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"in contrast to the accelerationist hypothesis, very high unemployment did not lead to lower and lower inflation, but rather just to ongoing low inflation." Olivier Blanchard (2018, p. 98)

"a community in which money wages fall without limit so long as unemployment exists is very unlike the real world", Joan Robinson (1937, p.122)

1. Introduction

The deflation puzzle is the failure of persistently high unemployment to exert a persistent downward impact on the rate of inflation. This paper investigates the role that loss aversion might play in explaining the existence of the deflation puzzle. We briefly review several existing explanations of the deflation puzzle, which are the hysteresis model of Blanchard, Cerruti and Summers (2015), hereafter BCS, the lubrication theory of Schultze (1959), Tobin (1972) and Akerlof, Dickens and Perry (1996) and the efficiency wage theory of Shapiro and Stiglitz (1984). We point out that to explain the deflation puzzle, each of these theories relies on an unexplained assumption of downward money wage rigidity. We then show that feelings of loss aversion by workers about cuts in money wages relative to reference money wages has the potential to explain the deflation puzzle. We present estimates for the US and Australia of the Phillips curve relation between inflation and unemployment using a specification that can allow for the existence of the influence of loss aversion. The estimating model we use was originally developed in Lye, McDonald and Sibly (2001). It extended the estimation model in Gruen, Pagan and Thompson (1999) to allow for the influence of loss aversion in wage setting. The estimates supported the importance of loss aversion in explaining the deflation puzzle. The new estimates reported here give further support to the importance of loss aversion and also compare favourably with the estimates of the natural rate model and estimates by BCS of the hysteresis NAIRU.

* We thank Jeff Borland and Tim Robinson for helpful comments.

As introduced by Bhaskar (1990), applying the concept of loss aversion and the prospect theory of Kahneman and Tversky (1979) to wage setting provides a behavioural micro foundation to resolve the deflation puzzle. If loss averse relative to a reference wage, workers would dislike a lower wage with a greater intensity that they would like a wage above the reference wage. Thus, there would be a discontinuity in the worker's utility function around the reference wage. When combined with bargaining theory and/or efficiency wage theory, the feeling of loss aversion by workers implies a range of wages and thus a range of rates of unemployment in which wages are determined by the worker's reference wage. That implication suggests the possibility that if reference wages have a degree of independence from the rate of unemployment then loss aversion can resolve the deflation puzzle.

The loss aversion theory implies a theoretical mechanism to determine the lower limit to the range of unemployment rates within which reference wages determine actual wages. We call this rate of unemployment umin. At unemployment rates below umin, the relatively buoyant state of the labour market will induce workers or employers to press for wages that exceed their reference wages. This lower limit can be related to labour supply factors such as unemployment benefits and trade union power.[1]

In recent years it appears that ongoing low wage inflation has not kept up with the growth of money output per worker, nor indeed with CPI inflation, see eg Krueger (2018) for the US and Isaac (2018) and Chua and Robinson (2018) for Australia. Both Krueger and Isaac argue that employer power has increased and worker power has decreased and this may be responsible for weak nominal wage growth. With the loss aversion theory, if the reference wage is thought of as influenced by workers' aspirations then decreases in power may cause workers to trim their ambitions and their reference wages. We extend our earlier loss aversion model to test for this idea by allowing the change in union power to have a direct influence on wage outcomes.

The practical importance of worker resistance to wage cuts was emphasised by Keynes (1936) and Robinson (1937). McDonald (2019) relates their ideas to loss aversion. It will be seen that their discussion of wage setting contains insights which although being neglected by

[1] The loss aversion theory also implies an upper limit to the range of unemployment rates within which reference wages determine actual wages. We call this umax. However, the support for the empirical existence of umax using wages as the dependent variable is not strong and so for this paper we exclude it.

the subsequent mainstream macroeconomic literature are relevant for the loss aversion approach.

The plan of the paper is as follows. In section 2 we discuss the missing element in the hysteresis model of Blanchard, Cerruti and Summers (2015), the lubrication theory of Schultze (1959), Tobin (1972) and Akerlof, Dickens and Perry (1996) and the efficiency wage theory of Shapiro and Stiglitz (1984), that is the lack of a theory of downward money wage rigidity. In section 3 we explore the potential of loss aversion by workers with respect to their wage to explain the deflation and deceleration puzzles. In Section 4 we present our estimates for the US and Australia of the two-regime, loss aversion-based model of the inflation unemployment relation and compare them with our estimates of the one-regime, natural rate version of the model and the BCS NAIRU model. Section 5 concludes the paper.

2. The missing element in three theories of the deflation puzzle

2.1 Hysteresis

BCS argue that labour market hysteresis may be caused by unemployed workers dropping out of the labour force or becoming unemployable.[2] This explanation of hysteresis pivots around the inability of unemployed workers to provide effective competition for the employed. The unemployed either cease to seek employment or become ineffective as employees. In discussions of this behavioural pattern, the deskilling of unemployed people is often emphasised.[3]

However, the BCS model lacks a convincing explanation for the lack of deflationary pressure at high rates of unemployment. A loss by the unemployed of the ability to compete is an incomplete explanation of downward wage rigidity because it doesn't explain why these workers do not negotiate lower wages that reflect their loss of skills and/or job finding ability. Thus, it relies on an unexplained rigidity in wages. For example, if an unemployed worker has lost 10% of his productivity due to deskilling, why then does he not negotiate a job with a

[2] They also mention three other causes of hysteresis unrelated to labour market activity; firms may invest less, reducing the capital stock; firms may do less research and development; reallocation and the associated productivity growth may suffer in a recession.

[3] In earlier analysis, Blanchard and Summers (1986), the emphasis was on insiders preventing outsiders from competing for their jobs. Trade union power could assist the insiders in keeping out the outsiders. Blanchard and Summers (1986) showed that trade unions dominated by insiders could generate a pattern of wage demands that would cause unemployment hysteresis. However, this theoretical demonstration can be overturned if union decision-making is assumed to be dominated by a subgroup of members who enjoy secure employment, as might follow from a combination of democratic decision-making and layoff by seniority, see McDonald (1991).

10% reduction in wages? If on-the-job activity is expected to restore his skills then the negotiated wage reduction could be temporary. One may also ask why a worker threatened with the loss of his job and anticipating the possibility of deskilling does not negotiate a downward adjustment in wages to prevent the loss of his job.[4]

The BCS model of the hysteresis natural rate has a second deficiency in that as specified it does not determine limits to the range of hysteresis. The lack of a theory of the lower limit implies a lack of guidance for policy makers on the non-inflationary potential level of activity and thus a lack of information on the output gap, a standard ingredient into policy rules such as the Taylor rule. BCS recognise this when they say, following an increase in the actual rate of unemployment, "the unemployment gap, and by implication inflation, will give a misleading signal about the degree of underutilization of resources in the economy", BCS, p.25. Their point is that inflation is not decreasing even though resources are underutilized.

