NOMINAL RIGIDITY AND MONETARY UNCERTAINTY

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Nominal Rigidity and Monetary Uncertainty *

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Abstract

A dynamic, stochastic optimising macromodel with predetermined money wages and labour market monopoly power is used to examine the effect on current macroeconomic variables of a temporary increase in variability of the future money supply. As a benchmark, we show that under perfect wage-price flexibility 'uncertainty irrelevance' holds, when monetary uncertainty is appropriately defined. The introduction of wage stickiness causes future monetary uncertainty to raise the nominal interest rate, with a deflationary impact on current price and output, for plausible parameterisations. It also causes the money wage to be set higher, increasing the 'natural' rate of unemployment.

Keywords: nominal rigidity, monetary uncertainty, output, interest rates

JEL classification: E 44

Introduction

Increases in uncertainty about future monetary conditions are often perceived to occur: for example during the approach to a general election, or following the election of a new government with unclear preferences[1], or during periods of technological innovation or deregulation in financial markets. Greater inflation uncertainty is also very often seen as a concomitant of high average inflation, and to constitute perhaps the main cost of high inflation.[2] Such increases in uncertainty are frequently blamed for causing changes in current macroeconomic variables, such as a rise in interest rates or a depression of demand. However the theoretical literature on the macroeconomic effects of monetary uncertainty, although substantial, is still underdeveloped in important directions. Best known is the analysis based on 'signal extraction' models of aggregate supply.[3] Other work in the tradition of finance theory has examined the impact of monetary uncertainty on asset prices in models with dynamically-optimising agents.[4]. Both these approaches assume Walrasian flex-price markets. Another tradition in macroeconomics suggests that nominal rigidities may play a critical role. In this paper we set out to analyse this role, and argue that it is a very important one.

The source of nominal rigidity which we consider is a predetermined money wage, an idea originally introduced in the one-period contracts models of Gray (1976) and Fischer (1977). This is a relatively mild form of nominal rigidity which has strong casual empirical support. Since our aim is to look at the *implications* of nominal rigidity not at the reasons for it, we will not here recite the well-known theoretical arguments concerning unindexed contracts. The novelty of our model relative to Gray-Fischer is that wage-setting behaviour, along with labour supply, consumption and money demand behaviour, are derived from full dynamic optimisation by agents who have rational expectations with respect to all moments of future variables. Recent work in the 'New Keynesian' mould has emphasised the importance of imperfect competition for

[1] The recent revival in the literature on political business cycles, although not the subject of this paper, has drawn attention to this.
[2] See for example the discussion of this issue in Driffill, Mizon and Ulph (1990)
[3] For example, Lucas (1973), Cukierman (1984)
[4] For example, Gertler and Grinols (1982), Stulz (1986).

macroeconomics, and we incorporate this here by considering a monopolistic labour market. The resulting economy could roughly be summarised as a dynamic stochastic version of Blanchard and Kiyotaki (1987) but with one-period contracts in place of 'menu costs'. The complexity of the task of extending models using the latter to a fully dynamic setting[5] is one more argument in favour of our present use of a more conventional story of nominal rigidities.[6]

We will show within this framework, firstly, that nominal rigidity is a necessary condition for future monetary uncertainty to affect any current macroeconomic variables. This is demonstrated in section 2 of the paper, where we present the model with perfect wage and price flexibility, and provide an 'uncertainty irrelevance' result which serves as a benchmark for what follows. This result is interesting for its own sake, since it is very easy to get 'uncertainty relevance' for what are essentially spurious reasons even with perfect wage-price flexibility, and considerable care needs to be exercised in setting up the model to avoid this. In section 3 we introduce predetermination of wages. Our principal result is that, for plausible parameterisations, an increase in future monetary uncertainty has a deflationary impact on current demand and thus on price and output. A second result which we obtain along the way is that monetary uncertainty induces wage-setters to set higher wages, which thereby raises the 'natural' rate of unemployment. By examining the case of 'full' nominal rigidity, as we do at the end of section 3, we are able to provide some insight into the features of preferences which give rise to these results. In particular we highlight the role of Kimball's (1990) 'relative prudence' measure, here applied to money-holding and to labour supply, as the key determinant of the responses to monetary uncertainty in the presence of nominal rigidities.

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[5] See, for example, the paper by Caplin and Leahy (1992)

[6] The closest relative to our model in the existing literature is perhaps that of Svensson (1986), which includes dynamically optimising households facing monetary uncertainty, and monopolistic firms who fix prices one period in advance. However Svensson does not analyse the effect of an increase in monetary uncertainty.

2. A Monopolistic Economy with Wage and Price Flexibility

Overview

The structure of the economy in a given time period closely follows a common pattern of many recent imperfectly competitive macromodels.[7] There are markets for goods, labour, money and bonds. There is a continuum of symmetric output sectors or industries, each producing a differentiated consumption good, some of which is bought by every consumer. The goods market in each industry is Walrasian.[8] Firms produce goods using labour, the supply of which is monopolised by an industry-specific trade union. As a result of the predetermined money wage the static part of the model is a completely standard 'textbook Keynesian' one, and can be described by the familiar apparatus of aggregate demand and aggregate supply curves.

The model departs from the typical pattern in being dynamic. Households are treated as infinitely-lived. They behave as perfect competitors in the goods market, but as monopoly suppliers in the labour market.[9] Household utility in each period depends on consumption, labour supply and on a measure of the transactions services provided by money. The current and future wage levels and the demands for goods and money are determined by dynamic optimisation under uncertainty, where agents are taken to maximise lifetime expected utility and to have rational expectations with respect to the probability distributions of relevant future variables.

The exogenous source of uncertainty in the economy is the sequence of future money supplies. The current money supply is taken to be fully observable: we are *not* concerned here with the problem of partial observability of contemporaneous shocks as in the'signal extraction' models of aggregate supply.

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[7] It is drawn in particular from section 2 of the recent survey of such models by Dixon and Rankin (1992)

[8] Monopoly power could easily be introduced into the goods market, but this complication would add little for present purposes.

[9] The typical agent is therefore a 'household-union', as in Blanchard and Kiyotaki (1987).

Demand for output of industry i

Industry demands are determined by standard Dixit-Stiglitz preferences over good types.[10] The continuum of industries is indexed by $i \in [0,1]$. The sub-problem facing the consumer is to allocate expenditure E_t over good-types, in order to solve:

$$\max\ c_t = [\int_0^1 c_{it}^{[\theta-1]/\theta} di\,]^{\theta/[\theta-1]} \text{ s.t. } E_t = \int_0^1 p_{it} c_{it} di \tag{1}$$

where $\theta > 1$ is the elasticity of substitution. This results in the familiar constant-elasticity demand function for output i:

$$c_{it} = \left[\frac{p_{it}}{p_t}\right]^{-\theta} \frac{E_t}{p_t} \qquad \text{where } p_t = [\int_0^1 p_{it}^{1-\theta}\,]^{1/[1-\theta]} \text{ is the price index} \tag{2}$$

From this, maximised sub-utility is found as $c_t = E_t/p_t$.

