral or other features of creditworthiness – neither of which is a low-cost activity. This cost differential appears to be reflected in average contract lives, implying that debt contracts are distinctly 'stickier' in nominal terms than are product prices.

On the third feature, the analysis of this paper will assume for simplicity that all debt interest payments are linked directly to the short-term interest rate. Maclennan *et al.* (1999, Table 2) show that in a number of EU countries – most notably the UK – interest payments are either directly related to a floating rate or are fixed for relatively short periods; additionally, in a much wider range of countries mortgage interest rates are adjusted considerably more frequently than are debt contracts and hence do adjust, albeit with a variable lag, to interest rate changes.[8] Finally, Graham and Wright (2003) examine the impact of some debt contracts being at fixed interest rates for the duration of the contract and show that, as long as the share of fixed rate contracts do not overwhelmingly predominate, the qualitative nature of the policy problem will be as assumed here.

The fourth empirical feature is crucial to the analysis of this paper, since without binding or near-binding credit constraints, the nature of debt contracts, as summarised in the first three features, need have little or no impact on consumption itself, other than via any impact on the consumer's lifetime wealth.[9] The maintained assumption in this paper will be that some consumers do face binding credit constraints – or, crucially, *behave* as if they do.

[7] The literature on the 'credit channel' of monetary policy has dealt with the link between debt or income gearing and the cycle, e.g., (Bernanke and Gertler, 1995) and there are models of credit rationing and endogenous collateral changes in the cycle (Stiglitz, 1999; Kiyotaki and Moore, 1997) but none, that I am aware of, have allowed for the role of nominal inertia in this process.

[8] Maclennan *et al*'s Table 2 shows that only in France and Denmark do strictly fixed rate mortgage contracts make up more than half the total; in most other EU countries it is a relatively small fraction.

[9] And hence, by implication, as Graham and Wright (2003) note, also need have no impact on the monetary policy transmission mechanism: a logical link that is usually ignored in discussions of the role of alternative mortgate systems.

Mankiw (2000) presents a range of direct evidence from the US of binding credit constraints in support of his proposed 'Savers-Spenders' model of the macroeconomy. There is also indirect evidence, such as that of Campbell and Mankiw (1990), from the strong correlation between consumption and disposable income, that such constraints can operate even when consumers have positive net worth. The implied share of the population facing credit constraints from Campbell and Mankiw's econometric results is just under one half: distinctly higher than the share of the population without assets.[10] An additional piece of indirect evidence (discussed further in Section 8) of a combined role for nominal debt contracts and credit constraints is the well-known empirical correlation between consumption and nominal (as opposed to real) interest rates (e.g., Blinder and Deaton, 1985; Bernanke and Blinder, 1992; Fuhrer and Moore, 1995; Wright, 2002*b*).

The combination of all four features implies a potentially important impact of nominal inertia in the transmission mechanism of monetary policy.

1.2. *The General Problem*

To formalise the combined impact of credit constraints and sticky debt contracts, assume in standard fashion that an infinitely lived consumer of type j ($j = 1,2$) chooses consumption in each period of life, $t = 0,1,...,\infty$, to maximise the present discounted value of an expected flow of instantaneous utilities:

$$V_t = \max_{\{C_{jt+i}\}} \sum_{i=0}^{\infty} \beta^i \mathrm{E}_t[U(C_{jt+i})] \quad (1)$$

where β is the consumer's discount factor; C_{jt} is consumption at time t; and the instantaneous per period utility (or felicity) function U enters in additive separable form, and is assumed to be continuously differentiable and strictly concave. E_t represents the expectations operator, evaluated given information at time t.[11]

The consumer faces two constraints. First, the identity for the evolution of financial assets:

$$A_{jt+1} = A_{jt}\left(\frac{1+R_t}{1+\Pi_{t+1}}\right) + Y_{jt} - C_{jt} \quad (2)$$

where A_t is the real value of financial assets; R_t is the 'safe' nominal interest rate, set in the current period, for repayment in the next; and Π_t is the inflation rate.[12] Second, a constraint that the consumer's debt cannot exceed some given level, i.e:

$$A_{jt} \geq -D_{jt}. \quad (3)$$

[10] Wolff (1998) gives the proportion of US households with zero or negative net worth at just under 20%.

[11] Wright (2001) examines the impact of introducing leisure into the utility function and hence endogenising labour supply. Section 7 briefly summarises the impact of this extension, that turns out not to affect the main results of this paper.

[12] Following Clarida *et al.* (1999) and many others, 'risky' assets are ignored but the 'safe' asset is subject to inflation risk.

Borrowing is by implication not ruled out but only up to an exogenous value for debt, the process for which will be described below.

1.3. *Log-Linearisation*

For the sake of analytical tractability, it will prove convenient in this paper to reduce all relationships to be linear in log deviations from equilibrium values. This will involve some approximations, that can however all be justified by the following assumption:

ASSUMPTION 1. (*Small Deviations*) *Percentage deviations from equilibrium values are sufficiently small that all products of percentage deviations from equilibrium are trivially different from zero, and can be neglected.*

Thus, for percentage deviations in any variable, $x_{it} \equiv (X_{it} - \hat{X}_{it})/\hat{X}_{it}$, it is assumed that the approximation $x_{jt+k}x_{lt+m} \approx 0, \forall j, \forall k, \forall l, \forall m$ holds with equality – an approximation that can be made arbitrarily exact by letting the variances of disturbances that drive the system become arbitrarily small. Thus, *inter alia,* the approximation $\log(1 + x_{it}) \approx x_{it}$ is also assumed to hold with equality. Since the nominal interest rate and the inflation rate are both already in percentage terms, Assumption 1 is applied to the magnitudes $1 + R_t$ and $1 + \Pi_t$.

1.4. *Case* 1: *Consumers for Whom Debt Constraints do not Bind*

Assume, following Campbell and Mankiw (1990) that, for some consumers, whose expenditure represents a constant fraction $1 - \lambda$ of total consumption, the second constraint, (3) does not bind. For this group of consumers ($j = 1$), the Euler equation for optimal consumption can (following Hall (1998), and many others) be approximated (applying Assumption 1) by:

$$c_{1t} = \mathrm{E}_t c_{1t+1} - \sigma(r_t - \mathrm{E}_t \pi_{t+1}) \tag{4}$$

where $\sigma = \left[\frac{U''(\hat{C}_{1t})\hat{C}_{1t}}{U'(\hat{C}_{1t})}\right]^{-1}$ is the intertemporal elasticity of substitution, and lower case letters denote log deviations from equilibrium, given Assumption 1. [13]

1.5. *Case* 2: *Consumers for Whom Debt Constraints Bind*

For the remaining group of consumers ($j = 2$), whose expenditure is a constant fraction λ of total consumption, it is assumed that constraint (3) binds (for the reasons discussed in Section 1.1). Log-linearisation of the intertemporal budget constraint (by application of Assumption 1), on the assumption that debt interest payments are set on a floating rate basis, implies that log deviations in constrained consumption must follow:

[13] Thus, e.g., $c_t = \log(C_t/\hat{C}_t)$, while $r_t = \log[(1 + R_t)/(1 + \hat{R}_t)]$, for the reasons given in the previous Section.

$$c_{2t} = y_{2t} - \delta r_t + \delta(\Delta d_{t+1} + \pi_{t+1}) \tag{5}$$

where $\delta = \hat{D}_t/\hat{C}_t$ is assumed constant.[14]

The sum of the first two terms on the right-hand side measures log deviations in what is conventionally described in national accounts statistics as 'real disposable income'; but although this is a real magnitude, its value is determined by the nominal interest rate. The bracketed term is the growth in the log of *nominal* debt. A credit constrained consumer's current 'saving ratio' (or dis-saving ratio) out of real disposable income must therefore precisely match the exogenously given change in nominal debt. While both of the two bracketed elements are dated $t + 1$, the assumption of sticky nominal debt contracts implies that the sum of the two terms is determined at time t: indeed, given binding debt constraints, for the consumer's budget constraint to hold, it must be.