In practice, the idea of a minimum rate of unemployment below which the hysteresis natural rate cannot be pushed by expanding aggregate demand without causing inflationary pressure is compelling. The estimation of the hysteresis natural rate as specified by BCS does allow implicitly for the influence of labour market factors in as far as these may be at times a binding constraint on the outcomes for unemployment and inflation but it does not measure their influence. It does not reveal at what times the lower constraint is binding. Thus, it does not reveal what labour market factors are a binding constraint, nor when they bind and nor where they would bind, that is it lacks information about the potential level of labour market activity.

2.2 Lubrication

Schultze (1959) and Tobin (1972) argued that creeping inflation will improve the reallocation of labour in response to heterogenous demand and productivity shocks across firms. They based their argument on the assumption that money wages are sticky downwards. If money wages cannot fall, then firms that experience unfavourable shocks can reduce their relative wage by simply holding their money wages constant as other firms increase their money wages. At low rates of inflation, this mechanism has less force and thus labour market adjustment requires higher unemployment. Building on this idea, Akerlof, Dickens and Perry

[4] Delong and Summers (2012, p.254) cite evidence from Davis and Wachter (2011) which suggests that workers who lose their jobs lose 'an extra amount…(equal to)…a 7.5 percent reduction in permanent earnings'. This loss raises the question of why wages were not reduced of those who maintained their jobs and thereby enjoyed the benefit of avoiding the income-reducing effect of hysteresis.

(1996) constructed a simulation model to show how heterogeneity across firms and downward money wage rigidity implies a weak influence of unemployment on wage inflation. From this simulation model they show that the long-run Phillips curve will move from being vertical to being negatively sloped for rates of inflation below 3%. Thus, this theory would seem to be an explanation of the deflation puzzle, at least at low rates of inflation.

However, these three papers assume downward money wage rigidity. They do not give an explanation of why money wages should be downward-rigid. Nor do they present a theory of the lower limit to the rate of unemployment below which their theory of sluggish wage growth would be overcome by an excess demand for labour. For example, in their simulation model, Akerlof, Dickens and Perry (1996, p.29)) base the lower limit on “the median of existing natural rate estimates” and on their observation that the recent experience of inflation and unemployment supports this median as an equilibrium value.

2.3 Efficiency wages

Shapiro and Stiglitz (1984), (1985) argue that their efficiency wage model, based on the assumption that it is costly for the employer to monitor the effort of employees, implies a sluggish adjustment of wages. They say “wage decreases by individual firms would only become attractive as the unemployment pool grows”, Shapiro and Stiglitz (1984, p. 439)) and later, in reply to the criticism of Carmichael (1985), “the efficiency wage theory also provides an explanation of wage dynamics: it explains why one firm may be slow to lower its wages until other firms do so”, Shapiro and Stiglitz (1985, p.1215). However, their argument does not explain “ongoing low inflation”; they are simply claiming that their efficiency wage mechanism explains a slow rate of decrease in the rate of inflation. Note also that they do not set out explicitly the dynamic process they have in mind.

3. The potential contribution of loss aversion

This section shows how incorporating loss aversion into theories of wage determination can provide a microeconomic foundation with the potential to resolve the deflation puzzle.

3.1 Theories of trade union bargaining and efficiency wages

Bhaskar (1990) incorporated loss aversion into wage bargaining models to explain wage rigidity in the face of high unemployment. His focus on trade unions continued from Keynes

(1936) and Robinson (1937). However, as indeed Bhaskar (1990) noted, an alternative path of influence of loss aversion to explain wage rigidity is efficiency wage theory. To have a microfoundation which can capture the implications for the deflation puzzle of incorporating loss aversion into both trade union bargaining and efficiency wages, in the Appendix we present a simple model that combines wage bargaining with efficiency wages. The model extends a model of Layard, Nickell and Jackman (1991, Annex 3.1) to incorporate loss aversion both in wage bargaining and in the determination of labour productivity. In this section we describe briefly how this combined trade union/efficiency wage model shows that loss aversion implies a range of unemployment rates within which wage inflation is determined by reference wage inflation.

As shown in the appendix, loss aversion implies that in the combined trade union/efficiency wage model the wage will be determined by the reference wage if the reference wage lies between limits determined by two values, $\{k^+, k^-\}$ of the mark-up of the wage on the reservation wage. These limits are related to the parameters of the model according to:

$$\frac{W^i}{W^{RES}} = \left(\frac{1}{1 - \frac{\phi}{1-\phi} \frac{\left(\beta_1 + \beta_2^i\right)\frac{1}{\alpha(1-h)} - 1}{1 - \frac{\theta^i}{\alpha(1-K)}}} \right)^{\frac{1}{\beta_1}} = k^i \text{ for } i=\{+, -\} \qquad (3.1.1)$$

where

W = money wage
W^{RES} = reservation money wage
β_1 = the worker's elasticity of utility wrt the wage
β_2^i = the worker's elasticity of utility wrt the wage relative to the reference wage
ϕ = union power = the weight of the worker's objective in the bargaining maximand
α = the elasticity of output wrt labour input
h = the reciprocal of the elasticity of the demand for the firm's product wrt price
θ^i = the elasticity of the worker's effort wrt the wage relative to the reference wage
K = a constant in the effort function

To capture loss aversion, assume $0 < \beta_2^+ < \beta_2^- < 1$ and $0 < \theta^+ < \theta^- < 1$. A decrease in the wage below the reference level will reduce utility and productivity by large amounts, given by β^- and θ^- respectively, relative to the effects of an increase in wage above the reference level, given by $\beta^+ < \beta^-$ and $\theta^+ < \theta^-$. $0 < \beta_2^+ < \beta_2^- < 1$ and $0 < \theta^+ < \theta^- < 1$ implies $k^- > k^+$ and thus a range of wages $\left\{k^+W^{RES}, k^-W^{RES}\right\}$ within which the actual wage is determined by equality with the reference wage.

As shown in the appendix, using standard assumptions for macro closure, $k^- > k^+$ implies a range of unemployment rates for which the wage rate is determined by the reference wage. This range is given by:

$$u^{min} = \frac{1 - \frac{1}{k^+}}{1 - b} \leq u \leq \frac{1 - \frac{1}{k^-}}{1 - b} = u^{max} \qquad (3.1.2)$$

where b=the unemployment benefit replacement ratio. From (3.1.2) both umin and umax are positively related to the unemployment benefit replacement ratio and to the size of the union power parameter. This provides the theoretical basis for including union power and the unemployment benefit replacement ratio in our econometric analysis of the determination of umin.