Demand for labour in industry i

The number of firms is fixed, so we consider a 'representative' firm in each industry. Technology is given by $y_{it} = \alpha \ell_{it}^{\sigma}$ $(\sigma \leq 1)$. Since the firm is a price- and wage-taker, its profit-maximising labour demand and output supply are determined by equating marginal labour productivity to the real wage in the usual way:

$$\ell_{it} = \left[\frac{1}{\sigma\alpha}\frac{W_{it}}{p_{it}}\right]^{\frac{1}{\sigma-1}} \tag{3}$$

$$y_{it} = \alpha\left[\frac{1}{\sigma\alpha}\frac{W_{it}}{p_{it}}\right]^{\frac{\sigma}{\sigma-1}} \tag{4}$$

The demand function faced by the monopoly union in industry i is not, however, (3), since the union recognises that it can influence the price of the industry's output, which must hence be endogenised. This is done by equating (2) and (4) to impose equilibrium in the goods market. Solving for p_{it} and plugging the result back into (3) then gives:

$$\ell_{it} = K_t W_{it}^{-\varepsilon} \quad \text{where } \varepsilon \equiv \frac{\theta}{\sigma+[1-\sigma]\theta}, \quad K_t \equiv [\sigma\alpha]^{\varepsilon}[E_t/\alpha p_t^{1-\theta}]^{-\varepsilon/\theta} \tag{5}$$

(5) is the demand function faced by the sector-i union, and has a constant money-wage elasticity ε. The shift parameter K_t is parametric to the union since the industry has

[10] Macroeconomic applications of this have become common: see, for example, Ball and Romer (1990).

measure zero in the economy as a whole, so that the general price index p_t and aggregate goods expenditure E_t are invariant to its decisions.

The modelling of money demand

The demand for money is a sufficiently important dimension of the household's decision problem that it merits separate mention before the overall optimisation problem of households is considered. Dynamically optimising models of portfolio decisions which include money as a dominated asset typically represent the transactions services which generate the demand for money either by a cash-in-advance constraint or by assuming that real money balances provide utility. The second approach, which is generally less restrictive as regards the form of money demand which results and which can encompass cash-in-advance as a special case, is the one we follow here.

In discrete-time models, there is more than one possible definition for the 'liquidity' variable which enters the utility function. Let us denote this variable quite generally as q_t. Two obvious specifications for q_t are 'end-of-period' real balances, $q_t \equiv M_t/p_t$ (where M_t is nominal balances held by the household at the end of period t), and 'beginning-of-period' real balances, $q_t \equiv M_{t-1}/p_t$.[11] The beginning-of-period specification accords much better with logic: it is surely cash held in *advance* of period t's goods purchases which we would expect to facilitate them, not cash held in arrears. However this specification also leads to a paradox: a money handout by the government to the household during period t, which will surely raise the demand for, and thus the price of, goods in period t, causes a liquidity *shortage*. This is because M_{t-1} is predetermined, so that the higher p_t depresses q_t. Such a specification thus prevents a proportional transfer of money from being neutral, in the strict sense of leaving all real variables and utility unaffected. When the transfer in question is a random future one, it also rules out straight away the possibility of monetary uncertainty being 'irrelevant'. This last has been shown in Rankin (1993), where in a simple pure-exchange economy it is demonstrated that although the end-of-

[11] Both of these can be found in the literature: for example, Sargent (1987, Ch.4), Leeper (1991) and Canova (1992) use the first, and Danthine and Donaldson (1986) and Danthine et al. (1987) use the second. However in none of these papers is the alternative specification discussed or the chosen one justified.

period real balance definition leads to 'uncertainty irrelevance', the beginning-of-period definition does not.

To avoid this paradox without resorting to the logically less satisfactory end-of-period specification, we instead use the following definition of liquidity:

$$q_t \equiv \frac{M_{t-1}+T_t}{p_t}$$

where T_t is the lump-sum money transfer from the government to the household received in period t. By including the current transfer in liquidity, we are allowing the household to use it to facilitate goods purchases from the moment it is received. As we will show, this makes money neutral when prices are flexible.[12]

Problem faced by dynamically-optimising households

In each period the representative household in sector i has to make four types of decision: how much to consume versus how much to save; how to allocate total consumption expenditure over different types of good (already considered); how to allocate saving plus pre-existing wealth between money and bonds; and what wage-employment combination to choose. These decisions are obtained by solving the problem:

maximise with respect to $\{c_t, M_t, \ell_t, W_t, a_t\}_{t=1}^{\infty}$

$$E_1\left(\Sigma_{t=1}^{\infty}\beta^t u(c_t, q_t, \ell_t)\right) \qquad \beta < 1 \tag{6}$$

subject to the budget constraints

$$a_t = i_t\frac{p_t}{p_{t+1}}\left[a_{t-1} + \pi_t + w_t\ell_t + \tau_t - c_t - [1-\frac{1}{i_t}]\frac{M_t}{p_t}\right] \qquad t = 1,\ldots,\infty \tag{7}$$

and to the labour demand functions (5).

[12] It might appear that this is equivalent to the end-of-period specification, since the government budget constraint implies that in money market equilibrium $M_{t-1}+T_t = M_t$. However although there are similarities, the household's decision problem is not the same under these two specifications.

(We suppress the i index, since this merely clutters the notation.) a_{t-1} denotes real asset wealth at the start of period t (holdings of money plus nominal bonds, deflated by p_t), π_t denotes firms' real profits, which are distributed equally to all households; w_t denotes the real wage; τ_t denotes a real lump-sum transfer from the government; i_t denotes the gross nominal interest rate payable on a nominal bond bought in period t, where a bond is a promise of one unit of money in period t+1.[13]