The real value of debtor consumption is thus directly affected by the interaction of two nominal magnitudes: the nominal interest rate and the increase in nominal debt.

1.6. *The Evolution of Nominal Debt Contracts*

For the reasons outlined in Section 1.1, it is assumed that debt contracts are sticky in nominal terms. To capture this in a form that is reasonably tractable, it will be assumed that nominal debt contracts evolve by a process analogous to Calvo's (1983) model of the aggregate price level. Thus, there is a constant probability that any given debt contract will be adjusted in the next period, with complete adjustment towards its optimal value.[15] Financial institutions choose the optimal nominal value of a new debt contract to minimise the expected cost of future deviations of real debt from its optimal value (from the financial institution's point of view), that is in turn a function of (exogenously given) collateral levels.

Graham and Wright (2003) show that in this framework the evolution of the aggregate value of the nominal debt of type 2 consumers can be well approximated at cyclical frequencies by:

$$\Delta d_{2t+1} + \pi_{t+1} \approx \alpha E_t \pi_{t+1} \tag{6}$$

where α is a positive coefficient, that will depend positively on the probability of contract adjustment and on ρ, the autoregressive coefficient for inflation (to be derived in Section 4 below). It will become evident from later discussion that the

[14] This simple form of the approximation also requires a zero real interest rate in steady state. The impact of relaxing this assumption introduces a small role for the level, as well as rate of change of real debt, but has minimal effects for empirically reasonable values. For details of derivation, see Graham and Wright (2003). In that derivation, δ is in turn equal to the ratio of collateral to constrained consumption. If some debt contracts are on a fixed interest rate basis, this will introduce yet more complex dynamics, but, to a reasonable approximation, the impact can be captured by a lower implied coefficient on r_t.

[15] The financial institution sets new debt contracts in nominal terms in period t to be in force from period $t + 1$ onward. Note that 1-period-ahead contracting, in some form, is not just a convenient assumption; it is a necessity, given the dependence of constrained consumption on next period's debt, as shown in (5).

magnitude of α is a key determinant of the results of this paper. It will be assumed that α is strictly less than unity (which will alway hold given a sufficient degree of stickiness of contracts).[16]

1.7. *Implications of Sticky Nominal Debt Contracts for Constrained Consumption*

Assume that the factor incomes of credit constrained consumers are a constant proportion of aggregate income Y_t. Then, assuming that the approximation for the evolution of real debt in (6) holds with equality, substituting into (5) gives:

$$c_{2t} = y_t - \delta(r_t - \alpha \mathrm{E}_t \pi_{t+1}) \tag{7}$$

Note that, having incorporated the adjustment process for real debt, constrained consumption in period t ceases to be a function of inflation and real debt in period $t+1$, since the impact of inflation on the evolution of real debt in (6) precisely offsets the impact on consumption in (5).

Equation (7) shows that the combined effect of credit constraints and sticky nominal debt contracts results in a key feature: constrained consumers respond both to real and nominal interest rates. Thus, with $\alpha < 1$, a simultaneous rise in inflation and in nominal rates that leaves the expected real interest rate unchanged will have a depressing impact on the expenditure of constrained consumers, since higher interest payments will depress their disposable income by an amount that is only partly offset by increases in real debt.

2. A 'Semi-Optimising' IS Curve With Constrained Consumers

The GDP identity can be written in log deviations (using Assumption 1) as:

$$y_t = \kappa c_t + e_t \tag{8}$$

where $\kappa = \hat{C}_t/\hat{Y}_t$ is assumed time-invariant and strictly less than unity; and $e_t \equiv (1-\kappa)\log[(Y_t - C_t)/(\hat{Y}_t - \hat{C}_t)]$ is a 'demand shock' a zero mean process that is, as is standard in the New Keynesian literature, assumed to evolve exogenously. For simplicity it will be assumed that e_t is not serially correlated,[17] thus:

$$\mathrm{E}_t e_{t+i} = 0 \quad \forall i > 0. \tag{9}$$

[16] See Graham and Wright (2003) for a full derivation of this framework, of which the following features are worthy of note in this context: (a) since such consumers are by assumption rationed in the debt market, it will always be optimal to respond fully to any increase in the level of debt offered by the financial institution, given Assumption 1. Hence the evolution of the debt constraint is exogenous to constrained consumers, consistent with (3). (b) The expression given in (6) is an approximation, because in the true process $\alpha = \alpha(\mathrm{L})$, a distributed lag polynomial. Allowing for this explicitly makes analytic solutions of the model considerably more intractable, since it also implies a polynomial lag specification in the rule for interest rates, defined below in Section 3. However both constrained consumption and the implied 'true' monetary policy rule are very well approximated at cyclical frequencies by static relationships. (c) For observed degrees of stickiness of debt contracts and inflation persistence, α will always be comfortably below unity.

[17] e_t is usually interpreted as a fiscal policy shock. The assumption that it is not serially correlated is convenient, though unlikely to be empirically plausible. Allowing for persistence of demand shocks would imply an additional source of persistence in both output and inflation, apart from that arising from the stickiness of inflation (to be derived below).

Given Assumption 1, log deviations in aggregate consumption can also be written as:

$$c_t = (1 - \lambda)c_{1t} + \lambda c_{2t}. \tag{10}$$

Hence, substituting into the Euler Equation for unconstrained consumers (4), using (8), (9), (10) and (7), solving as a forward difference equation for y_t and iterating forward (exploiting the fact that all variables are measured in deviations from equilibrium values and hence $\lim_{i\to\infty} \mathrm{E}_t x_{t+i} = 0$, for all x), implies the 'Semi-Optimising' IS Curve:

$$y_t = -\tilde{\sigma} \sum_{i=0}^{\infty} \mathrm{E}_t(r_{t+i} - \pi_{t+i+1}) + \frac{1}{1 - \lambda\kappa} e_t - \tilde{\delta}(r_t - \alpha \mathrm{E}_t \pi_{t+1}) \tag{11}$$

where $\tilde{\delta} = \delta\lambda\kappa/(1 - \lambda\kappa)$, and $\tilde{\sigma} = \sigma(1 - \lambda)\kappa/(1 - \lambda\kappa)$.

The first two terms in (11) give the standard 'optimising IS' specification if there are no constrained consumers (i.e., if $\lambda = 0$). For $\lambda > 0$, these terms are supplemented by an additional term. The stickier are debt contracts (and hence the lower is α), the more this last term will resemble the nominal interest rate. Note also that when $\lambda > 0$ the impact of the 'demand shock', e_t, is, in the absence of a policy response, subject to something close to a textbook Keynesian multiplier effect, due to the consumption behaviour of credit constrained consumers.

3. Monetary Stabilisation

It is evident from the previous Section that the two types of consumer will be affected asymmetrically by monetary policy. This asymmetry is at the core of the analysis of this paper.

As is now standard in most of the literature, monetary policy is represented by a policy rule for the short-term interest rate. However, any systematic rule for the interest rate must imply, via the IS curve, an equivalent representation as an implied rule for output. It proves analytically simpler to follow Clarida *et al.* (1999) in assuming that monetary policymakers choose the parameters in this output rule, with the rule for interest rates derived by inversion of the IS curve.

Monetary policy is assumed to face two constraints:

ASSUMPTION 2. (*Pure Monetary Stabilisation*): *The coefficients in the monetary policy output rule* (*and hence in the implied rule for nominal interest rates*) *must be consistent with monetary stabilisation: the operation of the rules must ensure that output and inflation deviations are mean zero stationary processes.*

ASSUMPTION 3. (*Rational Expectations*): *Private sector expectations must be consistent with these processes, and the monetary rules.*

For the sake of tractability, I shall throughout assume simple log-linear rules for the nominal interest rate and output, of the form:

$$y_t = \zeta_\pi \pi_t + \zeta_e e_t \tag{12}$$

$$r_t - \mathrm{E}_t\pi_{t+1} = \tau_\pi\pi_t + \tau_e e_t \tag{13}$$

where the coefficients in the rule for interest rate, (13), will be determined by the magnitudes of those in the output rule, (12), and the nature of the transmission mechanism.