In summary, for rates of unemployment between umin and umax, wages are determined by references wages. For rates of unemployment below umin, wages will exceed reference wages and for rates of unemployment above umax wages will fall short of reference wages. Umin and umax are determined by labour supply factors, that is worker power and the unemployment benefit replacement ratio.

3.2 The reference wage and the level of activity

To seek a resolution of the deflation puzzle, loss aversion directs attention to the behaviour of reference wages. In this section we discuss various theories of the determination of reference wages.

3.2.1 Money illusion and reference wages

Shafir, Diamond and Tversky (1997, pp. 347-8) propose that reference points "can often be nominal" and find evidence from surveys of opinions to support this with respect to wages. Earlier, Kahneman, Knetsch and Thaler (1986, p.731) found from surveys a strong aversion (62%) to a cut in nominal wages, even though a wage cut with the same real wage reduction in an inflationary environment in which money wages actually increased was acceptable for 78% of respondents. There would seem to be something special about cuts in nominal wages, for given real wage outcomes.[5]

The special importance of aversion to reductions in nominal wages rather than real wages suggests modelling the reference wage as the current nominal wage. This implies that the downward impact on reference wages of unemployment will be weaker at low rates of inflation. And not just at zero inflation. As noted above, the lubrication theory shows that heterogeneity of firms implies implies a weak influence of unemployment on wage inflation at low positive rates of inflation; up to 3 percent inflation according to the simulations in Akerlof, Dickens and Perry (1996). Specifying the reference wage as the existing money wage would provide a prospect theory base to the lubrication theory.

3.2.2 Passive approaches

Bhaskar (1990), following Keynes (1936), assumed the reference money wage is the money wage expected to be received by other workers. As noted above, under this assumption, in macroeconomic equilibrium any wage in the range defined above by (3.1.2) is a perfect-foresight equilibrium and so satisfies the rational expectations approach to reference level determination of Koszegi and Rabin (2006). This specification of reference wage determination resolves the deflation puzzle for rates of unemployment lying between umin and umax. That is, if workers expect the wages of other workers to be increasing then their reference money wage will be increasing and so their money wage demands will be increasing, independently of the rate of unemployment (provided of course that unemployment remains within the limits of umin and umax).

For u<umin the wage that maximises the wage bargain will exceed the reference wage. If actual wages are set accordingly they will exceed the expected wage. Then it is reasonable to suppose that wage expectations and thus the reference wage will be revised up in line with actual wages and this will lead to bargained wages adjusting upwards to maintain

[5] However, note that Kahneman, Knetsch and Thaler (1986, p.733) found that cuts in money wages are acceptable if firms are making losses; an example of their dual-entitlement model.Benigno and Fornaro (2015) present a list of references that suggest the existence of money wage rigidities. Holden and Wulfsberg (2009) find stronger evidence for downward money wage rigidity than downward real wage rigidity.

their excess over reference wages. This would tend to put upward pressure on wage inflation. However, the intensity of that pressure, and so whether wage rates would be accelerating, can be linked to whether, in Robinson’s words, “employers themselves throw their weight into the scale of rising wages”, Robinson (1937, p.15). If trade union bargaining dominates then employers would be resistant to wage increases: they would not throw their weight into the scale of rising wages and so acceleration would be weak or even non-existent. But if the efficiency wage mechanism dominates, then it is in the interest of employers to be pushing up wages in their search for optimal efficiency and given that employees are not against wage increases, the upward pressure would be greater.

For $u>umax$, bargained wages would fall short of reference wages. The logic above for $u<umin$ would apply in reverse, although perhaps with less intensity because the employed may be slow to adjust down their reference wages. Given the dislike by employees of reduced wages, self-serving bias may induce them to under-estimate the facts of wages below reference levels.

3.2.3 Active approaches and speed limits

Bhaskar’s, and Keynes’, approach to expectations formation can be described as passive. It is a bootstrap theory of inflation where unions simply follow other unions. A more active theory of reference wage setting can be derived from Robinson’s suggestion that unions “demand a rise and resist a cut [in money wages] whenever they feel strong enough to do so”, Robinson (1937, p.4). McDonald (2019) calls this Robinson’s proactive postulate and sets Robinson's view within prospect theory. Thus, the trade union is modelled as actively setting a reference money wage when it seeks to take advantage of an improvement in its position. By inducing its members to code a wage claim as the reference money wage, the union will strengthen the support the workers will give to achieving the money wage claim because if they fail then they will suffer loss aversion. This threat will strengthen their determination and cohesion.

Robinson’s proactive postulate provides a stronger basis to resolve the deflation puzzle than the passive approach to reference wage determination. Under the passive approach, any success by employers in preventing wages from increasing by the full amount of reference wages will get transferred over time into the reference wage and thus into actual wages, going forward. By contrast, Robinson’s proactive postulate implies that unions will increase money wages when they perceive an increase in nominal labour demand at the microeconomic level. If unions are powerful enough, they can ensure that money wages increase with the value of their marginal product, thereby ensuring that nominal unit labour costs increase with the rate of price inflation. Any falling behind in wages will be offset in subsequent periods, rather than being factored in in subsequent periods. Furthermore, improvements in labour productivity would also be transferred to increases in money wages if unions are strong enough to follow Robinson's proactive postulate.

Speed limits, that is a change in activity such as a reduction in the rate of unemployment driving a change in wages, is a common finding in the empirical literature, see eg Phillips (1958), Gordon (1990), (1997), (1998), (2018) Romer (1996), Gruen, Pagan and Thompson (1999).[6] Robinson's proactive postulate can be an explanation of the speed limit effect because it implies that an increase in nominal labour demand above trend may lead to a similar-sized increases in wages if unions are powerful enough.

Wages have fallen on occasion, such as in the early 1930s. A reconciliation of this downward speed-limit lies in how firms and their workers react to the threat of profits being replaced by losses. That is, a severe contraction in product demand may push some firms into extreme financial duress in which case workers may accept wage reductions to prevent mass layoffs, see eg Akerlof, Dickens and Perry (1996), Bewley (1999) and, for a theoretical account in the loss-aversion model, see McDonald (2019).

3.2.4 Employer influences on reference wages

The efficiency wage model has employers setting the wage. To avoid low efficiency employers would be conscious of the reference wage held in the minds of workers and these reference wages may be influenced by the actual wage or the wages of other workers, as in passive approaches, or by the perceived capacity to pay of the employers, as in the active approaches. Shafir, Diamond and Tversky (1997) present an efficiency wage model in which workers' effort is positively related to the increase in nominal wages at a given real wage. They also suggest, see Shafir, Diamond and Tversky (1997, fn. 22), that a longer history of past inflation may be the driving force in the effort function. This is an example of the passive approach.