The first-order conditions for solving the problem can be obtained by dynamic programming (the details are standard and so not presented). In any period t, the variables known to the household and thus nonstochastic are p_t, $i_t, a_{t-1}, \pi_t, \tau_t$ and K_t. We will refer to a particular sequence of realisations of these variables for s = 1,...,t as a 'history', h_t. All later-dated values of the variables are as yet unknown, though the household has rational expectations of them in all moments, i.e. knows their true joint probability distribution. Wage flexibility is permitted by allowing the household to choose W_t contingent on h_t, that is on contemporaneous as well as on earlier values of shocks. The resulting first-order conditions are expressible as:

$$u_c(t) = \beta E_t\left(i_t \frac{p_t}{p_{t+1}} u_c(t+1)\right) \tag{8}$$

$$E_t\left(\frac{1}{p_{t+1}} u_m(t+1)\right) = [i_t - 1] E_t\left(\frac{1}{p_{t+1}} u_c(t+1)\right) \tag{9}$$

$$\frac{W_{t+1}}{p_{t+1}} = \frac{\varepsilon}{\varepsilon - 1} \frac{u_L(t+1)}{u_c(t+1)} \tag{10}$$

where $u_c \equiv \partial u/\partial c_t$, $u_m \equiv \partial u/\partial q_t$, $u_L \equiv -\partial u/\partial \ell_t$; $E_t(.)$ denotes an expectation conditional on h_t. These ensure the optimality of the savings, money demand and wage-setting decisions, respectively. (8) is completely standard and needs no comment. (9) requires the expected marginal utility of an extra £1 allocated to money balances to equal the expected marginal utility of the foregone consumption due to the interest cost of holding the \$1 as money rather than bonds. Expectations enter this expression since the household must make its portfolio decision before it knows the realisations of variables

[13] Later we will assume that the outside supply of bonds is zero, so that in general equilibrium households will hold no bonds. Although we could formally exclude them from the household's budget constraint the latter looks more familiar if they are retained at this stage, and for the intuitive discussion of money demand behaviour it is helpful to speak in terms of the choice between money and bonds.

such as p_{t+1} which determine the usefulness of the money for facilitating period t+1's goods purchases. (10) indicates that the real wage the household sets, acting as a monopoly union, is a fixed mark-up $\varepsilon/[\varepsilon-1]$ on the competitive supply wage, the latter being the ratio of the marginal disutility of work to the marginal utility of consumption.

The stochastic behaviour of the money supply

The money stock at the end of period t is known once period t arrives: unlike in signal extraction models, we are not here concerned with problems in observing *current* demand shocks. Rather, the uncertainty which interests us is that attaching to *future* money supplies, i.e. to M_{t+s} for $s \geq 1$. In what follows we consider the process:

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

where ξ_{t+1} is an independently distributed shock with $E_t(\xi_{t+1}) \equiv 1$. An increase in monetary uncertainty will be defined as a mean-preserving spread (in the sense of Rothschild and Stiglitz (1970)) of ξ_{t+1}.[14]

The key feature of this definition is that the expected *inverse* monetary growth rate is held constant as uncertainty is increased. The first papers to consider monetary uncertainty in somewhat related optimising frameworks, such as Gertler and Grinols (1982) and Stulz (1986), adopted what is at first sight a more obvious definition, namely to hold the expected monetary growth rate itself constant as uncertainty is increased. Some later studies (though still a minority) such as Lucas and Stokey (1987) and Sims (1992) have instead considered the process (11), but without giving any explicit justification. In Rankin (1993) we have argued that (11) is a better benchmark for analysing the effects of monetary uncertainty because it rules out an effect which is spurious in the sense that it does not derive from individuals' preferences, and which is furthermore paradoxical insomuch as it involves a fall, not a rise, in the nominal interest rate, and a rise, not a fall, in economic welfare. This 'Fischer-Stulz' effect, as we refer to

[14] Since the government's budget constraint is $T_t = M_{t+1} - M_t$, the counterpart of an increase (or decrease) in the money stock is a lump-sum transfer (or tax) of equal size to all households. Hence there are no marginal distortions or redistributions of income associated with government transfers. We do not allow the government to issue bonds since Ricardian equivalence holds in this economy which implies that changing the money stock by open market operations is no different from doing so by taxes or transfers.

it, arises because the real interest rate ($r_t = i_t p_t/p_{t+1}$) is convex in the future price level and thus in the future money supply. Since it is linear in their *reciprocals* , the effect turns out to be conveniently eliminated by (11).

General equilibrium with wage-price flexibility

In general equilibrium, the markets for goods, money and bonds clear instantaneously in the Walrasian sense, while in each industry's labour market households set their optimal wages given the true demand curves for their labour. Since we have assumed complete symmetry in preferences and technologies across industries, it follows that equilibrium prices, wages, employment and output levels will be the same across all of them, which will in turn be the same (given that the measure of all industries is unity) as the aggregate values of these variables.

It is helpful to introduce the notation $m_t \equiv M_t/p_t$ for end-of-period real money balances. Note that money market equilibrium and the government budget constraint imply that $q_t = m_t$; while goods market equilibrium implies that $c_t = y_t$. Substituting the expression (10) for the real wage into the output supply function (4), we then have:

$$y_t = \alpha\left[\frac{1}{\sigma\alpha}\frac{\varepsilon}{\varepsilon-1}\frac{u_L(y_t,m_t,\ell_t)}{u_c(y_t,m_t,\ell_t)}\right]^{\frac{\sigma}{\sigma-1}} \tag{12}$$

Since y_t and ℓ_t are linked by the production function, (12) implicitly determines output as a function of real balances in any period. In fact if preferences are weakly separable in liquidity, such that $u_t = v(w(c_t,\ell_t),q_t)$, then u_L/u_c and hence y_t are independent of m_t. As could be expected in such a flex-price setting, output is completely independent of monetary variables under fairly mild conditions.

To obtain a complete description of the equilibrium time path we first combine the savings and portfolio first-order conditions (8) and (9) to eliminate i_t, substituting p_t by M_t/m_t and M_t/M_{t+1} by (11):

$$m_t u_c(y_t,m_t,\ell_t) = \beta\mu E_t(\xi_{t+1}m_{t+1}u_c(y_{t+1},m_{t+1},\ell_{t+1}) + \xi_{t+1}m_{t+1}u_m(y_{t+1},m_{t+1},\ell_{t+1})) \tag{13}$$

Since we have just seen that y_t and ℓ_t are implicit functions of m_t - call these $y(m_t)$ and $\ell(m_t)$ - (13) can be reduced to a relationship in real balances alone:

$$m_t u_c(y(m_t),m_t,\ell(m_t))$$

$$= \beta\mu E_t(\xi_{t+1}m_{t+1}u_c(y(m_{t+1}),m_{t+1},\ell(m_{t+1})) + \xi_{t+1}m_{t+1}u_m(y(m_{t+1}),m_{t+1},\ell(m_{t+1}))) \quad (14)$$

This is a first-order stochastic difference equation which defines the dynamic evolution of m_t and thence of all the other variables in the economy. Since m_t is not a predetermined variable, and since there is no serial correlation in ξ_t, the solution for m_t depends entirely on expected future events, not on past ones. In general it is possible, and indeed likely, that there are multiple stochastic processes for m_t which solve (14), both because of the forward-looking nature of the solution (absence of initial conditions) and because (14) is non-linear. However to explore the full range of possible dynamic behaviour is beyond the intention and scope of the paper: rather we shall suppose some particular equilibrium has been selected and examine how it is perturbed by a small increase in monetary uncertainty.[15]

The effect of an increase in monetary uncertainty on current variables

Note first that the contemporaneous shock ξ_t is absent from (14). Thus it does not affect m_t, and hence - even without the weak separability assumption - nor does it affect y_t or ℓ_t. In turn, this means that utility, or welfare, is unchanged. A temporary positive value of ξ_t equates to a permanent reduction in the level of the money supply, so this is confirmation that money is 'neutral' in the flex-price model. Current and future price levels simply fall in proportion to the money supply, with no real variables affected.