Assumption 2 has two impacts on the nature of the output rule: it rules out a constant term (and hence any inflationary bias arising from the targeting of output levels that are non-sustainable); it also implies, as will be shown below, a further restriction on the magnitude of ζ_π, to ensure the stationarity of π_t around zero.

In Section 6 the parameters in the output rule (and hence the implied parameters in the interest rate rule) will be derived from an optimisation exercise.[18] In contrast to structural parameters, that are all positive, the parameters in both rules can in principle be of any sign.

Deriving such an output rule from a policy loss function of the form $L(y_t^2, \pi_t^2)$, Clarida *et al.* (1999) along with many others, find that monetary policy will always 'lean against the wind' in the face of inflation shocks ($\zeta_\pi < 0$); and eliminate entirely the impact of demand shocks ($\zeta_e = 0$). As will become evident, however, neither of these features need necessarily hold if policy is concerned with expected utility maximisation, given the constraints in this paper.

Two aspects of the implied rule for nominal interest rates, (13), are worth noting:

1) It is very similar in form to the now benchmark 'Taylor Rule' (Taylor, 1993) but for the inclusion of e_t, rather than y_t. However, once the output rule is taken into account, (13) can straightforwardly be reparameterised as a standard 'Taylor Rule'. As such, it is usually assumed (again, on the basis of a policy loss function), that both τ_π and τ_e should be strictly positive.
2) It is common to view monetary policy as forward-looking in terms of inflation – i.e., to replace π_t with its expected value in a future period, e.g. (Clarida *et al*, 1999; Svensson, 1997; Batini and Haldane, 1997). In the model used here, however, the contemporaneous rule in (13) will be shown (in Section 4) to have an equivalent forward representation, (current inflation is a sufficient statistic for expected future inflation).

4. Inflation and Monetary Stabilisation

4.1. *A New Keynesian Phillips Curve*

Following Clarida *et al.* (1999) and many others, inflation is represented by a standard hybrid backward and forward-looking Phillips Curve, as follows:

$$\pi_t = \phi\pi_{t-1} + (1-\phi)\beta\mathrm{E}_t\pi_{t+1} + \gamma y_t + u_t \tag{14}$$

[18] Note that this optimisation is clearly constrained by the nature of the rule – an issue discussed further below, in Section 6.2.

where u_t is a mean-zero process which captures shocks to real marginal costs arising other than from movements in output: it is in some senses, therefore, a 'supply shock', but such shocks must by assumption not have permanent effects. For the sake of simplicity u_t is assumed serially uncorrelated: $E_t u_{t+i} = 0 \quad \forall i > 0$.

The parameter ϕ captures the degree of inherent stickiness in inflation. When $\phi = 0$, this implies the purely forward-looking 'optimising' Phillips Curve, that Kozicki and Tinsley (2002) note can arise from a wide class of linearised models of optimal pricing subject to frictions. Although the hybrid specification with $\phi > 0$ is often used (e.g., Clarida *et al.*, 1999; Batini and Haldane, 1997; Roberts, 1997), it is correctly regarded as having less secure microfoundations. Indeed, Kozicki and Tinsley (2002) note that this specific form must arise from an assumption of non-rational behaviour by some agents. However, they also show that a virtually identical specification, that includes a term in lagged inflation but also an additional lead, *can* arise from optimising behaviour if the dynamics of pricing frictions are more complex, as well as being much more data-consistent than the pure forward-looking version. Since in the particular context of this model, it is relatively straightforward to show that the inclusion of the additional term in (14) does not change the nature of the results, but does complicate derivations, the simpler hybrid version is used, despite its weaker microfoundations.[19]

4.2. *The Impact of Monetary Stabilisation on Inflation*

Appendix A shows that, substituting for output from (12) applying Assumption 3 (rational expectations), and recursively substituting for expected inflation, the forward-looking Phillips Curve in (14) implies the following general AR(1) reduced form:

$$\pi_t = \rho(\phi, \zeta_\pi)\pi_{t-1} + q_t \tag{15}$$

where q_t is a mean-zero, serially uncorrelated error process, given by

$$q_t = v(\phi, \zeta_\pi)\left(\frac{u_t + \gamma\zeta_e e_t}{1 + \gamma\zeta_\pi}\right) \tag{16}$$

and the autoregressive coefficient for inflation, ρ, will have the following features:

$$\rho(\phi, \zeta_\pi) = v(\phi, \zeta_\pi)\phi;\ \partial v/\partial\zeta_\pi > 0 \tag{17}$$

where $v(.)$ is defined in Appendix A.

Monetary policy in the general case therefore has two impacts: (16) shows that by setting ζ_π, the response of output to inflation in the output rule (12), it can dampen, or accentuate, the impact of both cost-push and demand shocks on innovations to inflation (q_t); in addition, in the presence of inflation stickiness ($\phi > 0$), (17) shows that it can also reduce or increase the degree of persistence of inflation, for a given degree of stickiness. Note however that when inflation is entirely forward-looking (if $\phi = 0$), this latter impact disappears.

[19] The implications of incorporating the necessary additional term in $E_t\pi_{t+2}$ into (14), consistent with optimising subject to second order lag polynomial frictions, are briefly summarised in Appendix A.

In general, policy can thus, by choosing ζ_π, effectively choose ρ. But this choice is constrained by Assumptions 2 and 3, that restrict the nature of monetary stabilisation. The following condition must hold:

PROPOSITION 1. *To satisfy Assumptions* 2 *and* 3, *the coefficient on inflation in the monetary policy output rule* (12) *cannot exceed an upper bound value,* $\bar{\zeta}_\pi$, *such that* ρ, *the autoregressive coefficient for inflation, is strictly less than unity. But as long as inflation is not purely backward-looking* ($\phi < 1$) *this value will be strictly greater than zero, allowing policy some scope to let output 'lean with the wind'.*

Proof. See Appendix A.

Proposition 1 places a constraint on the response of monetary policy to inflation. But the nature of this constraint is somewhat surprising. Given forward-looking behaviour, strict 'leaning against the wind' (as is typically taken for granted in the loss function literature) is not a binding requirement for monetary stabilisation. Conditional upon the expectation that monetary policymakers will always behave in a way that is consistent with ultimate stabilisation of inflation and output (i.e., will satisfy Assumption 2), forward-looking price-setting by the private sector will impart an automatic degree of stabilisation to the system, that can in principle be exploited (though not, as Proposition 1 makes clear, to an indefinite extent) by monetary policy. In due course it will be shown that, in some circumstances it may indeed prove not just feasible but also optimal to exploit this feature by 'leaning with the wind', by setting $\zeta_\pi > 0$, and thereby increasing inflation persistence.

As will become evident in the next Section, some degree of persistence in inflation ($\rho > 0$) is crucial to the nature of certain key results. While persistence is modelled here as arising from inherent stickiness in inflation ($\phi > 0$), it could in principle arise even with purely forward-looking inflation ($\phi = 0$) for other reasons: for example if the two driving error processes, u_t and e_t, were themselves serially correlated, as assumed by, for example, (Clarida *et al.* 1999). Inflation persistence would however in this case be a strictly exogenous phenomenon, thus Proposition 1 would not apply but other results that follow would be unaffected. The attraction of the derivation from underlying inflation stickiness, in contrast, is that it allows for a link between monetary policy and inflation persistence.[20]

5. The Nature of the Monetary Policy Rule for Nominal Interest Rates

5.1. *Derivation of the Interest Rate Rule*

Given the output rule (12), the implied coefficients for the monetary policy rule in (13) can be derived straightforwardly, by substituting from (12) and (13) into the IS curve, (11), using Assumption 3 (rational expectations), to set $E_t\pi_{t+i} = \rho^i\pi_t$, and equalising coefficients.