[6] Gordon places a lot of emphasis on the importance of speed limits, which is one of three vertices in his triangle model of inflation. Robinson observed that "movements of the level of employment are the chief influence determining movements in the level of money wages", Robinson (1937, p.7).

As with the trade union bargaining approach with passive reference wage setting, with efficiency wages, high unemployment, and thus a ready availability of outsiders, may enable employers to chip away at the real wage and thereby, in as far as reference wages follow actual wages, reduce the reference real wage. And again, this possibility suggests a certain fragility to the ability of prospect theory to resolve the deflation puzzle.

4. Estimates of the loss aversion model

4.1 The estimating model

To estimate the range model, we use a two-regime specification of the estimating model as in Lye, McDonald and Sibly (2001).

We use the following variables:

ULC= (log) unit labour costs

P=(log) consumer price level

P*=(log) expected price level based on forward-looking survey data

u=rate of unemployment

r_i =supply side factors

In our specification, we allow the coefficients of the SRPCs to take different values within two regimes which we will call from now on regimes of low and high rates of unemployment.[7] The behaviour of inflation across the two regimes behaves according to the following estimating equations.

$$\Delta_4 \ln ULC_t - \Delta_4 \ln P_{t-1} = \pi_t^P X_t^P + \left(1-\pi_t^P\right) X_t^R \qquad (4.1.1)$$

with the within-regime behaviour is described by

$$\begin{aligned} X_t^i &= a_1^i\left(\Delta_4 \ln P_t^* - \Delta_4 \ln\ P_{t-1}\right) + a_2^i (u_t - u_t^{\min}) + a_3^i\left(u_{t-1} - u_{t-2}\right) \\ &+ a_4^i\left(\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln P_{t-2}\right) + a_5^i\left(\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln ULC_{t-4}\right) + v_t^i \end{aligned} \qquad (4.1.2)$$

[7] The 2-regime specification

for i=low unemployment, high unemployment. $\Delta_4 x_t = 100*(x_t - x_{t-4})$, which approximates percentage change. u_t^{min}, the rate of unemployment between the low and high unemployment regimes, is related to supply-side factors, $r_{i,t}$, by

$$u_t^{min} = \alpha_0 + \sum_i \alpha_i r_{i,t} \tag{4.1.3}$$

In (4.1.1) the use in the dependent variable of the change in real unit labour costs (=change in nominal wages per employee divided by output per employee minus the change in the CPI) as the measure of wage inflation follows Gruen, Pagan and Thompson (1999) and Lye, McDonald and Sibly (2001). In our behavioural context, the difference between $\Delta_4 \ln ULC_t$ and $\Delta_4 \ln P_{t-1}$ can be interpreted as a measure of the sharing of the gains from rising total factor productivity between labour and capital. For example, the benchmark value of $\Delta_4 \ln ULC_t - \Delta_4 \ln P_{t-1} = 0$ implies, ignoring changes in the terms of trade, that real wages have kept up fully with the rise in labour productivity.[8]

(4.1.2) is based on an accelerationist specification in which the expected rate of inflation appears on the right-hand side with a coefficient of one. That is:

$$\Delta_4 \ln ULC_t = \Delta_4 \ln P_t^e + \text{ other variables} \tag{4.1.4}$$

Defining the expected consumer price level by a mixture of forward and backward-looking components according to $\Delta_4 \ln P_t^e = a_1^i \Delta_4 P_t^* + (1 - a_1^i) \Delta_4 \ln P_{t-1}$ gives (4.1.2).

$\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln P_{t-2}$ is the lagged dependent variable. $\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln ULC_{t-4}$ captures differences in the behaviour of inflation at quarterly and annual frequencies, see Gruen, Pagan and Thompson (1999).

Equation (4.1.1) determines the relative importance of the two inflation equations in (4.1.2) according to the continuous dummy variable π_t^p. This variable is specified to depend on u_t, u_t^{min} and the transition parameter, γ, according to the logistic:

[8] Gruen, Pagan and Thompson (1999, p.234) argued for ULC on the basis that ULC are more relevant for pricing decisions, which were a part of their two-equation model of wages and prices.

$$\pi_t^P = 1 - \frac{1}{1 + \exp\left[-\gamma(u_t - u_t^{min})\right]} \tag{4.1.5}$$

4.2 The estimates

In this section we discuss our estimates of the inflation-unemployment relation. First, we discuss how trade union power may influence wage outcomes while the economy is within the high unemployment regime. Then we discuss the implications of our estimates for the determination of umin, the shape of the short-run Phillips curve and the dynamics of inflation. Following that we compare the estimates with estimates using the natural rate of unemployment specification and with the hysteresis specification of BCS.