Since m_t is independent of ξ_t, it follows that m_{t+1} is independent of ξ_{t+1}. Thus $E_t(\xi_{t+1})$ ($\equiv 1$) can be factored out of the right-hand side of (14) to give:

[15] The dynamics of quite similar models have already been the studied in some depth in the literature: see for example Obstfeld and Rogoff (1983). In general the presence of non-linearity raises the possibility of cycles and 'chaos', but these are not aspects which we wish to pursue here.

$$m_t u_c(y(m_t),m_t,\ell(m_t))$$

$$= \beta\mu E_t(m_{t+1}u_c(y(m_{t+1}),m_{t+1},\ell(m_{t+1})) + m_{t+1}u_m(y(m_{t+1}),m_{t+1},\ell(m_{t+1}))) \qquad (15)$$

Note that monetary shocks have now been completely eliminated. Any mean-preserving change in the distribution of ξ_{t+1} which becomes known in period t will have no effect on current real balances m_t. Thus it will have no effect on current output or employment, or indeed on welfare. Not only is monetary uncertainty irrelevant for current and future real variables, it is also irrelevant for current *nominal* ones: M_t has not changed, so the invariance of m_t implies that p_t has not changed either. Nor has the nominal interest rate, as we can see by rearranging (9) to get:

$$i_t = 1 + \frac{E_t(\xi_{t+1}m_{t+1}u_m(y(m_{t+1}),m_{t+1},\ell(m_{t+1})))}{E_t(\xi_{t+1}m_{t+1}u_c(y(m_{t+1}),m_{t+1},\ell(m_{t+1})))} \qquad (16)$$

By our earlier argument $E_t(\xi_{t+1})$ can be cancelled from this, so that the right-hand side is unaffected by the distribution of ξ_{t+1}.[16]

The only published example of a similar 'uncertainty irrelevance' result would appear to be in Lucas and Stokey (1987; see their 'Example 2'), who study a cash-in-advance model. However they give little emphasis to their finding, since it is subsidiary to the main purpose of their paper. The result is also implicit in Stulz's (1986) continuous-time model, which like the present one uses utility of real money balances. It is not evident, however, because he posits an alternative stochastic process for monetary growth as discussed above.[17] Instead Stulz emphasises the effect (see his 'Proposition 1') which we earlier referred to as the 'Fischer-Stulz' effect. A forerunner of Stulz's paper is the analysis by Gertler and Grinols (1982), who obtain the conclusion that monetary uncertainty depresses the level of investment in physical capital and thus the long-run growth rate.[18] However, although they do not acknowledge it, their result is due to

[16] It is not completely true that *no* real variables change: the spread of the real interest rate, $r_t \equiv i_t p_t/p_{t+1}$, increases proportionally with the spread of $1/p_{t+1}$ and $1/M_{t+1}$,, but its expected value remains the same.

[17] If one defines $L \equiv 1/M$ and assumes that L, rather than M, follows a geometric Brownian motion, $dL = \mu dt + \sigma_M dz_M$, then uncertainty irrelevance follows immediately from Stulz's results.

[18] Their model, which also provides the basis for Stulz's, would now be described as an 'endogenous growth' model since it uses a linear-in-capital production technology; though, writing before the recent surge of interest in endogenous growth, Gertler and Grinols play down this feature.

injecting money into the economy as a subsidy to wealth, so that uncertainty operates through distortionary effects on the savings decision at the margin.

3. A Monopolistic Economy with Predetermined Wage Setting

We now turn to a more realistic setting for short-run macroeconomic analysis by introducing a short-lived nominal rigidity into the economy. Intuitively, we could expect this to affect the analysis of monetary uncertainty in two ways. Rigidity of the future money wage means that greater variability of the future money supply will now be associated with greater variability of future real variables: output, employment and real money balances. It would be surprising if this did not have some impact on current variables. Rigidity of the current money wage means, in turn, that any impact is likely to be reflected in current output and employment, not just in the current price level and nominal interest rate. In this section we first examine how predetermined wages modify the structure of the model. We proceed to see how monetary uncertainty affects the 'natural' rate of unemployment, before turning to the effects of future uncertainty on current variables. Results here are obtained for a particular parameterisation of preferences. In the final sub-section, we consider the case of 'full' nominal rigidity, which enables a generalisation of the results to a wider class of preferences.

Wage setting with predetermination

The household's decision-making is now subject to the restriction that the money wage for period t+1 must be chosen in period t. Since the wage is set in advance, ex post the demand for labour may turn out to be greater or less than expected, and the household has to decide whether to satisfy or to ration it. It is at this point that monopoly power becomes important, for the same reason as in the 'New Keynesian' models such as that of Blanchard and Kiyotaki (1987). Monopoly power, as reflected in the mark-up $\varepsilon/[\varepsilon-1]$ of greater than unity, implies that when demand is at or near its expected value the wage is above the marginal disutility of work measured in money terms . Thus if demand is greater than expected (up to some limit), positive marginal utility is still derived from supplying an extra unit and it is utility-maximising for the household not to ration firms. If demand shocks have an upper bound which is not too high, employment will hence always lie on the demand curve. This enables us to avoid the regime-switching problem which would occur with a competitive supply of labour, where negative shocks lead to employment on the demand curve but positive ones to employment on the supply curve. It also creates a macroeconomic setting in which positive aggregate demand shocks have the scope to raise output, rather than immediately causing the economy to hit a supply constraint.[19]

Repeating the optimisation with W_t now contingent on history h_{t-1} rather than h_t, we find that whereas the first-order conditions (8) and (9) still apply, the household's chosen wage is now given by:

$$W_{t+1} = \frac{\varepsilon}{\varepsilon-1}\,\frac{E_t(K_{t+1}u_L(t+1))}{E_t(\frac{1}{p_{t+1}}K_{t+1}u_c(t+1))} \tag{17}$$

In a deterministic world we could drop the expectations operators and this expression would revert to the earlier formula, (10). However the uncertainty which the household faces in period t+1 coupled with the requirement to set the wage ex ante means that expectations now in general enter. The shift parameter of the labour demand function, K_{t+1}, also enters, since it is stochastic and so cannot be cancelled.