[20] Section 8 notes that this also offers a new perspective on the observed high degree of persistence of inflation.

The response of real interest rates to the demand shock will be given by:

$$\tau_e = \frac{1 - \zeta_e(1 - \lambda\kappa)}{\kappa[(1 - \lambda)\sigma + \lambda\delta]}. \tag{18}$$

Note that the demand shock coefficient is unaffected by ρ.

The response of real interest rates to inflation will be given by:

$$\tau_\pi = \frac{-(1 - \rho)}{\kappa}\left[\frac{\zeta_\pi(1 - \lambda\kappa) + \lambda\delta\kappa\rho(1 - \alpha)}{(1 - \lambda)\sigma + \lambda\delta(1 - \rho)}\right]. \tag{19}$$

Note that this expression does not fully solve for τ_π, since it is specified in terms of $\rho = \rho(\zeta_\pi)$ and $\alpha = \alpha[\rho(\zeta_\pi)]$ but ρ must, given Assumption 2, always satisfy $0 \leq \rho < 1$, and, as discussed in Section 2.1, for sufficiently sticky debt contracts, $0 < \alpha < 1$, also.

The expressions in (18) and (19) are rather unwieldy, but the key features of interest to subsequent analysis can be summarised in two propositions.

5.2. *The Response of Real Interest Rates to Demand Shocks*

PROPOSITION 2. *With credit-constrained consumers* ($\lambda > 0$)*, a positive response of real interest rates to demand shocks can be consistent with amplification, rather than stabilisation, of demand shocks, in the underlying monetary policy output rule* ($\zeta_e > 1$).

Proof. By inspection of expression for τ_e (2). For $\tau_e < \dfrac{\lambda}{\lambda\delta + (1 - \lambda)\sigma} > 0$, ζ_e is greater than unity.

This feature arises because when $\lambda > 0$, a demand shock has knock-on effects, similar to the Keynesian multiplier, since constrained consumption (determined by (7)) is itself a function of aggregate income. Real interest rates need to rise a certain amount simply to offset these knock-on effects; a larger rise will be required actually to dampen the impact of demand shocks.

5.3. *The Response of Real Interest Rates to Inflation*

PROPOSITION 3. *With credit-constrained consumers* ($\lambda > 0$)*, sufficiently sticky nominal debt contracts* ($\alpha < 1$) *and inflation persistence* ($\rho > 0$) *the response of real interest rates to inflation may be negative even when the monetary policy output rule requires 'leaning against the wind'* ($\zeta_\pi < 0$).

Proof. By inspection of expression for τ_π in (19): the denominator is unambiguously positive but the numerator will be negative for $\zeta_\pi > [\lambda\delta\kappa(1 - \alpha)\rho]/(1 - \lambda\kappa) < 0$.

If inflation is serially uncorrelated ($\rho = 0$), the response of real interest rates will always be of opposite sign to the desired output response, as the loss function literature always assumes. But the intuition behind Proposition 3 is that, with sufficient stickiness of debt contracts, a rise in inflation generates contractionary effects even without any rise in real rates, as long as *nominal* interest rates rise, since such rises lower the disposable income of constrained consumers.[21]

6. Optimal Monetary Stabilisation

6.1. *Monetary Stabilisation and Consumption Variance*

Any given choice of parameters in the output rule, and hence the interest rate rule, will result in reduced forms for the consumption of the two types of representative consumer of the form:[22]

$$c_{1t} = \chi_{1\pi}(\zeta_\pi)\pi_t + \chi_{1e}(\zeta_e)e_t \tag{20}$$

$$c_{2t} = \chi_{2\pi}(\zeta_\pi)\pi_t + \chi_{2e}(\zeta_e)e_t. \tag{21}$$

The restricted nature of the monetary rules, given Assumptions 2 and 3, implies that c_{1t} and c_{2t} will both be zero mean processes: thus, unconditionally, policy will only impact on variances.

For interesting cases (i.e., $\lambda > 0$) it is fairly easy to show that it will not be possible for policy to set all four coefficients to zero. Thus shocks to both π_t and e_t will induce variance in the consumption of at least one type of consumer and generally both. The choice of monetary policy rule will thus determine the signs and relative magnitudes of the reduced form coefficients and hence the relative magnitudes of the variance of consumption of the two types.

It is worth noting that, unlike some other issues of social choice, the problem *requires* the monetary policymaker to make some decision and hence to take a position on the relative weighting to apply to the two type of consumers: there is no *Laisser-Faire* solution. Any policy rule for output, and hence for interest rates, will imply some distribution of consumption variance across the two groups. Not all such rules will be optimal, of course, but all imply some relative ranking.

Note also that this feature is distinctly more general than the specific model that generates it here. Any model in which there are nominal asymmetries of some form (Section 7 discusses other possible examples) will generate asymmetric responses to monetary stabilisation and hence will result in an analogous 'inside objective' arising from the model.

6.2. *Optimal Monetary Stabilisation*

Assume that the coefficients in the output rule (and hence in the interest rate rule) are chosen to maximise some social welfare function in the unconditional expected utilities of the two representative consumers:

[21] Note however that this feature will only arise from the interaction of all three factors: if just one of these is absent, the second term in the numerator of (19) will disappear and with it the sign ambiguity raised by Proposition 3.

[22] Precise definitions of reduced form coefficients are given in Appendix B.

$$\max_{\zeta_\pi,\zeta_e} S\{\mathrm{E}[u(C_{1t})],\mathrm{E}[u(C_{2t})]\} \tag{22}$$

Given the nature of the policy rules and the implied reduced forms for consumption of the the two groups, it is straightforward to show that, up to a second order Taylor approximation, this policy objective translates to be of the form:

$$\min_{\zeta_\pi,\zeta_e} W[\mathrm{var}(c_{1t}),\mathrm{var}(c_{2t})]. \tag{23}$$

Three features of this objective are worth noting.

(1) There is a clear implied constraint on the nature of the feasible objective for monetary stabilisation. Since consumption and output levels may well be sub-optimal, there might be a desire to set policy such that expected consumption was above levels consistent with the natural rate of output. Assumptions 2 and 3 rule this out, and restrict monetary stabilisation to impact solely on variances.[23]

(2) The one-to-one correspondence between expected utility maximisation and consumption variance minimisation also arises, fairly obviously, because consumption is the sole argument in the utility function. This issue, which is examined in more detail in (Wright, 2001), will be discussed in more detail in Section 7 below.

(3) The restriction of the policy objective to be in terms solely of unconditional, rather than conditional variances is, as Clarida *et al.* (1999) note, consistent with an assumption that policy be time-consistent, since, on reasonable conditions, there is an equivalence between assuming policy to minimise some function of the unconditional variances of consumption, and assuming that on average policy acts to minimise a function of *actual* squared deviations in consumption in any given period, i.e. that no account is taken of the impact of current policy on the policy objective in future periods.

6.3. *Two Extreme Cases*

It is possible to arrive at some clear-cut results for the general case of optimal monetary policy by reference to two extreme cases, when only the welfare of a single group matters.

6.3.1. *Case* 1. *Only unconstrained consumers matter*

It is interesting to look at this case first, since it will also describe optimal policy when there are no constrained consumers ($\lambda = 0$). As such, it also applies to the now-standard 'Optimising IS Curve', e.g. (McCallum and Nelson, 1999; Clarida

[23] Rotemberg and Woodford (1997) arrive at a similar restriction on monetary policy by a different route, by assuming that tax policies offset any sub-optimality in the level of output. Alternatively, Blinder (1997) and McCallum (1997) argue forcibly (albeit in the context of a standard loss function) that policymakers will be sufficiently rational to see through any inflationary bias – will, in effect, impose Assumptions 2 and 3 on themselves.

et al., 1999), and offers some marked contrasts with results that arise from minimising the usual loss function in output and inflation deviations.

