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# ABSTRACT

## Optimal Monetary Policy with Endogenous Contracts: Should we Return to a Commodity Standard?*

A representative agent who is employed chooses an optimal degree of wage indexation (to prices and the auction wage) in response to the monetary regime. Should that regime target the growth rate or the level of the money supply, or of prices (as in a commodity standard)? We find that, contrary to the usual finding from macroeconomic models with fixed wage contract structures, there are gains in welfare for the average household, with both real wages and employment being stabilized. The reason is that when the monetary regime shifts to targeting levels, indexation falls markedly; this flattens the aggregate supply curve and steepens the aggregate demand curve, providing a high degree of 'automatic' stabilization. The choice between targeting money or prices creates a trade-off between employment and real wage stability – implying a distributional conflict between insiders and outsiders in the labour market.

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## NON-TECHNICAL SUMMARY

It is generally assumed by economists and policy-makers that if monetary policy were to target the price or money-supply level rather than inflation or the money-supply growth rate, this would destabilise both inflation and output. The argument for this assumption is neatly put by Lars Svensson: 'The intuition is straightforward: in order to stabilize the price level under price-level targeting, higher-than-average inflation must be succeeded by lower-than-average inflation…(apparently implying)…higher inflation variability…(which)…via nominal rigidities…would then seem to result in higher output variability.' Essentially the same point would apply to targeting the level of money supply rather than its rate of growth. In this Paper we investigate whether allowing the nominal rigidities themselves to react endogenously to the change in monetary regime can overturn this judgement. We find in fact that it can.

Before going any further we should clarify what is meant by such targeting of levels. What it does not necessarily imply is that the level of prices or the money supply should show no upward trend over time – which is an often-encountered sense of 'price stability' for example. Targeting levels merely means that the level should return after a shock to whatever path has been set for it in the original target – that path could entail a steady growth rate of prices (inflation) for example of 2%. In time-series terms it amounts to saying that prices or money should be stationary (I(0)) around some deterministic trend which is not specified (or studied here). Targeting the rate of change implies by contrast that any shock is not subsequently corrected but rather incorporated into the new 'base' for the inflation or money growth target – so-called 'base drift' in which the level of the target variable is non-stationary (I(1)). Hence the argument about what trend rate to choose for prices or money – as for example in Friedman's optimum quantity of money debate or Feldstein's arguments for zero inflation – is a quite separate matter from what is under discussion here.

We tackle the issue in a macroeconomic model that is simplified as far as possible without losing the basic properties of aggregate demand and supply responses with recognisable dynamics – the reason for simplicity at this stage being that the endogenisation of rigidities involves an extra level of complexity which already taxes our available computational methods. Households are paid with cash which they receive at the end of the period (set here at a quarter) and hold for spending until the end of the next – a cash-in-advance set-up. Employed households (who control wage negotiations from the worker side) are concerned about the volatility of their consumption pattern out of these wages and to stabilise this they enter into a wage contract. This can link wages either to prices (indexation) or to the auction wage (a contingent clause which in practice is linked to employment variation) or not at all (a nominal

component) – in some weighted combination (the weights must add to one). Firms are indifferent to risk and accommodate workers' wishes in providing this insurance via contract structure, holding the expected real wage cost constant. Borrowing and saving are ruled out as a way of stabilizing consumption in the face of shocks within the contract horizon (which is set at 4 quarters); the reason, we assume, is that there is a cost either for renegotiating loans or for holding excess savings to deal with this problem and this exceeds the cost of insuring via contract structure.

This employed household choice is placed within a model with a Cobb-Douglas technology and a crude time-to-build investment set-up, in which there are shocks to productivity and to the supply of money. The government spends on unemployment benefits and raises taxes or borrows to pay for them; firms invest and hire labour to maximize profits, pay dividends with a long lag (so that these do not affect the consumption volatility of the employed), and also freely borrow and lend. The four markets – goods, labour, money and loans – are cleared by prices, the auction wage and the real interest rate, with the fourth (in this case, loans) being implicit via Walras' Law.

The employed household choice of contract structure is made (with assumed cooperation between households, perhaps coordinated by unions or government, as usually has occurred with indexation) to maximize its utility – this in practice means to minimize the variability of its consumption (i.e. its real wages). We use the method of stochastic simulations combined with a grid search for the minimum variance contract structure. In a previous paper (Minford, Nowell and Webb, 1999) we showed that indexation should rise not so much with the size of monetary shocks but rather mainly with their persistence (also with that of productivity shocks which are by almost definition non-stationary). The reason is that wages are spent with a lag so that consumption depends on lagged wages deflated by current prices; indexation would hence be received with a lag so that if shocks to prices were stationary they would have disappeared by the time the index compensation was received. This compensation would hence tend to destabilize rather than stabilize consumption when shocks are stationary. However if shocks are non-stationary (persistent) then they would not have disappeared and the indexation received would give compensation for an enduring change and therefore stabilize consumption. (It turned out that the auction contract share never rose much above 10% in the cases of policy interest – basically because if you want to insure against real wage fluctuations, tying to the volatile auction wage tends to worsen them.)

Since it is persistence in both shocks (monetary and real) that is inducing both the greater instability of real wages and the increasing indexation this produces, a natural avenue to investigate improvement in monetary policy is the reduction of persistence in money shocks (money-level targeting) or alternatively that of prices (price-level targeting) since prices are the route through which real wages are destabilized in a world of purely nominal contracts. Price-level targeting is of course the fiat-currency means of delivering a commodity standard, with the commodity basket defined by the retail price index.

In order to evaluate the monetary regime we compute the utility of the average household as opposed to the employed household, which makes the contract choice. This average we think of as the weighted combination of the employed ('insider') one and the frequently unemployed ('outsider') one; hence plainly this average will attach importance to employment fluctuations as well. (We adjust utility for the prospect that this household will have to pay taxes to offset unemployment benefit costs.)

The shift of monetary regime to the targeting of money or price levels reduces the persistence respectively of money and price shocks and so, not surprisingly, lowers the degree of indexation. This in turn changes the slopes of the aggregate demand and supply curves implied by the model. That of demand becomes steeper (because demand for money to pay wages is less affected by changing prices, with these not spilling over so much into wages via indexation). That of supply (the 'Phillips Curve') becomes flatter – plainly, variations in employment now elicit less wage variation with more nominal rigidity. This change in slopes is beneficial to the stability of both prices and employment in the face of productivity shocks; price stability with mainly nominal contracts also implies real wage stability.

This leaves money-supply shocks as a potential source of instability – a danger plainly enhanced by the reduction in indexation. But in switching from targeting the growth of money to its level (while keeping the variability of the current 'error' in money constant) we greatly reduce the volatility of the money supply because its errors no longer accumulate as they do when the growth rate is targeted.

Switching to price-level targeting from money-supply targeting involves a further change. Indexation falls further because prices and so real wages are far more stable when contracts are nominal so removing the major reason for indexation. The variance of real wages therefore falls, benefiting insiders.