Table 1 Estimates of the two-regime model for the US and Australia

Dependent variable: % change in ULC minus % change in CPI

green (light green)=sig diff from zero at 95% (90%) level

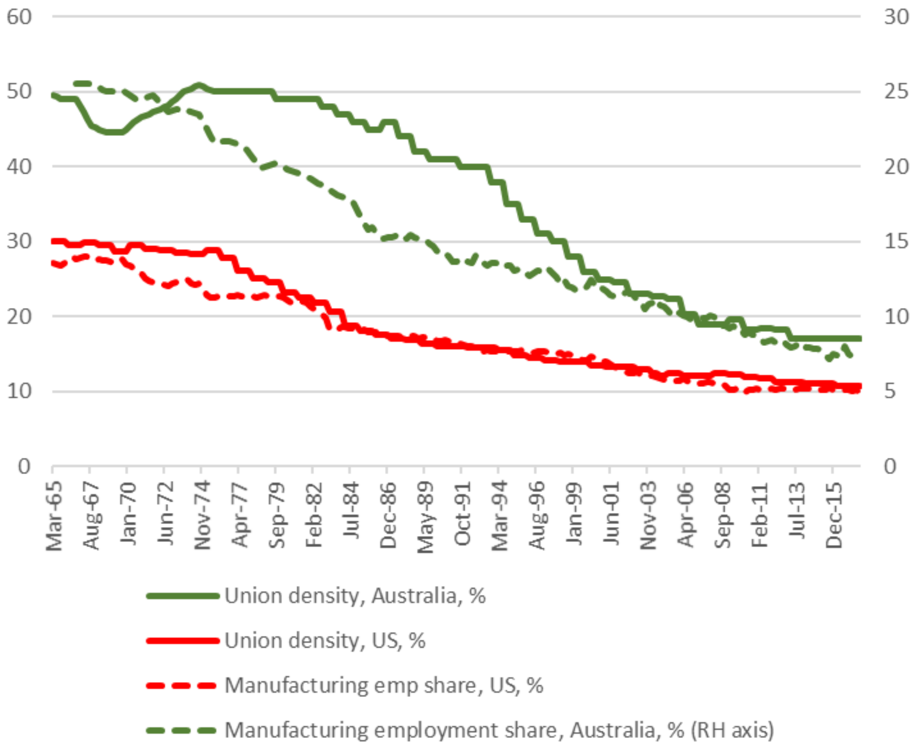
			US				Australia			
			1966:2 to 2017:4				1967:4 to 2017:3			
column			1	2	3	4	5	6	7	8
			coef	p value	coef	p value	coef	p value	coef	p value
umin equation		constant	-22.41	0.00	-22.42	0.00	-3.69	0.00	-2.18	0.09
		un ben	0.45	0.00	0.45	0.00	0.28	0.00	0.26	0.00
		union density	0.42	0.00	0.42	0.00	0.04	0.00	0.02	0.29
		female/non-white	3.17	0.00	3.18	0.00				
		teen	0.35	0.00	0.35	0.00				
		transition parameter	12.99	0.01	12.17	0.10	5.82	0.25	0.83	0.01
sigmas		peak	0.53	0.03	0.52	0.06	1.91	0.00	2.19	0.00
		range	1.10	0.00	1.10	0.00	1.26	0.00	1.42	0.00
SRPCs	peak	exp inf	0.04	0.91	0.02	0.95	0.17	0.12	0.16	0.22
		un level	-4.31	0.00	-4.52	0.00	-1.07	0.00	-0.98	0.00
		speed limit	-5.61	0.01	-5.53	0.01	-2.88	0.01	-3.80	0.00
		ldv	1.41	0.00	1.46	0.00	0.71	0.00	0.73	0.00
		qtly diffs	-1.05	0.00	-1.12	0.00	0.32	0.01	0.29	0.05
	range	exp inf	0.01	0.83	0.03	0.69	0.06	0.37	0.08	0.44
		un level	-0.18	0.02	-0.27	0.00	-0.09	0.26	-0.12	0.25
		speed limit	-0.38	0.16	-0.45	0.10	-0.74	0.04	-0.07	0.92
		ldv	0.51	0.00	0.53	0.00	0.75	0.00	0.70	0.00
		qtly diffs	0.45	0.00	0.45	0.00	0.45	0.00	0.51	0.00
		% ch manu employment	0.12	0.08			0.04	0.58		
test statistics	Log likelihood			-304.35		-343.83		-341.03		-341.57
	Akaike info criterion			3.12		3.13		3.58		3.58
	number of coefficients			19		18		17		16
average size of 95% CI on umin				0.87		0.43		0.75		1.47

4.2.1 Union power and our preferred specification of the estimating equation for Australia

In Table 1, Columns 3 and 4 for the US and 7 and 8 for Australia update the estimates of the specification of the two-regime, loss-aversion model we used in Lye, McDonald and

Sibly (2001). Columns 1 and 2 for the US and 3 and 4 for Australia report estimates from the extension of this specification to allow for union power to have a direct influence on wages when the economy is in the high unemployment regime. This we do by adding a variable for the change in union power to the list of variables in X_t^{range} in 4.1.2. However, having used union density as an explanatory variable in the umin equation, we considered alternative measures of union power. One variable that stands out is the share of manufacturing employment in total employment. As Figure 1 shows, this variable is corelated with union density for both the US and Australia.

Figure 1 Trade union power and employment in manufacturing US and Australia, 1965:1 to 2017:4



Columns 1 and 2 in Table 1 show that for the US the estimated coefficient on the percentage change in the manufacturing employment share is of the right sign in the high unemployment regime and marginally significant, with a p-value of 0.08. For Australia the coefficient has the right sign but is insignificant. Notwithstanding the insignificance of the estimated coefficient for Australia, we prefer the specification that includes the percentage change in the manufacturing employment share because the estimated coefficient on union density in the umin equation is more precisely estimated, with a p-value of 0.00 compared with 0.29 when the manufacturing employment share is not included. The greater precision of the estimated coefficients is reflected in the greater precision of the implied estimates of umin over the estimation period. The average size of the 95% confidence interval on umin is reduced from 1.47 percentage points to 0.75 percentage points, as reported in the bottom row of columns 6 and 8 in Table 1. Furthermore, the residuals without the percentage change in the manufacturing employment share have a mild negative trend, suggesting specification error. This trend is removed when the manufacturing employment share is included. So, in what follows for both economies we focus on the estimated specification with the percentage change in the manufacturing employment share included, that is the estimates in columns 1, 2, 5 and 6 of Table 1.

4.2.2 The patterns of umin

For both economies, the supply factors have a significant influence on umin. As reported in Table 1, the estimates of the coefficients on the unemployment benefit replacement ratio and union density are significant with p-values of 0.000 and with the correct signs. In addition, for the US the demographic variables are significant. The average size of the 95% confidence interval on umin for both economies is small. It will be seen below that the implied estimates of umin are well determined for both economies compared with estimates of the natural rate model.

The patterns of umin along with the 95% confidence intervals for both economies are shown in Figures 2 and 3. For the US, little time has been spent in the low unemployment regime; indeed only 12 quarters out of the 231 quarters in the estimation period. That is a mere 5% of the time. Australia, on the other hand, spent 31% of the estimation period in the low-unemployment regime. That was mainly in the earlier part of the estimation period.