The features of optimal monetary stabilisation in this extreme case are straightforward to derive. Let $\hat{\tau}_{\pi,1}, \hat{\tau}_{e,1}, \hat{\zeta}_{\pi,1}, \hat{\zeta}_{e,1}$ equal the optimal values in the policy rules for interest rates and output, that minimise the variance of the consumption of a representative type 1 consumer. The nature of this solution can be summarised as follows:

PROPOSITION 4. *If monetary stabilisation is only concerned with the welfare of unconstrained consumers, then real interest rates should respond to neither inflation nor to demand shocks. If there are credit-constrained consumers* ($\lambda > 0$); *sufficiently sticky nominal debt contracts* ($\alpha < 1$); *and persistent inflation* ($\rho > 0$), *then output should optimally 'lean against the wind' with respect to inflation* ($\hat{\zeta}_{\pi,1} < 0$) *and accentuate demand shocks* ($\hat{\zeta}_{e,1} > 1$).

Proof. See Appendix B.

In order to understand the intuition for this result, consider first the sub-case of the undistorted economy, with $\lambda = 0$. In this case (which also corresponds to the standard 'optimising IS curve' case) Proposition 4 implies that inflation should have no impact on either real interest rates or the level of output. In contrast, demand shocks should feed one-for-one into output. The contrast with standard results derived from a policy loss function in output and inflation deviations, which imply $\zeta_\pi < 0$, and $\zeta_e = 0$, is clear-cut. But the contrast arises from the inconsistency of the 'outside objectives' in such models and the models themselves. The standard results imply that monetary policy should *induce* variance in the consumption of forward-looking consumers but with no rationale for the gains to be derived from such a policy, other than the assumed loss function, which comes from outside the model. This is most obvious in the case of a demand shock: an objective of stabilising output, rather than consumption, would have to imply *de*stabilising consumption, if there are no constrained consumers. Once stabilising consumption variance is the objective, the variability of output itself is immaterial, hence in this case demand shocks would simply be ignored.[24]

If there are constrained consumers ($\lambda > 0$), but policy does not take their welfare into account, then the nature of the optimal output response consistent with unchanged real interest rates will depend on the nature of the process for constrained consumption. Given sufficiently sticky debt contracts ($\alpha < 1$), Proposition 4 implies that output will respond negatively to inflation shocks (since the rise in nominal rates required to hold real rates constant will reduce the consumption of constrained consumers – an implication of Proposition 3); and will accentuate demand shocks (a direct implication of Proposition 2), since constrained consumption will induce a Keynesian-style multiplier effect. It is straightforward to

[24] Variability of labour supply, which will be driven at least in part by output variability, and which will have an impact on expected utility, is of course being ignored at this stage but see Section 7 for a discussion of this issue, which turns out not to affect the result.

show that the consumption of constrained consumers in this special case will respond with the same signs as output.

6.3.2. *Case* 2. *Only constrained consumers matter*

For the opposite extreme case, let $\hat{\tau}_{\pi,2}, \hat{\tau}_{e,2}, \hat{\zeta}_{\pi,2}, \hat{\zeta}_{e,2}$ equal the optimal values in the policy rules for interest rates and output, that minimise the variance of the consumption of a representative type 2 consumer. The nature of this solution can be summarised as follows:

PROPOSITION 5. *If there are sufficiently sticky nominal debt contracts* ($\alpha < 1$); *and persistent inflation* ($\rho > 0$), *and policy is only concerned with the welfare of a representative constrained consumer, then real interest rates should fall in reponse to inflation and rise in response to demand shocks. Output should optimally 'lean with the wind' with respect to inflation* ($\hat{\zeta}_{\pi,2} > 0$) *and dampen, but not eliminate demand shocks* ($0 < \hat{\zeta}_{e,2} < 1$).

Proof. See Appendix B.

The intuition behind this result is that, if the sole objective of policy is to stabilise the consumption of constrained consumers, this is achieved by:

- *Reducing* real interest rates by enough to cause output to *rise* in the face of an inflationary shock. In order to offset the incipient contractionary impact on constrained consumption of a rise in nominal rates, output, and hence unconstrained consumption, needs to rise by precisely enough to offset this impact. Monetary policy therefore acts in a way that would conventionally be thought of as destabilising (subject, of course to the constraint implied by Proposition 1, that the resulting value of ρ must be strictly less than unity).
- *Raising* real interest rates in the face of a demand shock but only by enough to dampen, rather than entirely eliminate the impact of such shocks on output. Since constrained consumption is a function of output, the incipient upward impact needs to be offset by a rise in interest rates. Since this in turn depresses constrained consumption, the two effects will only balance if both output and interest rates rise. As this implies a rise in real, as well as nominal rates, the counterpart has to be a fall in unconstrained consumption.

6.4. *General Features of Optimal Monetary Stabilisation*

Without placing any restrictions on the nature of the social weighting function, $W()$ other than that it be non-decreasing in both arguments, certain general features of optimal monetary policy can be derived straightforwardly from Propositions 4 and 5. Let $\hat{\tau}_{\pi}, \hat{\tau}_{e}, \hat{\zeta}_{\pi}, \hat{\zeta}_{e}$ equal the optimal values in the policy rules for interest rates and output, that minimise (23) (and hence implicitly maximise (22)).

PROPOSITION 6. *With credit-constrained consumers* ($\lambda > 0$), *sufficiently sticky nominal debt contracts* ($\alpha < 1$) *and persistent inflation* ($\rho > 0$), *optimal monetary stabilisation will require real interest rates to fall in response to inflation* ($\hat{\tau}_\pi < 0$), *and rise in response to demand shocks* ($\hat{\tau}_e > 0$). *Policy may dampen or accentuate the direct impact of demand shocks on output, but will never eliminate their impact entirely* ($\hat{\zeta}_e > 0$). *The sign of the optimal response of output to inflation* ($\hat{\zeta}_\pi$) *is ambiguous.*

Proof. As long as $W_1', W_2' > 0$, the values $\hat{\zeta}_\pi, \hat{\zeta}_e$ that satisfy (22) will be a convex combination of the values $\hat{\zeta}_{\pi,1}, \hat{\zeta}_{e,1}$ that satisfy $\max_{\zeta_\pi,\zeta_e} \mathrm{E}[u(C_{1t})]$ and those values $\hat{\zeta}_{\pi,2}, \hat{\zeta}_{e,2}$ that satisfy $\max_{\zeta_\pi,\zeta_e} \mathrm{E}[u(C_{1t})]$, the properties of which are given in Propositions 4 and 5.

These features offer a clear contrast to the consensus in the loss function literature. The response of real interest rates to inflation is of the opposite sign; and while real interest rates must rise in the face of output shocks, the *magnitude* of the rise must be strictly less than in the loss function case, since it will never be optimal to eliminate the impact of demand shocks entirely.

A further implication of Proposition 6 is that the responses of the two types of consumers will always be of opposite signs: unconstrained consumption will never fall in the face of an inflation shock, and will never rise in the face of an output shock; *vice versa* for the responses of constrained consumers.

6.5. *Optimal Output Responses with a Linear Social Welfare Function*

Proposition 6 provides some unambiguous conclusions on the nature of optimal monetary stabilisation, with respect to the signs of changes in real interest rates, and of the consumption of the two types of consumers, in the face of inflation and demand shocks, if there is incomplete adjustment of debt contracts to expected inflation. But there were ambiguities with respect to the optimal responses of output. The ambiguity of the sign of the output response to inflation implies a corresponding ambiguity as to whether optimal monetary policy will tend to decrease or increase the persistence of inflation. As for demand shocks, the ambiguity relates to whether monetary policy will tend to dampen or accentuate them.