However the variance of employment rises. The reason is that the greater nominal rigidity induced by the price-level target reduces the effect of productivity shocks on employment as explained above – the slopes of demand and supply curves shifting further in the directions discussed. But this also increases the effect of money shocks; these are now more persistent and hence have higher cumulative variance, because in order to stabilize prices, money supply must offset the lagged effect of persistent productivity shocks on prices and this in turn implies that the money supply itself must be persistent.

Overall welfare is virtually unchanged. But a price rule therefore has a distributional effect, raising the welfare of those with continuous employment (‘insiders’), while reducing the welfare of those with variable employment (‘outsiders’).

One is finally tempted to ask whether it would help matters to switch from the ‘monetary base control’ method assumed in our discussion to this point to the interest rate setting method practised by most central banks. Within our model, what interest rate setting does is to make the current money supply respond to whatever other shocks are hitting the economy – in this case, the productivity shock. Hence in place of a random and independent money-supply error we have an error that is some multiple or fraction of the productivity error. Plainly the result for the economy of this switch will depend on the relative size of the variances of the two errors. To illustrate with a neutral case we assume (as seems to emerge in general from our empirical work in the earlier paper) that they are the same. In this case it turns out that the switch makes little difference. There is a slight reduction in the variance of both employment and real wages because the endogenous response of money to productivity is a coefficient of about a half; so when the two original error variances are the same this implies a reduction in the variance of the shock to money. However the small effect would be overturned if under monetary base control the independent money-supply shock had been (or could be made to be) very small.

In conclusion, we suggest that the general assumption that targeting levels would destabilize the economy is due for careful reconsideration. Besides the direct effect of such targeting on encouraging nominal wage rigidity, which we have argued has benefits in stabilizing the economy, it would also encourage the return of long-term nominal bonds by removing the possibly important long-term price-level risk premium. There may also be practical links to the debate on the choice of target for the deterministic inflation trend. The model we have set out here is deliberately simplistic. It should be possible to use these methods within more realistic models to examine this important policy topic further and check whether our suggestions here are robust.

# 1 Optimal monetary policy with endogenous contracts:should we return to a commodity standard?

**Patrick Minford (Cardiff University Business School and CEPR) and Eric Nowell (University of Liverpool)**[1]

**Revised August 2000**

In a previous paper (Minford, Nowell and Webb, 1999) we showed that wage contracts would respond to the nature of monetary policy; specifically that indexation would rise sharply with greater persistence in monetary shocks and that welfare would be maximised by a policy of targeting the level rather than the growth rate of money. That paper however did not investigate feedback policies or automatic rules (such as interest rate rules) relating current monetary behaviour to current events; it treated monetary policy as consisting of money supply shocks uncorrelated with other shocks and related solely to their own past with a varying degree of persistence. In this paper we attempt to broaden the discussion to these aspects.

We begin by considering feedback rules where money supply is used to react to past events. In this case current money shocks remain random events unrelated to other shocks. Later we extend this to the case of interest rate rules, which endogenise money supply shocks. Our method is to use stochastic simulations on a basic but still highly non-linear representative-agent macro model, while in parallel using a linearised and simplified version to attempt to understand what is going on. This basically numerical approach is not widely favoured; but we can at present see no alternative.

[1] We are grateful to Ray Barrell for comments in the course of last summer's Warwick Macromodelling Seminar which inspired the main thrust of this paper. We are also grateful to Vitor Gaspar for an important suggestion for simplifying and improving our welfare measure and to Huw Pill for suggesting an intuitive explanation of our unemployment results.

**An approach to the optimal feedback rule: price level targeting**

In our earlier paper we found that the persistence of productivity shocks would induce a fairly high degree of indexation even when monetary shocks were entirely random (non-persistent). The reason was that productivity shocks would disturb prices and so the real worth of nominal wage contracts; indexation was of little use in remedying this disturbance if it was temporary because by the time the indexation element had been spent the shock would have disappeared, but with a permanent disturbance indexation can help offset it with a lag. If into this already-indexed world of persistent productivity shocks, monetary persistence is also injected, indexation rises further, to help alleviate the increased disturbance to real wages. This higher indexation also helps to alleviate the instability in unemployment which accompanies the greater shock persistence of money- the point being that this persistence induces persistence in the economy's departure from its baseline and so disturbs unemployment too for longer.

Since it is persistence in both shocks (monetary and real) that is inducing both the greater instability of real wages and the increasing indexation this produces, a natural avenue to investigate improvement in monetary policy is price level targeting (this can be considered as 'cumulative inflation targeting' where any past deviation from the inflation target is offset with an opposite deviation the following period). The reason is that such a policy will eliminate the effect of persistence in shocks from the price level and so from the real value of a nominal wage contract. It should therefore get us back towards the 'I(0) world' in which we found that welfare was far higher than in the 'I(1) world' of high all-round persistence and high indexation.

In probing the idea of stationarity in targeting- that is, targeting the level of money rather than its growth rate, and the level of prices rather than inflation- we are joining a growing literature that is investigating the possibility of 'price stability', defined to mean prices whose long-term variance is kept low (as opposed to 'low inflation' under which price variance tends to infinity as the horizon lengthens). As noted by Svensson (1999), the consensus of earlier authors (Hall, 1984; Duguay, 1994; Bank of Canada, 1994; Fischer, 1994) has been that targeting prices rather than inflation (and presumably also by implication money rather than its growth rate) would lower long-term price variance at the expense of higher short-term inflation and output variance. As he puts it 'The intuition is straightforward: in order to stabilize the price level under price-level targeting, higher-than-average inflation must be succeeded by lower-than-average inflation.. (apparently implying).. higher inflation variability.. (which).. via nominal rigidities.. would then seem to result in higher output variability.' Svensson argues however that the consensus may be wrong: he gives an example where discretionary monetary policy facing a Phillips Curve with persistence in output actually raises inflation variability (without benefiting output stability) if it targets inflation rather than the price level- in effect the price level target is preventing some of the 'useless' inflationary discretion (useless because private agents fully anticipate it so that it has no effect on output). This result admittedly depends on there being no commitment that would rule out such useless discretion by other means- with such commitment price-targeting is inferior to inflation-targeting. McCallum and Nelson (1998) and Williams (1997) also report results with empirical macro models where reaction functions with price targeting produce lower, or no higher, short-term macro variance than those with inflation-targeting. Clearly these studies differ from this one both in the models used and in the welfare function being maximized. However, the government objective functions usually used are related to the consumer welfare measures used here; while our model is a simple prototype macro model. The main practical difference is that we are focusing on the added effect of changes in wage contract structure- an 'interesting issue', Svensson notes, as yet unexplored. It would seem, we find, that this added effect is a strong reason for preferring to target a nominal level rather than its rate of growth.