Figure 2 umin with confidence limits, US, 1966:2 to 2017:4

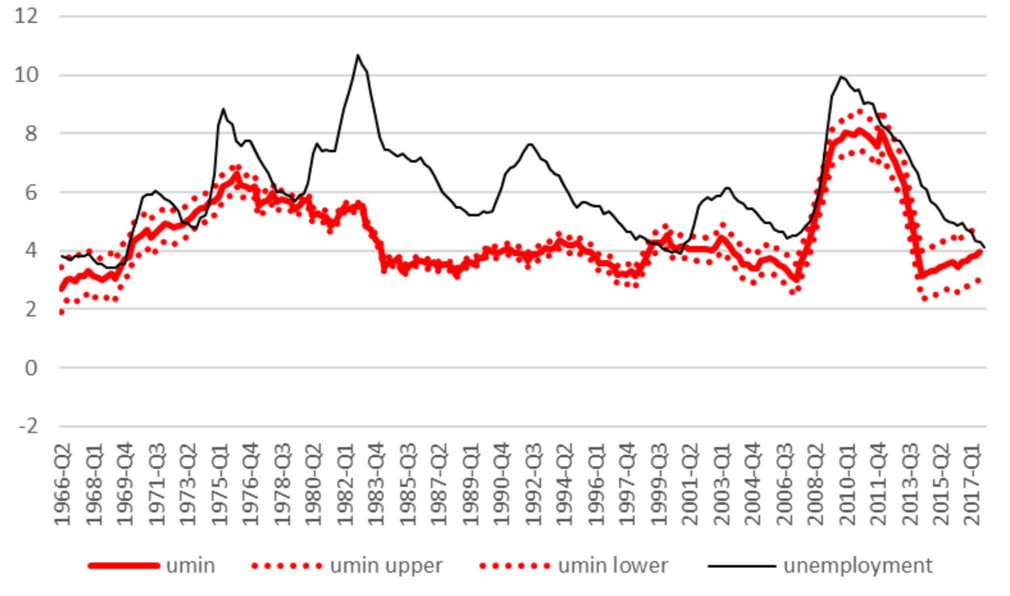
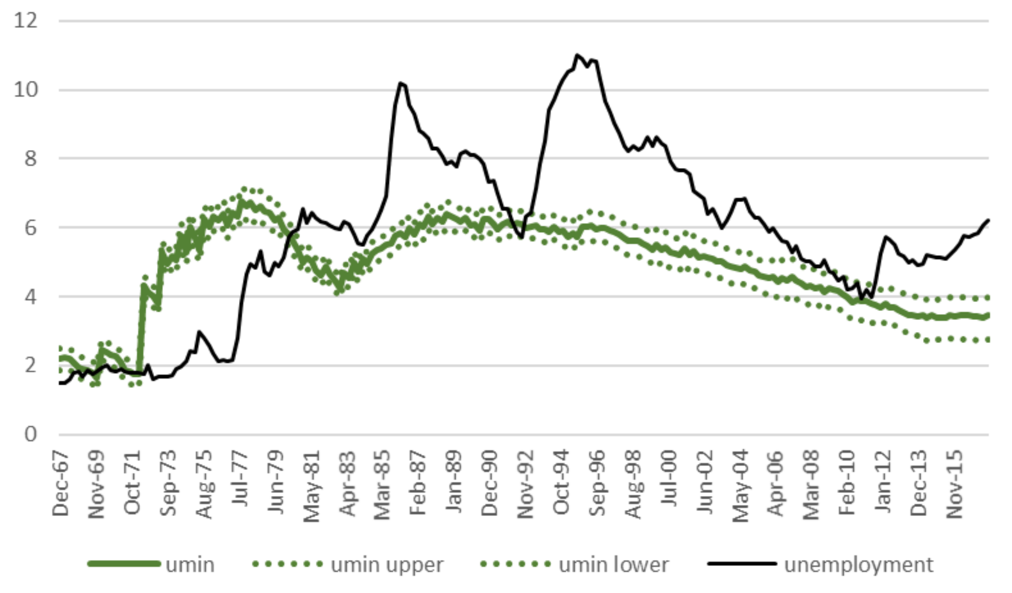


Figure 3 umin with confidence limits, Australia, 1967:4 to 2017:3



Bearing in mind that the patterns of umin and umax are determined by the patterns of the supply factors, there is an interesting similarity between Australia and the US. For both economies, the supply factors pushed up umin and umax to a maximum in the late 1970s and then tended to push umin down over the next 40 years to the end of the sample period. At the end of the data period, umin is at similar levels to those of the 1960s; at 4.1% and 4.0% for the US and Australia respectively, that is for 2017:4 and 2017:3. We suggest that the movement of supply factors played a major part in the surge in inflation in the late 1960s-early 1970s. Policymakers, being either unaware of this influence or aware but unable to respond effectively, struggled to keep up with the worsening possibilities for unemployment. Thereby this lack of knowledge about umin caused the surge in inflation. Subsequently, the downward stickiness of inflation when unemployment was within the high unemployment regime impaired the appreciation by policy makers of the improvement in possibilities for reducing unemployment due to the change in the supply factors. [9]

4.2.3 The short-run Phillips curves (SRPCs)

The SRPC is the relation between inflation and unemployment holding expected inflation constant and assuming no influence of changes in unemployment and inflation. Thus, the SRPC highlights the influence of the unemployment level effects. For the 2-regime model the SRPC is derived from (4.1.1) and (4.1.2) with $u_{t-1} = u_{t-2}$, $\Delta_4 \ln ULC_{t-1} = \Delta_4 \ln P_{t-2}$ and $\Delta_4 \ln ULC_{t-1} = \Delta_4 \ln ULC_{t-4}$. This gives the SRPC as:

$$\begin{aligned} \Delta_4 \ln ULC &= \Delta_4 \ln P^e + a_2^P (u - u^{min}) \text{ for } 0 \le u \le u^{min} \\ \Delta_4 \ln ULC &= \Delta_4 \ln P^e + a_2^R (u - u^{min}) \text{ for } u > u^{min} \end{aligned} \qquad (4.2.1)$$

The SRPCs for Australia and the US are plotted in Figure 4, assuming the expected rate of inflation=2.5% and umin=4%.

The pronounced kink on the SRPCs at unemployment equal to umin for both economies, sharper for the US, see Figure 4, shows the substantially larger estimates of the unemployment level effect in the low unemployment regime compared with the high unemployment regime; that is–4.31 compared with –0.18 for the US and –1.07 compared with –0.09 for Australia. The sharpness of the kink is partly determined by the high estimate of the transition parameter. Indeed, the low estimate for the transition parameter in column 7 for Australia when the % change in the manufacturing employment share is excluded would give a much smoother kink reflecting the gradual transition between the regimes as one goes from low unemployment regime to high unemployment regime.[10]

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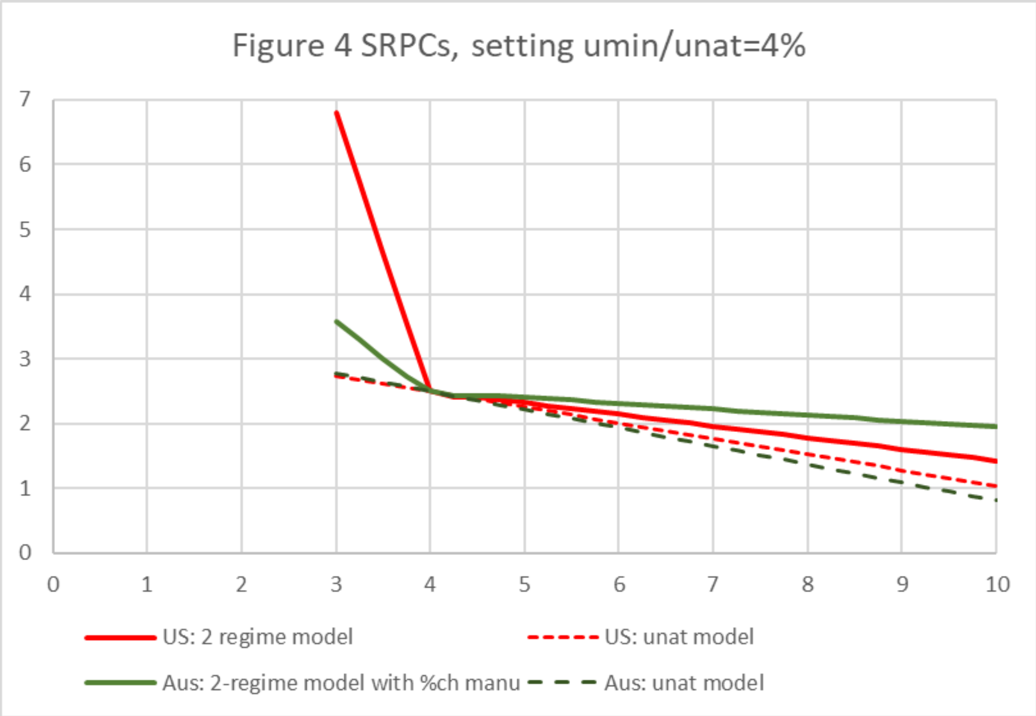
[9] The large temporary increase in the duration of unemployment benefits during the great recession, from 26 to 99 weeks, see Marinescu (2017), shows up in a large temporary increase in umin, see Figure 2. Note that this large increase in umin was less than the large increase in actual unemployment and so was not a constraining factor on unemployment.