Further insights into the nature of these ambiguities can be arrived at by assuming a specific functional form for $W()$. Since the derivations involved in demonstrating the resulting features of optimal stabilisation are however both lengthy and tedious these are relegated to a separate paper (Wright, 2002*a*), with only a summary of key features summarised here.

A simple assumption is that $W()$ is linear, with the stabilisation problem having the following form:

$$\max_{\zeta_\pi,\zeta_e} S = (1-\Theta)\mathrm{E}[u(C_{1t})] + \Theta\mathrm{E}[u(C_{2t})]. \qquad (24)$$

This specification can be rationalised as the commonly used Benthamite (or utilitarian) social welfare function by setting Θ, the weight on the expected utility of constrained consumers, equal to their population share. Setting Θ equal to zero or unity is equivalent to the two extreme benchmark cases analysed previously. In a voting model, Θ might also be viewed as a (0,1) dummy, depending on whether the median voter is a constrained or unconstrained consumer.

Since λ represents a factor income share, rather than a population share, and since collateral constraints are more likely to be binding for those with relatively low factor incomes, it is reasonable to assume that $\lambda < \Theta$. The case $\lambda < \frac{1}{2}$ also appears more likely both on *a priori* grounds and given the econometric estimates of Campbell and Mankiw (1990) and others. Assuming this to be the case, Wright (2002*a*) shows that, for some values $\tilde{\Theta}_e$ and $\tilde{\Theta}_\pi$,

- Optimal monetary stabilisation will imply that output should 'lean with the wind' with respect to inflation ($\hat{\zeta}_\pi > 0$), if $\Theta > \tilde{\Theta}_\pi$;
- It will dampen (but, from Proposition 6, never eliminate) demand shocks ($0 < \hat{\zeta}_e < 1$), if $\Theta > \tilde{\Theta}_e$;
- For plausible underlying structural parameter values, both $\tilde{\Theta}_\pi$ and $\tilde{\Theta}_e$ will normally be strictly less than one half;
- Hence, if, for example, the welfare of both types of consumer is given an equal weight ($\Theta = \frac{1}{2}$) optimal monetary stabilisation is likely to result in an output rule that requires 'leaning against the wind' with respect to demand shocks, but 'leaning with the wind' with respect to inflation.[25]

7. Extensions of the Model

7.1. *Other Types of Asymmetry*

In the interests of simplicity the main model analysed in this paper is restricted to just two types of consumer. It would however be fairly easy to amend the model to allow for other types of asymmetry, of which possible examples might be:

TYPE 3. *Constrained consumers with no collateral (and thus a special case of type 2 consumers, with* $\delta = 0$). These would not be affected by the effect of monetary stabilisation working through interest rates but *would* be affected by the impact on output. Allowing for such consumers would thus introduce a utility-based rationale for output stabilisation and would therefore bring the optimum somewhat closer to that implied by the standard policy loss function. But note that the optimal value of ζ_π, the response of output to inflation, is in any case likely to be in the neighbourhood of zero (since $\hat{\zeta}_{\pi,1}$ and $\hat{\zeta}_{\pi,2}$ are of opposite signs).[26] Thus allowing

[25] Wright (2002*b*) also discusses optimal stabilisation with a Rawlsian 'Max-Min' weighting function. The results are in general qualitatively similar. The Rawlsian approach does however suggest an additional possible rationale for 'leaning with the wind'. If, consistent with the above assumptions on λ and Θ the *level* of consumption of constrained consumers is lower than that of unconstrained consumers, equal variances of (log) consumption would leave constrained consumers still worse off in terms of expected utility. A Rawlsian criterion would therefore imply raising the variance of unconstrained consumption and lowering that of constrained consumption – thus pushing the optimum closer to, or even as far as the extreme case where only constrained consumers matter. Rawlsian stabilisation would thereby become a form of redistribution in response to consumption inequality but with the redistibution occurring via expected utility (hence the variance of consumption), rather than via the level of consumption itself. I am grateful to one of the referees for pointing this out.

[26] Note however that, from Proposition 3, real rates will still optimally fall in response to inflation even if $\zeta_\pi = 0$, as long as there are some type 2 consumers.

for type 3s would only therefore be likely to have a significant impact on ζ_e, tending to push it towards zero; but as long as type 1 and type 2 consumers are also of importance, the optimal value of ζ_e will always be positive.

TYPE 4. *Unconstrained consumers whose assets, rather than liabilities, are fixed in nominal terms.* Such consumers would be affected by inflation with the opposite sign to the type 2 constrained consumers considered in the main paper. But, whilst debtors face constraints that arise from capital market imperfections that are likely to make their debt contracts distinctly sticky (due to the transactions costs of measuring collateral), this does not apply to creditors, who by assumption will not be credit-constrained. Thus, while creditors holding nominal financial assets bear a real return risk that is the mirror image of the real return risk faced by debtors, the impact of this risk on their *consumption* will be distinctly less. Indeed, to the extent that inflation risks to real returns can be hedged (given the existence of indexed bonds and real assets such as equities) real return risk due to inflation will be of relatively modest significance for reasonably stable inflation rates and type 4 consumers should therefore behave almost identically to unconstrained type 1 consumers.

TYPE 5. *Constrained consumers without collateral, whose income is set in nominal terms.* These are closer to a mirror image of type 2 constrained consumers, since, if type 5s have no collateral, to the extent that their real income is affected by inflation, this will impact directly on their consumption. In principle, therefore, the impact of type 2 consumers on optimal monetary stabilisation, as analysed in this paper, might in effect be 'cancelled out' in an economy with a sufficiently high proportion of type 5s.[27] This is unlikely to be the case in the richer economies of Europe or North America, but in many transitional and developing economies, the impact of type 5s on optimal monetary stabilisation might well outweigh the impact of type 2s, thus implying that poorer economies should optimally be somewhat tougher on inflation variability than richer countries, in which type 2s will tend to become more important. In practice, of course the reverse has almost invariably been the case, with poorer countries having distinctly more variable inflation. This presumably reflects a combination of two factors: (a) the political balance of power and (b) the fact that the type 5 consumers are frequently employees of a government that may itself somewhat resemble a type 2 consumer.

7.2. The Impact of Labour Supply Variability on Optimal Monetary Stabilisation

In this paper the exclusive focus on consumption variance as the sole argument of the objective function for monetary stabilisation can be rationalised

[27] Note however that the debt-to-consumption ratio (and hence the implied collateral ratio) δ may well be well above unity for many constrained consumers (typical loan-to-income ratios for mortgages in the UK, for example, are around 3); thus one type 2 consumer may only be cancelled out, in terms of impact on aggregate consumption, by several type 5 consumers.

straightforwardly in terms of expected utility, since consumption is assumed to be the single argument in the utility function of both types of consumer. An obvious extension, analysed in a separate paper (Wright, 2001) is to examine the welfare implications of fluctuations in labour supply, as well as consumption. This is particularly pertinent to any comparison of the results in this paper with those of Rotemberg and Woodford (1997), where a utility-based objective is also assumed, but where the results for optimal policy are very much closer to the standard loss function results.

Since the focus of the analysis in this paper is on capital market, rather than labour market imperfections, Wright (2001) analyses a model with endogenous labour supply, and a unified (though not necessarily competitive) labour market. For a wide range of parameter values, the general features of optimal monetary stabilisation in this paper are preserved in this extended version: indeed for most cases the range of possible values of optimal policy parameters lies strictly within the range derived in this paper.[28]

This assumption of a perfectly unified labour market that gives this result is in contrast to the 'yeoman farmer' framework of Rotemberg and Woodford, in which the labour market is perfectly segmented: hence in their model workers cannot hedge idiosyncratic labour supply risk (in turn due to the timing of output price changes in a Calvo contracting framework). Indeed, since in their model idiosyncratic consumption risk is perfectly insurable (allowing them to model consumption as that of a single representative agent), labour supply fluctuations are the primary source of the welfare costs of output and inflation fluctuations. The contrast between the results in this paper and those in Rotemberg and Woodford can thus be seen as arising from the assumptions made about the nature of imperfections in capital and labour markets in the two models. In a more general model, in which there were both capital and labour market imperfections, the extent to which the features of optimal monetary stabilisation were closer to the model here, or that of Rotemberg and Woodford, would thus depend on the relative quantitative importance of capital market versus labour market imperfections.