In what follows we begin by recapping the approach and results of our previous paper. We then set out the ideas of the various forms of targeting within a tractable linearised and simplified version of our model; we also roughly estimate the sort of effects we might expect from a calibration of that version (based on that of the full model). We then present the results from the stochastic simulations of the full non-linear model; we focus on the overall welfare measure of the representative consumer household, with full allowance for all 'social costs' that revert to it through implied taxation, and we also look separately at the two elements that mainly contribute to this overall measure, the variance of worker consumption and the variance of unemployment (the former we think of entirely 'private' the latter as partly 'social' in that it interacts with the social benefit distortion).

**A representative agent model of indexation**

In our earlier paper we set out a simple model of a representative household with a cash-in-advance constraint facing a financial marketplace in which the costs of continuous borrowing to smooth consumption in the short term (within some notional 'borrowing period') are excessive; thus it attempts to smooth its consumption through wage arrangements (i.e. 'contracts'). These may make wages be fixed nominally in advance, or indexed to prices, or indexed to auction wages; a contract specifies that wages react in some proportion to each of these elements (proportions add to unity to preserve homogeneity). Indexation is imperfect in two senses: the index used is biased in the short term because of fixed weights and it is paid retrospectively. These two features imply that 100% indexation is not automatic. Our paper explored how households will maximize their expected utility via a (coordinated) choice of contract proportions. The household with the power over contract structure is assumed to be fully employed, in line with the well-known facts of bargaining, whereas the average representative household in the model does have unemployed time; it follows that contract structure effectively minimizes the variance of the real wage, given that the expected real wage and employment are invariant to contract structure.

Our paper found that in the face of stationary productivity and money supply shocks indexation would be minimal with only a slight tendency to rise as the variance of money shocks rose dramatically. However when shocks to either became highly persistent indexation to prices or to their close competitor, auction wages, (which together we term 'real wage protection') become large, becoming largest when both shocks are persistent. We looked at experience in the OECD in the 1970s where it is well-known that real wage protection was substantial; our calibrated model, when estimated variances and persistence of money and productivity shocks were fed into it, predicted high protection in all countries we could cover, apparently in line with the facts. We also found, contrary to much casual comment, that there was little evidence of any diminution of real wage protection in the 1990s; our model also predicted as much, for even though the variance of money supply shocks fell by then, their persistence remained essentially unchanged. Our preliminary explorations of optimal monetary policy indicated that there were welfare gains to be had by reducing the persistence of money supply shocks. It is this result that we wish to extend in this paper.

The model is set out in full in Appendix 1 together with its linearised and simplified version in Appendix 2. We embed our representative household in an environment of profit-maximizing competitive firms which on a large proportion of their capital stock face a long lag before installation (a simple time-to-build set-up) and a government that levies taxes and pays unemployment benefits (which distort households' leisure decisions and introduce a 'social welfare' element into monetary policy). Firms and governments use the financial markets costlessly and settle mutual cash demands through index-linked loans; since there is no binding cash constraint on these agents, these loans are assumed to be unaffected by the imperfections of the price index which are short term in nature. This model is too simplified in many ways to match the data of a modern economy whether in trend or dynamics; however its focus is purely on the wage contract decision and its simplicity is justified in terms of its ability to match the facts about wage contracts, which as argued above is reasonably impressive.

In order to assess the welfare of society from different monetary policy rules we use the following utility function for the average household:

$u_t = \frac{(c_t - s_t)^\lambda [l + a_t]^{1-\lambda})^{1-\rho} - 1}{1-\rho}(1)$

We take expectations of it directly as contract structure changes. In the above $s_t$ represents what might be called the 'social' element of utility. Because households get unemployment benefit on their spells of eligible unemployment, $a_t$, this implies that their choice is distorted; they choose leisure ($l$, which we in practice set at unity, is the ineligible part of leisure) in response to the differential between wages and benefits. But then of course they must pay for the benefit burden via taxes; the present discounted value of this tax burden is the same as this benefit bill and so we deduct this from their consumption to obtain total private utility.In their choice of wage contracts this is what households maximize the expected value of; and in its choice of monetary policy it is also what the authorities will maximize.

Our numerical method treats each period outcome as a stochastic experiment of equal likelihood in every future period. Thus the expected utility in every future period is simply the average of these stochastic outcomes. Discounting such a constant expected utility would merely multiply it by a constant, which we ignore.

**Targeting the level of money or prices - some mechanics**

If we take the linearised version of our model, we find the following solutions in general:

$p_t = \pi(Qm_t - V'\phi_t)(2)$

where $\pi = \frac{1}{Qv'(1-a_0)+V'(1-v')}$

and

$W_t = lV'\phi_t + (1-l)Qm_t(3)$

where $l = \frac{Qv'(1-a_0)}{Qv'(1-a_0)+V'(1-v')}$

Recall that $W_t$ (the auction wage, and the shadow price of labour supply) also directly determines employment through the labour supply function. Thus we can take it and employment as the same subject to some linear transformation.

Real (consumed) wages are:

$\overline{W}_{t-1} - p_t = \alpha W_{t-1} + v' p_{t-1} - p_t (4)$

Suppose that

$\phi_t = \phi_{t-1} + \eta_t (5)$

that is productivity follows a random walk. What we found in our previous paper was that households raise their real wage protection (of their real consumed wage), the more persistent are price level shocks. Thus if there was zero protection ($\alpha = v' = 0$)they would be wide open to the variability of $p_t$. The more persistent the price shocks, the higher that variability, because the shocks would cumulate.

If we now compare a money supply rule that eliminates money shock persistence with one that eliminates price shock persistence, the first plainly eliminates one independent source of persistence in price shocks. Thus we would expect to find, and do, that protection falls. The second takes the process one stage further, eliminating all price shock persistence. Thus we should find that protection falls further still. (In the full nonlinear model there are other sources of persistence, and these keep some incentive to protection alive; hence it does not disappear altogether.)

A price level rule is one that sets

$0 = E_t p_{t+1} = \pi(Q E_t m_{t+1} - V' E_t \phi_{t+1}) (6)$

and hence

$E_t m_{t+1} = \frac{V'}{Q} E_t \phi_{t+1} = \frac{V'}{Q} \phi_t (7)$

whence the 'price level rule' is

$m_t = \frac{V'}{Q} \phi_{t-1} + \epsilon_t (8)$

whereas the ('pure money') rule that eliminates money shock persistence is simply

$m_t = \epsilon_t (9)$

Notice that under the price level rule money supply accommodates known past productivity shifts; this removes persistence from price shocks, though at the cost of persistence in money shocks.