An AD-AS framework

If W_t is predetermined in period t and firms are never labour-rationed, then the economy's aggregate supply function is given directly by the goods supply function (4), here reproduced:

$$y_t = \alpha\left[\frac{1}{\sigma\alpha}\frac{W_t}{p_t}\right]^{\frac{\sigma}{\sigma-1}} \qquad \text{AS} \tag{18}$$

This gives the familiar 'Keynesian' upward-sloping aggregate supply curve in (y_t,p_t)-space (see Figure 1). Its slope is determined by σ, which controls the extent of

[19] The general similarity between a monopolistic equilibrium and an excess supply situation is well known, and goes back to Benassy (1976).

diminishing returns to labour. When $\sigma = 1$ the AS curve is completely horizontal, leading to 'full' nominal rigidity in the sense that the price as well as the wage is completely predetermined. This provides a useful special case for our later analysis.

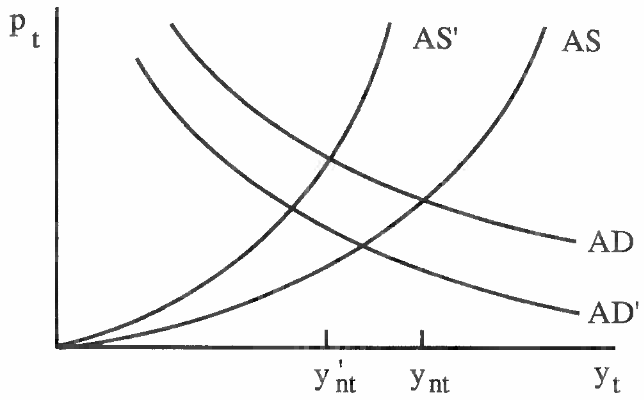

Figure 1

The aggregate demand curve may be derived by first noting that the relationship (13) continues to hold, since the first-order conditions (8) and (9) from which it is derived remain in force. If we write ℓ_t as $\alpha^{-1/\sigma}y_t^{1/\sigma}$ by using the production function, then (13) can be expressed as:

$$\frac{M_t}{p_t}u_c(y_t,\frac{M_t}{p_t},\alpha^{-1/\sigma}y_t^{1/\sigma}) = Z_t \qquad \text{AD} \tag{19}$$

$$\text{where} \quad Z_t \equiv \beta\mu E_t(\xi_{t+1}m_{t+1}u_c(y_{t+1},m_{t+1},\ell_{t+1}) + \xi_{t+1}m_{t+1}u_m(y_{t+1},m_{t+1},\ell_{t+1})) \tag{20}$$

Since, as we shall see, the dynamics of the economy remain entirely forward-looking, Z_t - which is just the right-hand side of (13) - is unaffected by shocks in period t. Instead it constitutes the channel through which all anticipated future changes affect the current price and output levels. Note that concavity of the utility function requires $u_{cc} < 0$, so that sufficient conditions for the AD curve to have the usual downward slope are $u_{cm} \geq 0$, $u_{c\ell} \leq 0$.

(18) and (19) together give us a familiar picture (see Figure 1). Using this apparatus it is easy to reproduce standard comparative static results: for example, a decrease in M_t shifts the AD to AD' lowering price and output.. Such a decrease in M_t must of course be

unanticipated, i.e. due to a particular (greater than unity) realisation of the shock ξ_t. If it was anticipated in t-1 and was thus associated with a change in the probability distribution of M_t, it would also have an effect on W_t and hence on the AS curve. Note that the equilibrium remains purely forward-looking, in that it is not affected by monetary shocks in period t-1: although W_t is set in period t-1, it is determined only by expectations of events in period t, as (17) shows.

Monetary uncertainty and the 'natural rate' of unemployment

We will refer to the level of output which results when the monetary shock takes its expected value, i.e. when $\xi_t = 1$, as the 'natural rate', denoted y_{nt}.[20] An equation for y_{nt} is obtained by using the AS function (18) to substitute p_t out of the AD relationship (19), and setting $M_t = M_{t-1}/\mu$. Advancing it to period t+1 we get:

$$\left[\frac{1}{\mu}\frac{M_t}{W_{t+1}}[\sigma\alpha]\alpha^{[1-\sigma]/\sigma}y_{nt+1}^{[\sigma-1]/\sigma}\right]u_c\left(y_{nt+1},\ \frac{1}{\mu}\frac{M_t}{W_{t+1}}[\sigma\alpha]\alpha^{[1-\sigma]/\sigma}y_{nt+1}^{[\sigma-1]/\sigma},\ \alpha^{-1/\sigma}y_{nt+1}^{1/\sigma}\right) = Z_{t+1} \tag{21}$$

This shows that (under the conditions for AD to slope downwards) y_{nt+1} depends negatively on W_{t+1}/M_t and Z_{t+1}. Let us define $W_{t+1}/M_t \equiv \gamma_t$. γ_t is predetermined in period t+1 since both W_{t+1} and M_t are predetermined. From (17) it is given by:

$$\gamma_t = \frac{\varepsilon}{\varepsilon-1}\frac{E_t(K_{t+1}u_L(y_{t+1},m_{t+1},\ell_{t+1}))}{M_t E_t(K_{t+1}u_c(y_{t+1},m_{t+1},\ell_{t+1}))} \tag{21}$$

Now consider a temporary increase in monetary uncertainty which becomes known in period t, i.e. a mean-preserving spread of ξ_{t+1} with unchanged distributions of ξ_{t+s} for s > 1. This will not affect Z_{t+1} (since it depends on the distribution of ξ_{t+2}, not ξ_{t+1}) but it will in general affect γ_t. We now show that for a common class of preferences, the effect on γ_t is always positive. Monetary uncertainty thus causes a rise in W_{t+1} (M_t being unchanged), and thence a fall in the natural rate of output. In Figure 1 (now applied to (t+1)-dated variables), this is represented by an upward shift of AS to AS', AD remaining fixed in the no-shock position.