8. Data Perspectives

While the main focus of the paper has been on normative conclusions, the analysis also appears to offer some useful insights into observed behaviour:

1. The 'semi-optimising IS curve' is consistent with the well-documented correlation between nominal interest rates and output (Bernanke and Blinder, 1992; Fuhrer and Moore, 1995; Wright, 2002*b*), that would clearly represent an anomaly if the empirical IS Curve simply reflected intertemporal substitution.

[28] As in this paper, only unconstrained consumers are intertemporal optimisers but consumers of both types are assumed to be *intra*temporal optimisers. Since the intratemporal and intertemporal optimality conditions are linked via the marginal utility of consumption, the labour supply of both types of consumer, as well as their consumption, will optimally respond to both types of shock.

2. Another apparent empirical anomaly for the 'loss function' literature has been the repeated finding that, except in relatively recent years, the response of real interest rates to inflation (τ_π in this paper) has been close to zero, or negative, in many countries – even those, most notably Germany, with a reputation for pursuing a hard line on inflation; see (Bernanke and Mihov, 1997; Bernanke and Gertler, 1997; Clarida *et al.*, 1998; Wright, 2002*b*). Such behaviour has typically been assumed simply to represent 'bad' policy, with behaviour in recent years represented as evidence that central bankers have learned the error of their ways. The analysis of this paper offers a clear alternative to this view: the response of policy may possibly have been optimal in the sense used in this paper. By implication, policy in recent years may have been sub-optimal.
3. The analysis of this paper also casts an interesting new light on the well-known near-unit root nature of inflation in many countries in many periods. Even if there is structural inflation stickiness ($\phi > 0$) high values of ϕ are very hard to reconcile with underlying optimising behaviour.[29] However, Appendix A shows that even when systematic monetary policy responds to inflation by 'leaning against the wind' in terms of output ($\zeta_\pi < 0$) ρ can nonetheless be greater than ϕ. And Proposition 1 shows that 'leaning with the wind' can raise ρ even further towards unity. Thus the near-unit root properties of inflation reflect not just the degree of inherent stickiness of inflation but also the nature of monetary stabilisation. Even if the sign of the output response to inflation has not actually been positive, the analysis of this paper does help to explain why it may have been optimal for monetary policy to tolerate a significant degree of persistence of inflation.

The correspondence between the model and these empirical features depends, of course, on two key features. First, it requires sufficient stickiness in nominal debt contracts (implying a relatively low value for α). Second, and more crucially, as noted at the outset of this paper, it requires the assumption that this stickiness *matters*, because credit constraints are binding.[30] It is certainly suggestive that, when the macroeconomy is modelled, as here, on the assumption that the combination of sticky nominal debt and credit constraints *do* matter, this helps to explain a number of features that would otherwise be puzzling in the more standard representative agent/loss function framework. One obvious area for future empirical research, suggested by the analysis of this paper, is whether, for example, the clear differences between institutional arrangements for debt contracts across countries imply corresponding differences both in the nature of the transmission mechanism and, as a direct result, in the nature of monetary policy itself, as this paper would suggest that they should.

[29] Even in Kozicki and Tinsley's (2002) fully optimising derivation a high value of ϕ requires changes in the inflation rate to generate relatively more costly frictions than changes in prices.

[30] Or, as Graham and Wright (2003) note, that consumers *behave* as if they do, as in, for example, Carroll's (2001) model of precautionary saving.

9. Conclusions

This paper has examined the implications of nominal asymmetries, both for the transmission mechanism of monetary policy and for the objectives of optimal monetary stabilisation. Optimal monetary stabilisation is derived as a mechanism to achieve a socially desirable outcome in the face of these asymmetries, by allocating consumption variance between different types of agent.

The particular form of nominal asymmetry examined in the main part of this paper – the combination of binding credit constraints and sticky nominal debt contracts – implies that some, credit-constrained, consumers will be affected by fluctuations in both output and the nominal, as well as real, interest rate. At the same time unconstrained consumers will be affected, via the usual Euler Equation response, by the impact of monetary policy on the real interest rate.

The results of the analysis have thrown up a number of normative conclusions that clearly conflict with the 'loss function' consensus in most recent literature on monetary stabilisation in a New Keynesian framework of sticky prices. Most notably:

- that optimal monetary stabilisation implies cutting real interest rates in the face of inflationary shocks if debt contracts are sticky;
- there are plausible circumstances in which it may be optimal to induce a positive response of output to such shocks ('leaning with the wind'), thereby increasing, rather than reducing the persistence of inflation;
- that the optimal response to demand shocks is to raise real interest rates, but never by enough to eliminate their impact on output entirely.

While these features conflict with the normative results of the loss function literature, they do not appear obviously inconsistent with the data – indeed they provide a plausible explanation for some features of the data that are a puzzle in the loss function framework.

Central bankers are unlikely to be enthusiastic about the normative conclusions of this paper and possibly not without reason. Most obvious is the implication that it may be optimal for policy to increase, rather than decrease the persistence of inflation. It should be noted, of course, that this conclusion emphatically does not provide an optimising rationale for destabilising policy but merely for a *lesser* degree of stabilisation than that implied by the consensus in the loss function literature.[31] Nonetheless, one reason for caution in response to the results of this paper arises if there is a very strong degree of structural stickiness in inflation (ϕ close to, or even equal to unity). If, in the extreme case, inflation were fully backward-looking ($\phi = 1$) there would, for example, be simply no scope for 'leaning with the wind'. Any attempt to pursue it, possibly on the mistaken assumption that ϕ was less than unity, would run the risk of inducing explosive behaviour in inflation.

A second reason for caution in interpreting the results of this paper is that, while they do seem to undermine standard 'loss function' results, further explorations of

[31] It has almost no implications for the optimal *level* of inflation but for the fact that the higher unconditional variance of inflation resulting from 'leaning with the wind' might (possibly) put a lower bound on the mean inflation rate if the zero bound on nominal rates puts real limits on monetary stabilisation (Rotemberg and Woodford, 1997).

the consequences of relaxing the single representative agent assumption may in turn undermine the results presented here.

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Appendix

A. Derivation of Reduced Form Representations of Inflation, and Proof of Proposition 1

A.1. *The Impact of Monetary Policy on the Inflation Process*
Using the monetary policy rule for output (1) to eliminate output from the Phillips Curve (25) implies:

$$\pi_t = \frac{\phi}{1-\gamma\zeta_\pi}\pi_{t-1} + \frac{(1-\phi)\beta}{1-\gamma\zeta_\pi}\mathrm{E}_t\pi_{t+1} + \frac{u_t+\gamma\zeta_e e_t}{1-\gamma\zeta_\pi}. \tag{25}$$

Applying Assumption 2 (rational expectations) and recursively substituting for expected values of future inflation in terms of current inflation, a backward-looking AR(1) specification for inflation results:

$$\pi_t = \rho(\phi,\zeta_\pi)\pi_{t-1} + q_t \tag{26}$$

where

$$\rho(\phi,\zeta_\pi) = v(\phi,\zeta_\pi)\phi$$
$$v(\phi,\zeta_\pi) = \frac{1}{1-\gamma\zeta_\pi}\left[\frac{(1-\gamma\zeta_\pi^2-\beta(\phi-\phi^2)}{(1-\gamma\zeta_\pi)^2-2\beta(\phi-\phi^2)}\right] \geq 0$$
$$q_t = \frac{v(\phi,\zeta_\pi)}{1-\gamma\zeta_\pi}(u_t+\gamma\zeta_e e_t).$$