When these are substituted into (3) we obtain

(price level rule, 8)$W_t = (1-l)Q\epsilon_t + V'(l\phi_t + [1-l]\phi_{t-1})(10)$

(pure money rule, 9)$W_t = (1-l)Q\epsilon_t + V'(l\phi_t)(11)$

and when into (4) we obtain:

(price level rule) $\overline{W}_{t-1} - p_t = \pi V'[\eta_t - v'\eta_{t-1}] + \alpha V'[l\eta_{t-1} + \phi_{t-2}] - \pi Q[\epsilon_t - v'\epsilon_{t-1}] + \alpha Q(1 - l)\epsilon_{t-1}(12)$

and

(money level rule) $\overline{W}_{t-1} - p_t = \pi V'[\phi_t - v'\phi_{t-1}] - \pi Q[\epsilon_t - v'\epsilon_{t-1}] + \alpha V'[l\phi_{t-1}] + \alpha Q(1-l)\epsilon_{t-1}(13)$

The parameters $l$and $\pi$ rise and fall respectively with indexation. Both $V'$ and $Q$ vary inversely with the share of auction contracts,$\alpha$:

$Q = \frac{1}{\alpha\mu(1-a_0)+(\overline{W}_0 - B_0)a_0\sigma}; V' = \frac{1}{\alpha + a_0\sigma(\frac{1}{\mu(1-\tau_0)} - \frac{\mu}{1-a_0})}$

We will refer back to these expressions when we go on to consider how level-targeting of money and prices compare in stochastic simulations of the model with rate of growth targeting and with each other.

**Targeting nominal levels not rates of change**

*a)Money growth versus money level targeting*

We noted earlier the results of Svensson and others comparing price- with inflation-targeting rules under fixed contract structures: while the previous consensus suggested that price-targeting would create a cost in short-term macro variability, these more recent studies are ambivalent. Our results, repeated in Table 1 below show (col.3 versus col.1) that money-level targeting is superior to money-growth targeting. Our focus here has been on contract structure shift as the main factor behind the superiority of level- over growth-targeting for nominal variables. Could it however be that our particular model or welfare criteria are important factors, contract structure held constant? Table 1 also compares the two types of targeting with contract structure given (col.2 versus col.1)..

What we see here is in fact that in a heavily indexed world with exogenous contracts changes in money supply persistence have rather small effects on welfare. As we can see below from the linearised model the variance of worker consumption in such a world is positively related to the variance of inflation: this goes up with money-level targeting. The variance of the auction wage (and so unemployment) is related (slightly) to the variance of the money shock: this falls as persistence is reduced by money-level targeting.

$>$From (4) we can see that the real spendable wage, with $\alpha$ close to zero and $v'$ close to 1, approximates to minus the inflation rate. $>$From (3) we can see that the auction wage, with $l$ close to 1, the term in the money shock is small but its persistence will raise its variance.

What is striking is that the changes in variances are quite small as money's persistence changes between columns one and two with given contract structure. It is the third column, where contract structure is allowed to be reoptimized, that shows a large reduction in unemployment variance while consumption variance is essentially restored to its original size. The implication is clear: it is the change in contract structure, not the model, that delivers the gains from targeting the level of money.

*b) Inflation versus price-level targeting*

Under price-level targeting as we have seen (when $\phi_t$ is a random walk as we shall assume throughout)

$m_t = \frac{V'}{Q}\phi_{t-1} + \epsilon_t (14)$

whence

$W_t = (1-l)Q\epsilon_t + V'(l\phi_t + [1-l]\phi_{t-1}) (15)$

and using (4), (10) and (2)

$\overline{W}_{t-1} - p_t = \pi V'[\eta_t - v'\eta_{t-1}] + \alpha V'[l\eta_{t-1} + \phi_{t-2}] - \pi Q[\epsilon_t - v'\epsilon_{t-1}] + \alpha Q(1-l)\epsilon_{t-1} (16)$

As we saw earlier, minimization of the variance of real wages leads to a low degree of real wage protection (v=13, w=88, $\alpha = 2$).

Under inflation-targeting, the rule sets (we assume for simplicity the target is zero inflation)

$E_t p_{t+1} = p_t (17)$

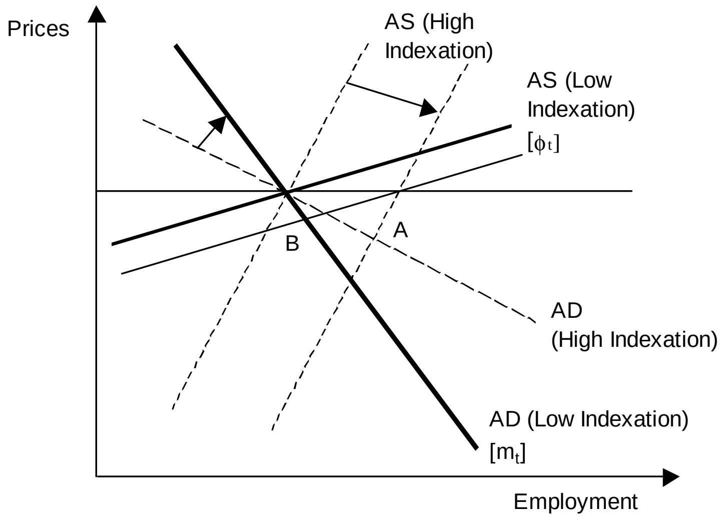
$>$From this it follows that $E_t m_{t+1} = m_t (18)$

whence $m_t$ should also be a random walk. Thus this is the equivalent of our original I(1) money supply rule, or pure money growth targeting. In our simulations in the full model we assume that inflation targeting is the money growth rule of Table 1.

Comparing price- and inflation-targeting in the full model (Table 2) we thus find essentially the same as comparing money- and money-growth-targeting. For *given* contract structures the differences in variances are small. The big difference comes when contract structure is allowed to vary.

*c) why does level-targeting have a stabilising effect?*

To understand this we can go back to the stylised representation of the linearised model- Figures 4-6 in Appendix 2. The essential point is that as indexation falls the aggregate supply curve flattens, while the aggregate demand curve steepens.




The effect of reduced indexation on slopes of AS and AD curves
[$\phi_t$ = Productivity Shock; $m_t$ = Monetary Shock]

Figure 1

The resulting intersections for a supply shock as shown at A (high indexation) and B (low indexation). Thus the drop in indexation is stabilising to both employment and prices in the face of a supply shock. Of course for a money (demand) shock the result is greater employment instability, though probably less price instability.

*d) Comparing money- and price-level targeting*

Our stochastic simulation results for the two nominal level targets are recapped in Table 3

According to the full nonlinear model indexation falls substantially as the rule moves from pure money to a price rule. The net result is that the variance of real wages falls, while the variance of employment rises. Overall welfare is virtually unchanged. But a price rule therefore has a distributional effect, raising the welfare of those with continuous employment ('insiders'), while reducing the welfare of those with variable employment ('outsiders').

What seems to be happening is that the greater nominal rigidity induced by the price level target reduces the effect of productivity shocks on auction wages and employment as suggested in Figure 1. But it increases the effect of money shocks; and these are now more persistent and hence have higher cumulative variance.

With regard to real spendable wages, money level targeting includes the effect of the lagged price level times the indexation parameter. Price level targeting, by eliminating indexation, removes this effect, leaving only the temporary shock of the current price level.