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[20] This terminology should not be taken to imply that the natural rate is independent of demand-side factors other than unanticipated monetary shocks

The family of preferences which we will study is the constant relative risk aversion (CRRA) class. This is widely known and used, and also enables us to obtain explicit reduced forms for several variables of interest. Thus we parameterise the utility function as:

$$u_t = \frac{c_t^{1-\rho}}{1-\rho} + a\frac{q_t^{1-\pi}}{1-\pi} - d\ell_t^e \qquad \rho,\pi,a,d > 0,\ e > 1 \tag{22}$$

CRRA utility yields a simple form for the AD function (19),

$$y_t = [\frac{M_t}{p_t Z_t}]^{1/\rho} \tag{23}$$

which can be used with the AS function (18) to solve explicitly for y_t and m_t. In this way we can find expressions for $y_{t+1}, m_{t+1}, \ell_{t+1}, K_{t+1}$ as functions of ξ_{t+1}, Z_{t+1} and γ_t itself. Used in (21), these enable us to derive the following reduced form for γ_t:

$$\gamma_t = (\text{+ve constant}) \times \frac{1}{Z_{t+1}}\left\{\frac{E_t(\xi_{t+1}^{e/(\sigma[1-\rho]-1)})}{E_t(\xi_{t+1}^{\sigma[1-\rho]/(\sigma[1-\rho]-1)})}\right\}^{\frac{1-\sigma[1-\rho]}{e-\sigma[1-\rho]}} \tag{24}$$

Consider the effect of a mean-preserving spread of ξ_{t+1} on this. $1-\sigma[1-\rho]$ and $e-\sigma[1-\rho]$ are always positive, so that γ_t is unambiguously increasing in the quotient $\{.\}$. In the numerator of $\{.\}$ we have a convex function of ξ_{t+1}, since the exponent $e/(\sigma[1-\rho]-1)$ is negative. In the denominator we have a concave function if $\rho > 1$, since the exponent is positive and less than one; but a convex one if $\rho < 1$, when the exponent is negative. Thus, by Rothschild and Stiglitz's (1970) result, uncertainty raises the expected value of the numerator, and respectively lowers or raises that of the denominator as $\rho > 1$ or < 1. This implies an unambiguous increase in γ_t if $\rho > 1$. If $\rho < 1$ the effect is not immediately clear, but an answer can be obtained if we suppose ξ_{t+1} has a lognormal distribution.[21] In this case (24) can be resolved into:

$$\gamma_t = (\text{+ve constant}) \times [1+c_\xi^2]^{\frac{e+1}{2(1-[1-\rho]\sigma)}} \tag{24'}$$

[21] Since the support of the lognormal distribution is unbounded above, it strictly speaking causes a violation of the condition for employment aways to be on the labour demand curve. The results will nevertheless hold at least for low degrees of uncertainty, since by making c_ξ sufficiently small we can squeeze to zero the probability of a regime switch.

where c_ξ is the coefficient of variation of ξ_{t+1}. The exponent here is positive for all ρ. Hence under this rather standard distributional assumption, monetary uncertainty causes γ_t to rise irrespective of the degree of relative risk aversion in consumption.[22]

The effect of future monetary uncertainty on current price and output

We saw from the AS-AD system that the impact of future changes on current variables comes through Z_t, which is defined in (20). Z_t is the sum of two components, one in u_c and one in u_m. To see how a mean-preserving spread of ξ_{t+1} which becomes known in period t affects the u_c-component, note that advancing (19) by one period we have:

$$m_{t+1}u_c(t+1) \;=\; \beta\mu E_{t+1}(\xi_{t+2}m_{t+2}u_c(t+2) + \xi_{t+2}m_{t+2}u_m(t+2)) \;\equiv\; Z_{t+1} \qquad (25)$$

The completely forward-looking nature of the dynamics means that Z_{t+1} is known in period t. Multiplying through by ξ_{t+1} and taking expectations as of period t, we therefore obtain:

$$E_t(\xi_{t+1}m_{t+1}u_c(t+1)) \;=\; E_t(\xi_{t+1}Z_{t+1}) \;=\; Z_{t+1} \qquad (26)$$

Since the increase in uncertainty is temporary, i.e. the spread of ξ_{t+2} is unchanged, Z_{t+1} can be treated as exogenous. Thus we have that the u_c-component of Z_t is unaffected by the increase in uncertainty. If uncertainty affects current variables it must do so by affecting the u_m-component.

To see the effect on the u_m-component, we work again with the CRRA utility function (22). This enables the following reduced form to be derived:

$$E_t(\xi_{t+1}m_{t+1}u_m(t+1))$$

$$= (\text{+ve constant}) \times Z_{t+1}^{1-\pi}\underbrace{\left\{\frac{E_t(\xi_{t+1}^{e/(\sigma[1-\rho]-1)})}{E_t(\xi_{t+1}^{\sigma[1-\rho]/(\sigma[1-\rho]-1)})}\right\}^{\frac{\rho\sigma[1-\pi]}{\sigma[1-\rho]-e}}}_{\text{term A}}\underbrace{E_t(\xi_{t+1}^{(1-\sigma[1-\rho\pi])/(1-\sigma[1-\rho])})}_{\text{term B}} \qquad (27)$$

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[22] The effects of monetary uncertainty on the wage set by unions have been examined in two somewhat similar but static models by Sorensen (1991, 1992). However neither is directly comparable since money supply uncertainty is introduced endogenously, by making either government preferences or the variables on which monetary policy feeds back, stochastic.

Term A is recognisable from the expression for γ_t and represents the effect of the rise in W_{t+1} at any given realisation of ξ_{t+1}. We saw that a mean-preserving spread of ξ_{t+1} increases the quotient {.}, so that from (27) the effect on Z_t via W_{t+1} is respectively positive or negative as $\pi > 1$ or < 1. Term B represents the effect of uncertainty at a given W_{t+1}. The positive exponent of ξ_{t+1} is greater than 1 if $\pi > 1$ or less than 1 if $\pi < 1$, indicating a convex or concave function. Term B thus increases or decreases with the spread of ξ_{t+1} under the same conditions as term A. The sign of the net effect on Z_t hence depends only on π. If $\pi > 1$, Z_t rises; if $\pi < 1$, Z_t falls.

Returning to the AS and AD curves and their defining equations (18) and (23), we see that an increase in Z_t unambiguously shifts the AD curve to the left. A rise in Z_t thus lowers current price and output; a fall in Z_t raises them. Thus we arrive at the main finding of the paper: with nominal rigidity future monetary uncertainty acquires an impact on current variables, and its sign depends critically on preferences over money. Specifically, for an economy with CRRA preferences, the impact is deflationary if relative risk aversion in money-holding is greater than unity, reflationary if less than unity. On the dividing line where it equals unity, uncertainty has no impact on the present despite the nominal rigidities: this is the special case where utility of money is logarithmic. The logarithmic form is encountered extremely widely in the literature.[23] The authors who have used it have clearly been motivated by its convenience, yet here we see that for analysing the effects of monetary uncertainty it is potentially very misleading. To this author the case $\pi > 1$ seems the most plausible: this is consistent both with strong risk aversion in money holding and with the idea that consumption and money are likely to be complements rather than substitutes. This leads us to believe that monetary uncertainty is most likely to have a deflationary impact, a conclusion which accords with a view often expressed by commentators on macroeconomic events.