[10] The estimated value of the transition parameter (γ=12.99) for the US implies that the regime dummy goes from 0.8 to 0.2 over an interval of 0.2% points of unemployment. For Australia, γ=5.82 implies that the regime



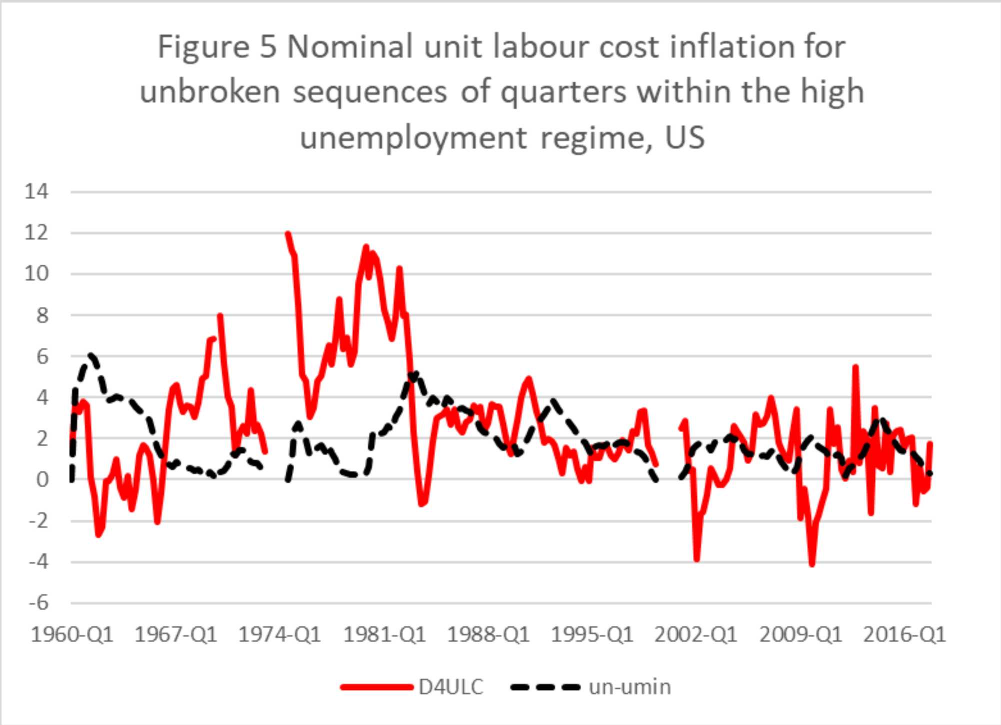
The greater sensitivity of inflation to unemployment at low compared with high rates is not only reflected in the steeper SRPCs at low unemployment. The speed limit effect is also greater in the low unemployment regime than at high unemployment. Indeed, the speed limit coefficient for both economies is large and highly significant in the low unemployment regime and relatively small and indeed, for the US, insignificant in the high unemployment regime.

4.2.4 Deceleration

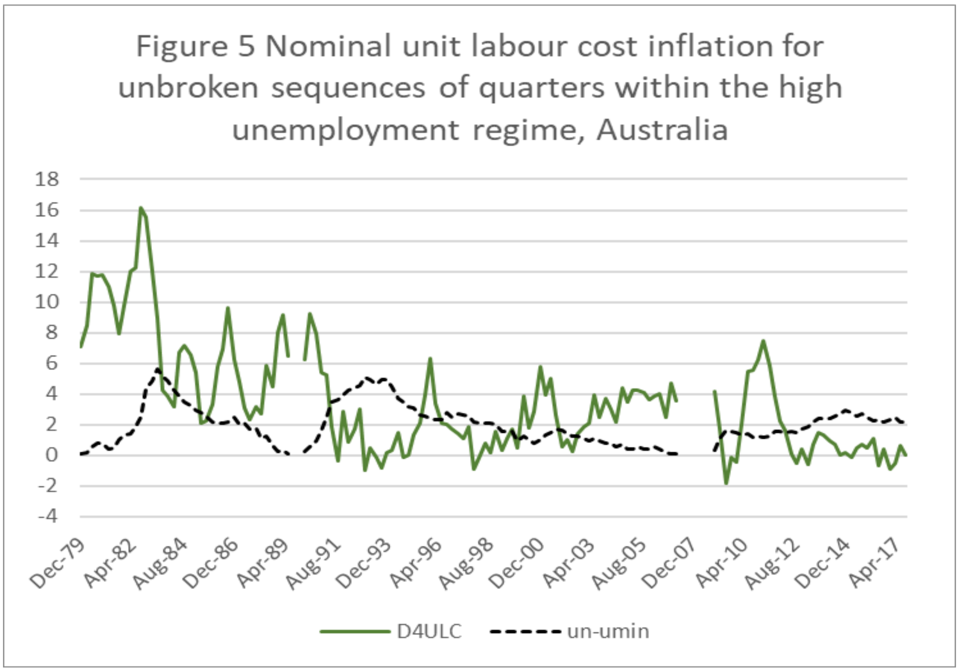
The very weak deflation effect of high unemployment, indeed insignificant for Australia, suggests that the forces of deceleration at high unemployment rates would be small. Supporting this inference, there is no evidence to suggest that in either the US or the Australian economies was the rate of unit labour cost deflation decreasing as time spent in the regime of high rates of unemployment increased. Figure 5 shows the rate of nominal unit labour cost inflation for the US during the four sequences of quarters when the US economy was in the high-unemployment regime. For none of these sequences does unit labour cost inflation tend to decrease as time spent in the high-unemployment regime increases. The

dummy goes from 0.8 to 0.2 over an interval of 0.5% points of unemployment. For Australia without the manufacturing variable the estimated transition parameter is γ=0.83, which increases this measure of the size of transition to 3.4% points of unemployment, implying quite a smoother transition.

deceleration logic does not show up even when the time spent in the high-unemployment regime is considerable: that is the 100 quarters from 1974:3 to 1999:2.