Using (2), (3) and (4), and for simplicity approximating $\alpha = 0$, then under the money rule, $m_t = \epsilon_t$, we have the following variances:

Var $W_t = 4(lV')^2\sigma_\eta^2 + [(1-l)Q]^2\sigma_\epsilon^2$(19)

and Var $(\overline{W}_{t-1} - p_t)$=$\pi^2\{Q^2(1+v'^2)\sigma_\epsilon^2 + V'^2(1+3(1-v')^2\sigma_\eta^2\}$(20)

where $l \approx 0.7, v' \approx$0.5

whereas under the price rule we have approximating $v' = l = 0$ :

Var $W_t = 3(V')^2\sigma_\eta^2 + Q^2\sigma_\epsilon^2(21)$

and Var $(\overline{W}_{t-1} - p_t)$=$\pi^2\{Q^2\sigma_\epsilon^2 + V'^2\sigma_\eta^2\}(22)$

What we see is that (22) is less than (20) and (21) more than (19), as in our simulations.

**Interest rate targeting- what does it do?**

Up to this point we have been considering rules for fixing the money supply for the current period. In practice most central banks set interest rates for the current period, letting the money supply therefore be whatever is necessary to meet that interest-rate target. In effect what this rule does is to force $\epsilon_t$, the innovation in money, to respond to other shocks so as to fix interest rates, instead of being an autonomous random variable as we have assumed hitherto. In terms of this model it forces $\epsilon_t$ to respond to the innovation in $\phi_t$, the supply shock. We will discuss this in the context of a price-level targeting rule.

Thus we can see at once that an interest-rate rule closes down any pure variance in the money supply (demand); this will be stabilising both for prices and output/employment. However, it forces money supply to accommodate real shocks so that the rise in demand is just equal to the rise in supply, avoiding upward pressure on interest rates. This will increase the response of output and employment, and decrease the response of prices.

Our linearised model yields:

$p_t = m_{t-1} - d_t + K_t - (1+e)K_{t-1}(6L)$

$K_t = k'd_t - jr_t(2L)$

where $k\prime, j$ are the collections of parameters in (2L) (Appendix 2) and hence $k\prime \succ j$

Note that the nominal interest rate is

$NR_t = r_t + E_t p_{t+1} - p_t (23)$

which since under price-level targeting $E_t p_{t+1} = 0$ defaults to

$NR_t = r_t - p_t (24)$

Interest rate targeting implies that

$NR_t = E_{t-1} NR_t (25)$

where this is the predicted $NR_t$ required to implement the price-level target rule. It therefore follows that

$(p_t - E_{t-1}p_t) - (r_t - E_{t-1}r_t) = 0$

or $p_t^{ue} - r_t^{ue} = 0 (26)$

where $^{ue}$ denotes 'unexpected'. Our model above implies:

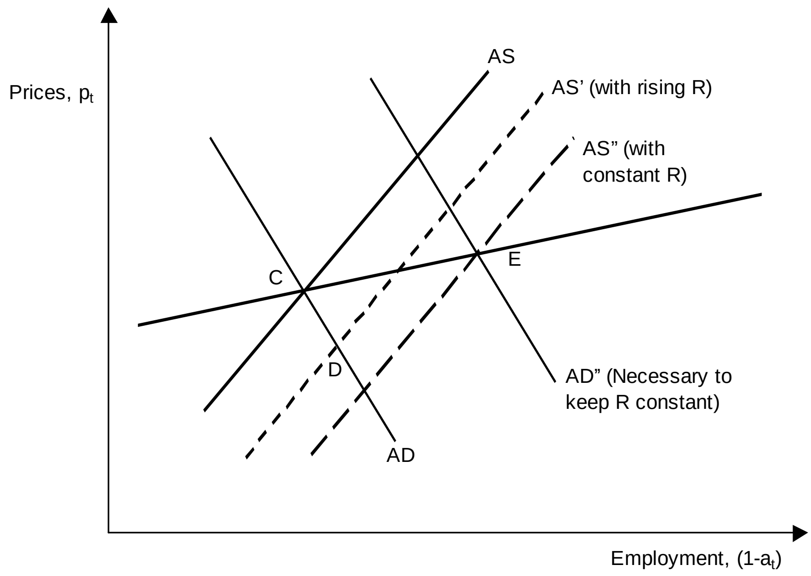
$p_t^{ue} = (K_t - d_t)^{ue} = (k' - 1)d_t^{ue} - jr_t^{ue} (27)$

Thus

$(1 + j)p_t^{ue} = (k' - 1)d_t^{ue} - j(r_t^{ue} - p_t^{ue})$ (28)

Thus $p_t^{ue} = \frac{(k'-1)}{1+j} d_t^{ue} (29)$ under interest rate targeting

This gives rise to the trajectory in (prices, employment) space as shown in Figure 2, shown as the line connecting points C and E.



The effects of Interest Rate Fixing (for one period ahead)

Figure 2

Hence if, as is the case in this model, $\frac{(k'-1)}{1+j}$ is close to zero (so that the CE line is virtually flat) then effectively $p_t^{ue} \simeq 0$. Using equation (2) this implies that

$$\pi(Qm_t^{ue} - V'\phi_t^{ue}) \simeq 0$$

$$\text{or } m_t^{ue} \simeq \frac{V'}{Q}\phi_t^{ue} (30)$$

Hence the shock to the money supply automatically responds positively to (accommodates) the productivity shock, as illustrated in Figure 2. $\frac{V'}{Q}$ in our calibration lies in the range of 0.5-0.6 (corresponding to an $\alpha$ from 0 to 1); thus a 1% shock rise in productivity will provoke a half percent shock rise in money supply. This is somewhat similar to the idea of price-level targeting, only contemporaneously.

In the full model we show (Table 4) that the interest rate setting element in the price rule reduces the variance of both employment and real wages; it does not change the contract structure from one with overwhelmingly nominal wages.

To understand why we can again consult the linearised model. The interest-setting element introduces a response to $\eta_t$in place of $\epsilon_t$so that the new rule is:

$m_t = \frac{V'}{Q}(\phi_{t-1} + \eta_t) = \frac{V'}{Q}\phi_t$(31)

in place of

$m_t = (\frac{V'}{Q}\phi_{t-1} + \epsilon_t)$(32)

On our assumption here that the variance of the monetary and productivity innovation are the same, replacing the monetary innovation with half the productivity one will of course reduce variance. However the replacement also introduces a correlation between the two innovations where there was none before. So the effect is not self-evident.

We can argue intuitively as follows. Real spendable wages, with both indexation and auction wages having very low shares, will vary mainly because of variation in prices. The interest-setting rule approximately eliminates this variation and so will reduce the variance of real wages. Formally, we can see this from the variance expressions for real wages (ignoring terms in $v'$ and $l$ as very small)

under the price rule alone Var $(\overline{W}_{t-1} - p_t)$=$\pi^2\{[(\alpha Q)^2 + (\frac{Q}{V'})^2]\sigma_\epsilon^2 + [1 + 3(\alpha V')^2]\sigma_\eta^2\}$(33)

with the interest-setting element added $Var(\overline{W}_{t-1} - p_t) = 3(\alpha V')^2\sigma_\eta^2$(34) which is plainly smaller.