We can probe more deeply into the mechanism by which future uncertainty is transmitted to the present. The effect is entirely channelled through the nominal interest rate. To see this note that Z_t is the result of combining the household's first-order

[23] See for example Gertler and Grinols (1982), Stulz (1986), Leeper (1991), Corsetti and Pesenti (1992), Grinols and Turnovsky (1993)

conditions (8) and (9) to eliminate i_t, and so to generate the equation (13) or (19). Multiplying through (8), which is the condition for optimal savings, by m_t we can get:

$$m_t u_c(y_t,m_t,\ell_t) = \beta\mu i_t E_t\{\xi_{t+1} m_{t+1} u_c(y_{t+1},m_{t+1},\ell_{t+1})\} \tag{28}$$

This is half-way to equation (13) or (19), and the right-hand side is Z_t, where i_t has not yet been substituted out. Now from (26) we know that $E_t(\xi_{t+1}m_{t+1}u_c(t+1))$ equals Z_{t+1} which is not affected by the spread of ξ_{t+1}. Thus (28) shows that the change in Z_t must come entirely from the nominal interest rate. This gives us an intuitive handle on how uncertainty affects current aggregate demand. If $\pi > 1$, there is a rise in i_t and thus, ceteris paribus, in the real interest rate. This raises the expected marginal utility from postponing a unit of consumption - which, multiplied by m_t, is just Z_t or the right-hand-side of (28). The household is thus induced to save more, depressing current demand. If $\pi < 1$, i_t falls and current demand is boosted.

It remains to understand why monetary uncertainty affects the nominal interest rate. Consider again the first-order condition (9), which can be regarded as an equation for determining i_t. (9) says that for portfolio balance at the end of period t, the expected gain of utility from real balances by shifting \$1 from bonds to money must equal the expected loss of utility from foregone future consumption due to the loss of \$$(i_t$-1) in interest. Now the expected increase in utility from \$1 more spent on future consumption is in equilibrium not affected by monetary uncertainty. We know this since $E_t(\frac{1}{p_{t+1}}u_c(t+1)) = \frac{1}{M_t}E_t(\xi_{t+1}m_{t+1}u_c(t+1))$ which by (26) equals $\frac{1}{M_t}Z_{t+1}$ and is independent of the spread of ξ_{t+1}. Hence any change in i_t must be due to a change in $E_t(\frac{1}{p_{t+1}}u_m(t+1))$, the expected marginal utility of money (EMUM). If EMUM rises, for example, the household will attempt to reallocate its portfolio towards money, but since the supply of money M_t is fixed the interest rate will be forced up until the condition (9) is restored. The change in the nominal interest rate is thus due to a change in the desire to hold money. In the next sub-section we will see how this change is linked to preferences over money.

The case of full nominal rigidity

We now consider the special case where $\sigma = 1$, i.e. constant returns to labour. This implies that $y_t = \alpha\ell_t$, and that the AS curve is horizontal:

$$p_{t+1} = \frac{1}{\alpha}W_{t+1} \qquad \text{AS} \tag{29}$$

We now have 'full' nominal rigidity since p_{t+1} as well as W_{t+1} is predetermined. With the benefit of this simplification, we can extend the analysis to a more general class of preferences, the additively separable class.

Additive separability implies that marginal utility with respect to an argument of u(.) depends only on that argument itself. Thus we can write:

$$u_c = \underset{(-)}{u_c(c)}, \qquad u_m = \underset{(-)}{u_m(m)}, \qquad u_L = \underset{(+)}{u_L(\ell)} \tag{30}$$

The indicated signs of partial derivatives are those necessary for strict convexity of u(.).[24] We will see that also important is the curvature of the marginal utilities in their arguments. Kimball (1990), in analysing the strength of the precautionary savings motive, utilises two measures of the strength of this curvature, which by analogy with absolute and relative risk aversion he refers to as the degrees of absolute and relative 'prudence'. The second will turn out to be particularly useful here, so we shall define relative prudence in money-holding and in labour supply as:

$$p_R(m) \equiv -\frac{m u_{mmm}(m)}{u_{mm}(m)}, \qquad p_R(\ell) \equiv \frac{\ell u_{L\ell\ell}(\ell)}{u_{L\ell}(\ell)} \tag{31}$$

As we will see there is some presumption that these measures will be positive, though this is not inevitably the case.

In looking at the transmission mechanism of monetary uncertainty we saw that the critical factor is whether it raises or lowers the expected marginal utility of money (EMUM). Under full nominal rigidity and additive separability we can write:

[24] To preserve familiarity of notation, we write m not q as the argument of $u_m(.)$, even though the equality of m to q is only true in equilibrium.

$$\mathrm{EMUM} = \frac{1}{p_{t+1}} E_t\left(u_m\left(\frac{M_{t+1}}{p_{t+1}}\right)\right) \tag{32}$$

Monetary uncertainty in the shape of a mean-preserving spread of $1/M_{t+1}$ affects this in two ways. First is the indirect effect due to inducing households to set a higher W_{t+1}, which raises p_{t+1} proportionately. Since $u_{mm} < 0$ the effect is ambiguous, but it is easy to show that it depends on the degree of relative risk aversion in money-holding: if $-mu_{mm}/u_m$ exceeds unity, EMUM rises; if less than unity, EMUM falls. The second effect is the direct one at given p_{t+1}. This depends on the curvature of u_m in $1/M_{t+1}$. Computing the second derivative we obtain (dropping time subscripts):

$$\frac{d^2}{d(1/M)^2}\left(u_m\left(\frac{M}{p}\right)\right) = -u_{mm}[M^3/p][p_R(m) - 2] \tag{33}$$

The critical parameter is thus the degree of relative prudence in money-holding. If this exceeds two, u_m is convex in 1/M, whence a mean-preserving spread of 1/M raises EMUM. If it is smaller than two, EMUM is lowered. The magnitude of $p_R(m)$ hence determines the strength of the 'precautionary' demand for money (and whether there *is* a precautionary demand, since it could be negative).

To avoid conflicts in the two effects on EMUM, the coefficients of relative risk aversion and of relative prudence must either both lie above, or both below, their critical values. For the CRRA utility function it happens that this is always the case, because for this function we have:

$$\frac{-mu_{mm}}{u_m} = \pi, \qquad \frac{-mu_{mmm}}{u_{mm}} = \pi+1 \tag{34}$$

Thus π controls two properties of the utility function at the same time. More generally risk aversion and prudence need not go together. For example it is easy to construct a class of 'constant relative prudence' utility functions, which is simply the CRRA functional form plus an additional linear term. In such a class the coefficient of relative risk aversion (which is no longer constant) can be made to lie either side of unity for any given coefficient of relative prudence. However in the absence of any different preconceptions about the correct relationship between the two coefficients, it is not obvious that the restriction implied by the CRRA function is unreasonable.