Note that $v(\phi,0) > 1$: thus, if policy neither leans with or against the wind with respect to inflation ($\zeta_\pi = 0$), $\rho > \phi$.[32]

A.2. *Proof of Proposition 1*
The upper bound value for ζ_π, $\overline{\zeta}_\pi(\phi)$, consistent with monetary stabilisation, as defined in Assumption 2, will be the minimum value of ζ_π that satisfies $\rho(\phi,\ \zeta_\pi) = 1$. From (26), it is evident that $\rho(1,\ 0) = 1$, implying $\overline{\zeta}_\pi(1) = 0$. For $0 \leq \phi < 1$, $\rho'_\phi(\phi,0) > 0$ implying $0 \leq \rho(\phi,\ 0) < 1$.[33] For $0 \leq \phi < 1$ (letting $z = \phi - \phi^2 \leq \frac{1}{4}$) $\rho'_{\zeta_\pi}(\phi,0) = \gamma\phi[1-\beta(z-2\beta z^2)]$

[32] If, consistent with the fully optimising specification of Kozicki and Tinsley (2002, equation (49)), the underlying Phillips Curve includes an additional term in $\mathrm{E}_t\pi_{t+2}$ (with a necessary parameter restriction that the coefficient thereon equal $-\beta^2\phi$), the single amendment that results is that the 2nd term in the denominator of the bracketed expression in the definition of $v(.)$ is scaled, not by 2, but by $1 + G$, where $G > 0$ is a function of the underlying parameters in the Phillips Curve. This amendment does not change any of the qualitative properties of the reduced form.

[33] Since $\rho'_\phi(\phi,0) = v(\phi,0) + \phi v'_\phi(\phi,0); v \geq 1;$ and $v'_\phi(\phi,0) = -2\beta(\phi-\frac{1}{2})\left[1-2\left(\phi-\phi^2\right)^2\right]^{-2}$ which is positive for $\phi < \frac{1}{2}$. It is negative for $\phi > \frac{1}{2}$ but the numerator is linear and decreasing in ϕ, and $v'_\phi(1,0) = -\beta$ implying a minimum value in (0,1) of $\rho'_\phi(1,0) = 1-\beta > 0$.

$(1 - 2\beta z)^{-2} > 0$ implying that $\bar{\zeta}_\pi(\phi) > 0$ for values of ϕ strictly below unity. $\bar{\zeta}_\pi(\phi)$ will however be finite for strictly positive values of ϕ, since as ζ_π tends to so some finite value $\tilde{\zeta}_\pi > \bar{\zeta}_\pi$, $v(\phi,\zeta_\pi) \to \infty$.[34]

B. Proofs of Propositions 4 and 5

The reduced form coefficients for the consumption of the two groups of consumers in (20) and (21) are given by:

$$\chi_{1\pi}(\zeta_\pi) = \frac{-\sigma\tau_\pi(\zeta_\pi)}{1 - \rho(\zeta_\pi)} \tag{27}$$

$$\chi_{1e}(\zeta_e) = -\sigma\tau_e(\zeta_e) \tag{28}$$

$$\chi_{2\pi}(\zeta_\pi) = \zeta_\pi - \delta\{\tau_\pi(\zeta_\pi) + [1 - \alpha(\zeta_\pi)]\rho(\zeta_\pi)\} \tag{29}$$

$$\chi_{2e}(\zeta_e) = \zeta_e - \delta\tau_e(\zeta_e). \tag{30}$$

Using these definitions, the proof of Proposition 4 is given by:

Proof. $\max_{\zeta_\pi,\zeta_e} \mathrm{E}[u(C_{1t})] \Rightarrow \min_{\zeta_\pi,\zeta_e} \mathrm{var}(c_{1t}) = \min_{\zeta_\pi,\zeta_e}[\chi_{1\pi}(\zeta_\pi)^2 \ \mathrm{var}(\pi_t) + \chi_{1e}(\zeta_e)^2 \ \mathrm{var}(e_t) + 2\chi_{1\pi}(\zeta_\pi)\chi_{1e}(\zeta_e)\mathrm{cov}(\pi_t, e_t)]$ which is minimised at zero if $\chi_{1\pi}(\zeta_\pi) = \chi_{1e}(\zeta_e) = 0$. From (27) and (28) this requires $\hat{\tau}_{\pi,1}(\hat{\zeta}_{\pi,1}) = \hat{\tau}_{e,1}(\hat{\zeta}_{e,1}) = 0$. Setting (19) and (18) equal to zero implies

$$\hat{\zeta}_{\pi,1} = \frac{-\kappa\lambda\delta[1 - \alpha(\hat{\zeta}_{\pi,1})]\rho(\hat{\zeta}_{\pi,1})}{1 - \kappa\lambda} < 0 \tag{31}$$

and

$$\hat{\zeta}_{e,1} = \frac{1}{1 - \kappa\lambda} > 1 \tag{32}$$

with $\lambda > 0$, $\phi > 0$ (hence $\rho(\hat{\zeta}_{\pi,1}) > 0$), and $\alpha(\hat{\zeta}_{\pi,1}) < 1$, both inequalities will hold in strict form.

The proof of Proposition 5 is given by:

Proof. Analogously to the proof of Proposition 4, $\max_{\zeta_\pi,\zeta_e} \mathrm{E}[u(C_{2t})] \Rightarrow \min_{\zeta_\pi,\zeta_e} \mathrm{var}(c_{2t}) = \min_{\zeta_\pi,\zeta_e}[\chi_{2\pi}(\zeta_\pi)^2\mathrm{var}(\pi_t) + \chi_{2e}(\zeta_e)^2\mathrm{var}(e_t) + 2\chi_{2\pi}(\zeta_\pi)\chi_{2e}(\zeta_e)\mathrm{cov}(\pi_t,e_t)]$ which is minimised at zero if $\chi_{2\pi}(\zeta_\pi) = \chi_{2e}(\zeta_e) = 0$. Setting $\chi_{2\pi}(\hat{\zeta}_{\pi,2}) = 0$ in (29) and substituting for $\hat{\tau}_{\pi,2}(\hat{\zeta}_{\pi,2})$ from (19) implies

$$\begin{aligned}\hat{\zeta}_{\pi,2} &= \delta\{[1 - \alpha(\hat{\zeta}_{\pi,2})]\rho(\hat{\zeta}_{\pi,2}) + \hat{\tau}_{\pi,2}(\hat{\zeta}_{\pi,2})\} \\ &= \frac{\kappa\delta\rho(\hat{\zeta}_{\pi,2})[1 - \alpha(\hat{\zeta}_{\pi,2})]}{1 + \dfrac{\delta[1 - \rho(\hat{\zeta}_{\pi,2})]}{(1 - \lambda)\sigma}[1 + \lambda(1 - \kappa)]} > 0.\end{aligned} \tag{33}$$

Substituting back into (19) implies $\hat{\tau}_{\pi,2}(\hat{\zeta}_{\pi,2}) < 0$, unambiguously.

Setting $\chi_{2e}(\hat{\zeta}_{e,2}) = 0$ in (30) and substituting for $\hat{\tau}_{e,2}(\hat{\zeta}_{e,2})$ from (18) implies

$$\begin{aligned}\hat{\zeta}_{e,2} &= \delta\hat{\tau}_{e,2}(\hat{\zeta}_{e,2}) \\ &= \frac{\delta}{\delta + \kappa(1 - \lambda)\sigma}.\end{aligned} \tag{34}$$

Thus $0 < \hat{\zeta}_{e,2} < 1$. Substituting back into (18) implies $\hat{\tau}_{e,2}(\hat{\zeta}_{e,2}) > 0$.

[34] $\tilde{\zeta}_\pi$ is the smallest solution to $(1 - \gamma\zeta_\pi)^2 - 2\beta(\phi - \phi^2) = 0$.

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