If we turn to the auction wage, and again ignore terms in $l$, then in both cases $W_t = Qm_t$. Here comparing (32) and (33) we can see that the replacement of the monetary innovation with half the productivity innovation is not offset by any cross correlation as both are uncorrelated with $\phi_{t-1}$.Hence, as is easily verifiable, under our assumption of equal variability in the two innovations, the variance of auction wages falls as the interest-setting element is introduced.

If we now ask why the optimal contract structure does not change when this element is added, we can examine (34) and ask what adjustment to contract shares would be desirable from that inherited with the price rule alone. (34) reveals that the optimum will be where $\alpha$ is reduced as much as possible since this will also reduce $\alpha V'$. However, $\alpha$ at 0.02 is already as low as possible; any lower and the model fails to converge (presumably because there is insufficient elasticity in labour demand.) Indeed if it could have gone any lower, (33) reveals it would have done so with the price rule alone.

**Conclusions**

In this paper we have set up a model where an employed representative agent chooses an optimal degree of wage indexation (to prices and the auction wage) in response to the monetary regime. We then asked whether that regime should target the growth rate or the level of the money supply; or of prices? And should the current money supply be exogenous (as in 'monetary base control'), or endogenously fixed by an interest rate rule, as is the general practice of central banks? We have suggested that these familiar choices appear in an unfamiliar light when indexation is endogenous. When the monetary regime moves to a price level rule with exogenous stationary money supply shocks, the aggregate supply curve flattens and the aggregate demand curve steepens, generating a high degree of macro stability (i.e. in the face of supply shocks) provided that money supply shocks themselves are low-variance and stationary.

What we have found is that there is a general class of monetary rules that target the level of a nominal variable, whether money or prices, whether via interest-rate setting or via money supply control, that is markedly superior to the class currently in use, that target rates of change of the nominal variables. The reason for this superiority is strong shift in contract structure away from indexation to nominal. This shift is strongest when a price-level rather than money-level target is in place- but in welfare terms it is hard to choose between the two, as there is a trade-off between the interests of insiders (who prefer the price rule) and outsiders (who prefer the money rule). In purely practical terms, given the difficulties of targeting money, the price rule with interest-setting would be the easiest to attempt.

A price-level rule is the fiat-currency equivalent of a commodity standard in which the price level is stabilised by varying supplies of the commodity; problems with commodity standards can arise when shocks to the supply of the commodity are volatile and non-stationary (as occurred for quite long episodes under the gold standard)- the high degree of nominal rigidity makes employment vulnerable to such monetary shocks. But if a fiat currency provider can manage to keep shocks to the supply of fiat currency stationary and stable, then this regime appears to be beneficial. Since it is governments that provide fiat currency, one must then ask whether there is some mechanism which might induce them to behave like this; plainly one such mechanism would be currency competition within domains spanned by several currencies. Another would be popular understanding of the welfare gains, leading to political pressure, arguably similar to the process that has created a new anti-inflationary consensus.

The model in which we have been examining these questions is plainly extremely simple, with a restricted menu of shocks. Further work is needed to examine the robustness of these nominal-level rules under a wider set of models and shocks.

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**Table 1:**

(Standard deviations of shocks: $st.dev.\ of\ \epsilon = st.dev.\eta = 0.01$)

(productivity process: $\phi_t = \phi_{t-1} + \eta_t$)

| | Money growth rule | Money level rule contract structure optimal for growth rule | Money level rule with contracts optimised |
|---|---|---|---|
| variance of real consumed wage | 0.00946 | 0.00952 | 0.00944 |
| variance of unemployment | 0.00286 | 0.00278 | 0.00153 |
| h'hold welfare | -0.01737 | -0.01757 | -0.01574 |
| wage contract shares (%) | | | |
| nominal share | 13 | 13 | 44 |
| indexed share | 80 | 80 | 51 |
| auction share | 7 | 7 | 5 |

**Table 2:**

(Standard deviations of shocks: $st.dev.\ of\ \epsilon = st.dev.\eta = 0.01$)

(productivity process: $\phi_t = \phi_{t-1} + \eta_t$)

| | Inflation target* | Price level target | Price level target |
|---|---|---|---|
| | contract structure optimal for inflation target | | with contracts optimised |
| variance of real consumed wage | 0.00946 | 0.00912 | 0.00871 |
| variance of unemployment | 0.00286 | 0.00325 | 0.00220 |
| h'hold welfare | -0.01737 | -0.01841 | -0.01581 |
| wage contract shares (%) | | | |
| nominal share | 13 | 13 | 88 |
| indexed share | 80 | 80 | 10 |
| auction share | 7 | 7 | 2 |

* results assume inflation target rule is the same as a money growth target rule.

**Table 3**

(Standard deviations of shocks: $st.dev.\ of\ \epsilon = st.dev.\eta = 0.01$)

(productivity process: $\phi_t = \phi_{t-1} + \eta_t$)

| | Pure money rule | Price level rule |
|---|---|---|
| variance of real | | |
| consumed wage | 0.00944 | 0.00871 |
| variance of | | |
| unemployment | 0.00153 | 0.00220 |
| | | |
| h'hold welfare | -0.01574 | -0.01581 |
| | | |
| wage contract shares (%) | | |
| nominal share | 44 | 88 |
| indexed share | 51 | 10 |
| auction share | 5 | 2 |

**Table 4:**

(Standard deviations of shocks: $st.dev.\eta = 0.01$)

(productivity process: $\phi_t = \phi_{t-1} + \eta_t$)

| | A) Price level rule with money supply control | B) Price level rule with interest rate rule contracts as for A) | C) Price level rule with interest rate rule contracts optimised |
|---|---|---|---|
| variance of real consumed wage | 0.00871 | 0.00835 | 0.00835 |
| variance of unemployment | 0.00220 | 0.00193 | 0.00193 |
| h'hold welfare | -0.01581 | -0.01527 | -0.01527 |
| wage contract shares (%) | | | |
| nominal share | 88 | 88 | 88 |
| indexed share | 10 | 10 | 10 |
| auction share | 2 | 2 | 2 |

**Appendix 1 : The Model Equations**

1 Supply of work

$$a_t = a_o \cdot (W_t \diagup (b_t \cdot P_{t-4}))^{-\sigma} \cdot \epsilon_t$$

2 Demand for Capital Goods

$$K_t = (1-k) \cdot (1-\mu) \cdot E_{t-20}\left[d_t \cdot (1 \diagup R_t + e) \cdot (1-T_t)\right] + k \cdot$$
$$(1-\mu) \cdot d_t \cdot (1-T_t) \cdot (1 \diagup r_t + e)$$

3 Output Function

$$d_t = \phi_t \cdot K_t^{(1-\mu)} \cdot (n_0 \cdot (1-a_t) \cdot N)^{\mu} \cdot d_0$$

4 Wage rate, normalised on $W_t$

$$\bar{W}_t = (1-v-w) \cdot W_t + v \cdot E_{t-4}\left[W_t \diagup P_t\right] \cdot P_t + w \cdot E_{t-4}\left[W_t\right]$$