A second point on which the assumption of full nominal rigidity helps to provide insight concerns why monetary uncertainty raises the wage. Since p_{t+1} is now nonstochastic we can rewrite (17) as an expression for the real wage:

$$\frac{W_{t+1}}{p_{t+1}} = \frac{\varepsilon}{\varepsilon-1}\frac{E_t(K_{t+1}u_L(t+1))}{E_t(K_{t+1}u_c(t+1))} \tag{35}$$

K_{t+1} can be replaced in this by its reduced form $\alpha^{\theta-1}p^{\theta}_{t+1}y_{t+1}$, whence the nonstochastic components $\alpha^{\theta-1}p^{\theta}_{t+1}$ cancel. Equating the real wage to the marginal product of labour, α, and using additive utility we obtain:

$$\frac{\varepsilon}{\varepsilon-1}\frac{E_t(y_{t+1}u_L(\frac{1}{\alpha}y_{t+1}))}{E_t(y_{t+1}u_c(y_{t+1}))} = \alpha \tag{36}$$

Since the AS-AD system makes y_{t+1} a function of (W_{t+1},M_{t+1}), this equation implicitly determines W_{t+1} as a function of the distribution of M_{t+1}. To make this more explicit, and to enable us to isolate the role played by preferences over labour supply, let us here assume that subutility over consumption is logarithmic (i.e. CRRA with $\rho = 1$). Then the AD function is given by (23) with $\rho = 1$, and combining with the AS function (29) we can express y_{t+1} as:

$$y_{t+1} = \frac{\alpha M_{t+1}}{W_{t+1}Z_{t+1}} \tag{37}$$

Noting also that $cu_c(c) = 1$ under this assumption, we have that the expectation in the denominator in (36) goes to unity.

The effect of monetary uncertainty on the wage now depends on whether an increased spread of $1/M_{t+1}$ raises or lowers $E_t(y_{t+1}u_L(\frac{1}{\alpha}y_{t+1}))$ at given W_{t+1}. If it raises it, then W_{t+1} must increase to keep (36) satisfied (remember $u_L(\ell)$ is an increasing function); if it lowers it, W_{t+1} must fall. From (37), y_{t+1} is convex in $1/M_{t+1}$. Since an increasing convex function of a convex function is convex, a sufficient but not necessary condition for $y_{t+1}u_L(\frac{1}{\alpha}y_{t+1})$ to be convex in $1/M_{t+1}$ and thus for W_{t+1} to rise, is that $\ell u_L(\ell)$ is convex in ℓ. Computing the second derivative of this we have:

$$\frac{d^2}{d\ell^2}(\ell u_L(\ell)) = u_{L\ell}[p_R(\ell) + 2] \tag{38}$$

Thus relative prudence in labour supply greater than -2 is sufficient to ensure that monetary uncertainty raises the wage. This condition is very likely be satisfied for any sensible disutility of labour function. For example it is automatically satisfied if marginal disutility of labour is convex in labour ($p_R(\ell) > 0$). If there is a finite upper bound $\bar{\ell}$ on ℓ, it is plausible that marginal disutility of labour should tend to infinity as ℓ tends to $\bar{\ell}$, which suggests that u_L will be convex at least for high ℓ. Even without this, the degree of concavity necessary in u_L before the wage will fall is extreme: taking into account the convexity of y_{t+1} in $1/M_{t+1}$, we easily show that $p_R(\ell)$ would need to be less than -4 -2/[$\ell u_{L\ell}/u_L$].

Monetary uncertainty and welfare

We have so far focused on the effects of monetary uncertainty on observable macroeconomic variables, but the optimising framework of the model also allows us directly to examine its effect on the most fundamental variable for evaluative purposes, welfare. Since agents are symmetric and have symmetric experiences, we can simply consider the effect on the lifetime expected utility of a typical household. Intuitively, one would guess the impact to be negative, but the net impact is the sum of numerous separate effects not all of which are negative: for example, if the current price p_t falls, this raises current real balances m_t which ceteris paribus raises utility. The potential for ambiguity in the overall sign is thus considerable, and in our investigation of this question (the details are omitted since their information value is modest) we have not been able to prove that welfare falls in absolutely all cases. However we can prove a negative impact for a substantial subset of cases under CRRA preferences, and by contrast have not succeeded in proving a positive impact for any case. Our general conclusion is therefore the expected one, that monetary uncertainty reduces welfare.

4. Conclusions

Nominal rigidity causes future monetary uncertainty to matter for the present. A temporary increase in future uncertainty, under the most plausible parameterisation of the economy, raises the nominal interest rate, deflating current aggregate demand and thereby depressing the current price and output levels. Future monetary uncertainty also matters for the future: by causing wage-setters to fix a higher future money wage it raises the future 'natural rate' of unemployment. In addition, of course, it increases the variability of the future price and output levels. Given all this it is not surprising that the impact on economic welfare is generally found to be negative.

The present paper is only a first attempt at studying the implications of nominal rigidity for monetary uncertainty in a dynamic optimising framework, and its limitations will be apparent. It would be desirable, for example, to be able to consider a wider class of household preferences than the CRRA class. As was seen, we were able to make some progress in this direction for the case of full nominal rigidity. Recent work by Epstein and Zin (1989), Weil (1990) and others has pointed out the limitation of expected utility theory that it ties the attitude towards risk together with the intertemporal substitutability of consumption. To see whether these features affect the macroeconomic response to monetary uncertainty differently would also be desirable. At present this still seems an ambitious goal: in our framework advancing beyond additively separable preferences is already difficult. It must be acknowledged that the relative risk aversion parameters in the CRRA function determine more than the attitude towards risk: they control the intraperiod and interperiod substitutabilities as well. However this criticism could equally be made of many other studies, and by advancing beyond the widely-used logarithmic utility function we have already uncovered some key limitations of the latter. Moreover in general it cannot be expected that the response to uncertainty will depend only on agents' attitude towards risk - in principle it is likely to depend on any significant non-linearities in the relationships of the economy, including in technology. Thus although future work may disentangle rather better the role of pure attitude towards risk, it will still be the interaction of this along with other factors which will determine the macroeconomic response to uncertainty.

A number of further applications of the model are possible, and we plan to pursue some of these. A fuller asset menu including for example shares, indexed bonds and titles to government transfers could be introduced so that the effects on asset prices could be investigated. This is the focus of the studies typical in the finance literature. However their formal exclusion does not make any difference to the real effects found here, since when all households are identical in tastes and endowments and subject to identical random shocks, there is no potential for inter-household asset trade. A second application would be to introduce fiscal and supply-side uncertainty, and so to expand the set of macroeconomic shocks. Finally, we hope that the framework may be useful in open-economy applications, since it could permit imperfect international substitutability of domestic- and foreign currency bonds and thus relaxation of powerful restrictions such as the uncovered interest parity condition, in a setting where demand is not irrelevant for output.

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