5 Official Price Index

$$\ln(P_t) = \ln(p_t) + c \cdot (\ln(p_t) - \ln(E_{t-1}[p_t]))$$

6 Goods market clearing (normalised on $r_t$ after substituting Eqn. 2 for $k_t$)

$$d_t = M_{t-1} \diagup p_t + K_t - (1-e)K_{t-1}$$

7 Labour Market Clearing, normalised on $p_t$

$$N \cdot (1-a_t) = (\mu \cdot d_t \cdot (1-T_t) \cdot p_t) \diagup \bar{W}_t$$

8 Money Market Clearing, normalised on $\bar{W}_t$

$$M_t = N \cdot \left(\bar{W}_t \cdot (1-a_t) + b_t \cdot P_{t-4} \cdot a_t\right)$$

9 Efficiency

$R_t = E_t [f(r)]^{1/20} - 1;\ f(r) = \prod_{i=1}^{20} (1 + r_{t+i})$

10 Money Supply

$M_t = \bar{M}_t + m_t$

11 Government Budget Constraint

$b_t^g = (M_{t-1} - M_t + N \cdot B_t \cdot P_{t-4} \cdot a_t - d_t \cdot p_t \cdot T_t) / p_t + (1 + r_{t-1}) \cdot b_{t-1}^g$

12 Firm's budget constraint

$d_t (1 - T_t) = K_t - K_{t-1} + \left(\bar{W}_t \cdot (1 - a_t) \cdot N\right) / p_t + b_{t-1}^p \cdot (1 + r_{t-1}) - b_t^p$

Note: By Walras' Law, the bond market clearing equation,

$b_t^p + b_t^g = 0$, is redundant.

**Variables and coefficients for the CGE model**

*Endogenous variables : initial values*

| | | | |
|---|---|---|---|
| 1 | $a_t$ | Supply of Work | 0.10 |
| 2 | $K_t$ | Capital Stock | 6.00 |
| 3 | $d_t$ | Output Function | 1.00 |
| 4 | $W_t$ | Wage Rate | 1.00 |
| 5 | $P_t$ | Official Price Index | 1.00 |
| 6 | $r_t$ | Real Interest Rate (1-quarter) | 0.02 |
| 7 | $p_t$ | Price level | 1.00 |
| 8 | $\bar{W}_t$ | Average Wage | 1.00 |
| 9 | $R_t$ | Long term real interest rate | 0.02 |
| 10 | $M_t$ | Money Supply | 1.00 |
| 11 | $b_t^g$, $b_t^p$ | Bonds (Government, firms) outstanding | 0.00 |

*Exogenous variables : initial values*

| | | | |
|---|---|---|---|
| 1 | $b_t$ | Benefits | 0.60 |
| 2 | $\epsilon_\tau$ | N(1.0, 0.01) | 1.00 |
| 3 | $E_{t-20}\left[d_t\right]$ | Expectation | 1.00 |
| 4 | $\phi_t$ | N(1.0, 0.01) | 1.00 |
| 5 | $E_{t-4}\left[W_t \cdot P_t\right]$ | Expectation | 1.00 |
| 6 | $E_{t-4}\left[W_t\right]$ | Expectation | 1.00 |
| 7 | $E_{t-4}\left[p_t\right]$ | Expectation | 1.00 |
| 8 | $\bar{M}_t$ | Money Supply Target | 1.00 |
| 9 | $m_t$ | Money Shock | 0.00 |
| 10 | $E_t\left[f\left(r\right)\right]$ | Expectation | 1.4474 |
| | $f\left(r\right) = \Pi_{i=1}^{20}\left(1 + r_{t-i}\right)$ | | |
| 11 | $T_t$ | Tax rate | 0.10 |

*Coefficients*

| | | | |
|---|---|---|---|
| 1 | $a_0$ | $=$ | 0.46 |
| 2 | $\sigma$ | $=$ | 3.00 |
| 3 | $k$ | $=$ | 0.30 |
| 4 | $\mu$ | $=$ | 0.70 |
| 5 | $n_0$ | $=$ | 0.699 |
| 6 | $N$ | $=$ | 1.00 (population) |
| 7 | $v$ | $=$ | 0.20 (initial value) |
| 8 | $w$ | $=$ | 0.50 (initial value) |
| 9 | $c$ | $=$ | 0.20 |
| 10 | $d_0$ | $=$ | 0.995 |
| 11 | $e$ | $=$ | 0.03 (depreciation) |

**Appendix 2: The linearised model**

(1L) $a_t = -a_0 \sigma W_t$

(2L) $K_t = \{\frac{k(1-\mu)(1-r_o)}{(r_0+e)}\}\{(d_t - [\frac{r_t}{(r_o+e)}]\}$

(3L) $d_t = \frac{(1-\mu)}{K_0} K_t + \phi_t - \frac{\mu}{(1-a_0)} a_t$

(4L) $\overline{W}_t = \alpha W_t + v P_t$

(5L) $P_t = (1+c) p_t$

(6L) $d_t = m_{t-1} - p_t + K_t - (1-e) K_{t-1}$

(7L) $a_t = -[\mu(1-T_o)](d_t + p_t - \overline{W}_t)$

(8L) $m_t = (1-a_o)\overline{W}_t - (\overline{W}_o - B_o) a_t$

(9L) $\overline{W}_{t-1} - p_t = \alpha W_{t-1} + v(1+c) p_{t-1} - p_t$

where $\alpha = (1 - v - w)$;equation numbers correspond to Appendix 1

Equation (9L) is the implied behaviour of the employed consumer's living standard, whose uncertainty is being minimised by the contract structure. We can progressively reduce the simultaneous block of equations (1L)-(8L) to three as follows. We can use equations (3L), the production function, and (6L), the supply of savings from goods market clearing, while also using (1L) to eliminate $a_t$, to obtain:

(10$L$) $\Delta d_t = Z(d_t - m_{t-1} + p_t - eK_{t-1}) + \Delta\phi_t + \frac{a_o}{(1-a_o)} \Delta W_t$

where $Z = \frac{1-\mu}{K_o}$

This is the output supply made available by savings (and so capital) and by labour supply; the first terms in $Z$ emerge from equation (6L) as the amount of savings (i.e. the output not devoted to consumption which is $m_t - p_t$). Note in passing that we can solve equation (2L) for $r_t$ conditional on $d_t$, $m_{t-1}$, and $p_t$: since the latter determine available savings, the interest rate has to force the demand for capital to equal this availability. Hence equation (2L) and the interest rate are in a second, recursive block, and can therefore be ignored.

Equations (1L) and (7L), labour supply and demand, yield with 4L and 5L, defining wages and the price index,

$$(11L) \qquad W_t = \frac{\mu(1-To)}{\alpha\mu(1-T_o)+a_o\sigma}[d_t + (1-v')p_t]$$

where $v' = v(1+c)$

(11L) therefore specifies the free wages that would clear the labour market, given output and the price level. (10L) and (11L) between them constitute the supply-side of the model, augmented to include the market for savings (which depend on last period's money supply).

Finally, using the money market equation (8L) together with labour supply (1L) (which defines the split between benefits and wage payments) we obtain:

$$(12L) \qquad W_t = \frac{1}{\alpha\mu(1-a_o)+(\overline{W}_o-B_o)a_o\sigma}[m_t - (1-a_o)v'p_t]$$

(12L) is reminiscent of Robertson's 'wages fund'; there is a certain stock of money available to pay wages and benefits and given the structure of contracts, it determines free (auction) wages.

The full solution is complex. However, we can represent the model's main workings by reducing equations (10L) and (11L) to a 'supply curve' between free wages and the price level; and juxtapose it with the 'demand curve' given by (12L), the wages fund equation. We neglect terms in Z as of small magnitude, and in this case the supply curve from (10L) and (11L) becomes:

$$(13L) \qquad W_t = V'[\phi_t + (1-v')p_t]$$

where $V' = \frac{V\mu(1-T_o)}{1-V\mu^2(1-T_o)\frac{a_o\sigma}{1-a_o}}$ and $V = \frac{1}{\alpha\mu(1-T_o)+a_o\sigma}$

The demand curve, $(12L)$, is:

$$(12L) \qquad W_t = Q(m_t - v'(1-a_o)p_t)$$

where $Q = \frac{1}{\alpha\mu(1-a_o)+(\overline{W}_o - B_o)a_o\sigma}$

For $0 < v' < 1$ the resulting demand and supply picture is familiar. Figure 3 shows the model in $p_t$, $W_t$ space; since labour supply (1-$a_t$) varies directly with the auction wage, this is also price level, employment space (output depends also on the capital stock, but is closely related to employment, and so this is also effectively familiar price, output space.)

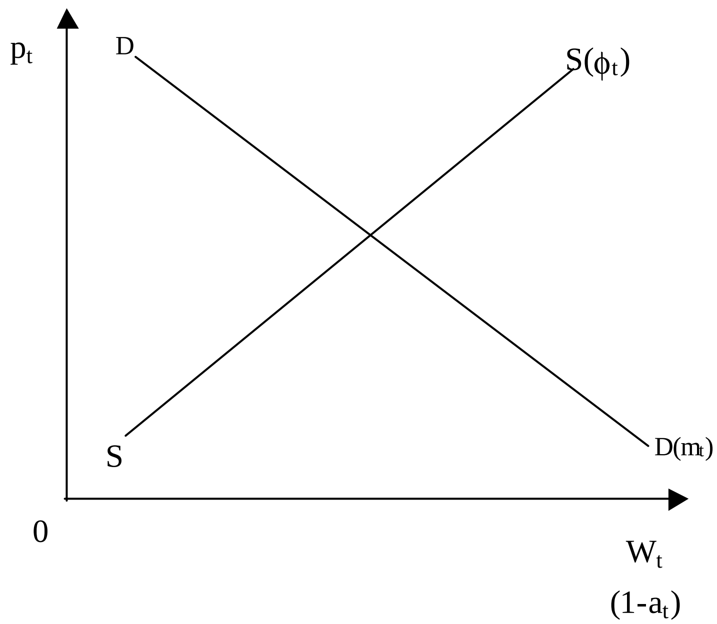


Figure 3

As $v'$ tends to 0, DD steepens (Fig. 4); as $v'$ tends to 1 the SS steepens (Fig.5).

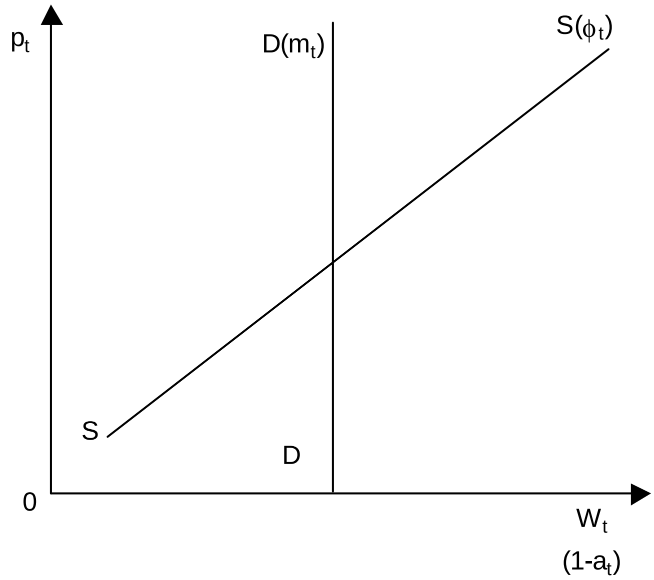


Figure 4 - No Indexation

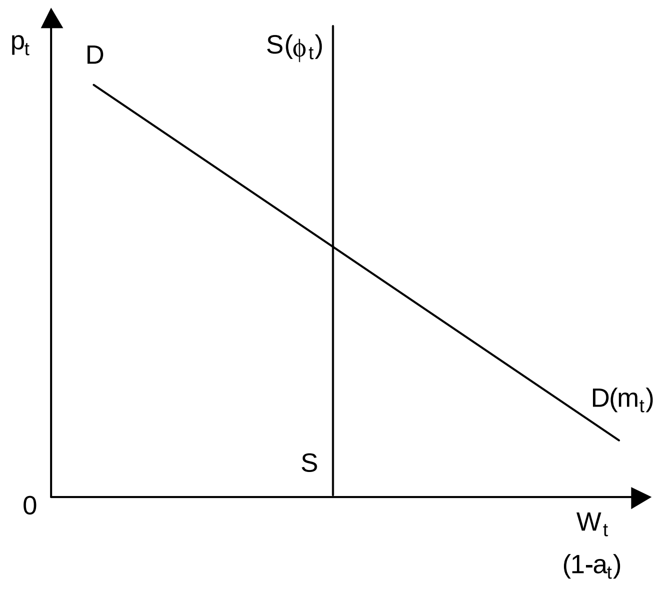


Figure 5 - Full Indexation

Glossary of expressions for the linearised model:

$$p_t = \pi(Qm_t - V'\phi_t)$$

$$\pi = \frac{1}{Qv'(1-a_0)+V'(1-v')}$$

$$W_t = lV'\phi_t + (1-l)Qm_t$$

$$l = \frac{Qv'(1-a_0)}{Qv'(1-a_0)+V'(1-v')}$$

$$\overline{W}_{t-1} - p_t = \alpha W_{t-1} + v'p_{t-1} - p_t$$

$$Q = \frac{1}{\alpha\mu(1-a_0)+(\overline{W}_0-B_0)a_0\sigma}; V' = \frac{1}{\alpha+a_0\sigma(\frac{1}{\mu(1-\tau_0)}-\frac{\mu}{1-a_0})}$$

$$\alpha = 1 - v - w$$

For $\alpha = 0, Q = 8.33; V' = 3.7; \frac{V'}{Q} = 0.44$

For $\alpha = 1, Q = 1.20; V' = 0.77; \frac{V'}{Q} = 0.56$