For Australia, the unbroken sequences within the high unemployment regime show no evidence of deceleration, see Figure 6. This supports the inference that the insignificant estimate of the unemployment level effect in the high-unemployment regime implies no deceleration of inflation while in that regime.

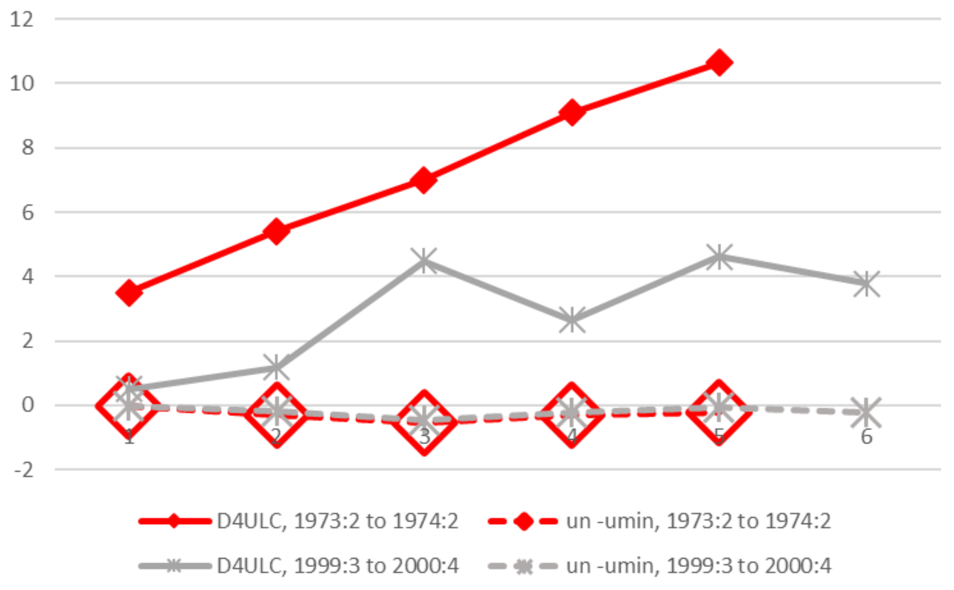


4.2.5 Acceleration

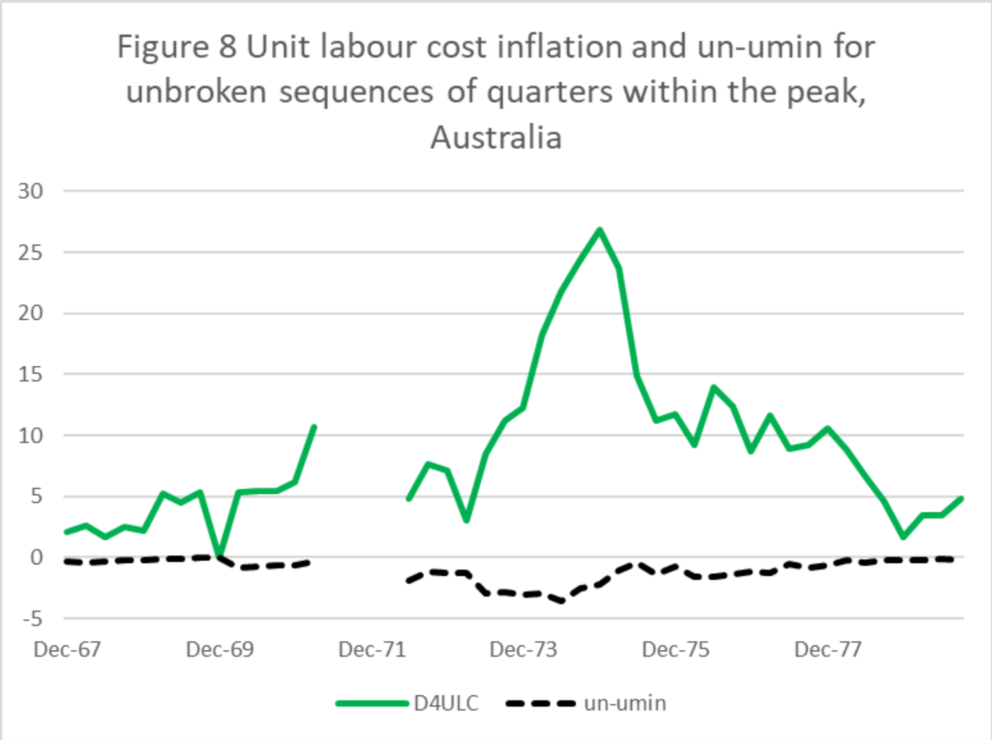
For the five consecutive quarters when the US economy was in the low unemployment regime from 1973:2 to 1974:2 nominal ULC inflation was increasing, in line with the acceleration hypothesis, see Figure 7. The increase in ULC inflation was quite substantial, being about 7% points of inflation over 5 quarters. Note also that during this sequence, actual unemployment was not far below umin. So, a small amount of excess demand caused substantial acceleration of wage inflation.

However, for the six consecutive quarters 1999: 3 to 2000:4, during which the gap between actual unemployment and umin was similar in size to the earlier period, ULC inflation shows a rather muted increase suggesting a lack of acceleration dynamics.

Figure 7 Nominal unit labour cost inflation and un-umin for unbroken sequences of quarters within the low unemployment regime, US



For Australia, there seems to be evidence of acceleration in the early period of an unbroken sequence of quarters within the low unemployment regime, that is for the 14 quarters 1967:4 to 1971:3, see Figure 8. However, the later sequence of 30 quarters within the low unemployment regime, 1972:2 to 1979:3, shows a more complicated history. The suggestion of acceleration in the first part of this sequence ends abruptly in 1974:4 and is followed by a reduction in wage inflation. This abrupt cessation of acceleration may reflect the substantial reduction in the size of the gap between unemployment and inflation immediately following 1974:2. From 1974:2 to 1975:2 the un-umin gap fell from -3.6 to -0.41 percentage points.



Following 1975:2, unit labour cost inflation decreases even though the un-umin gap remained negative for the remaining five years of this sequence of quarters in the low unemployment regime. This was a period of substantial interaction between the Arbitration Commission, a centralised wage-fixing body, and trade unions, aimed at controlling the rate of wage inflation, including notably the introduction of wage indexation in 1975. Our exploration using the two-regime model in Lye and McDonald (2006) finds weak statistical support for the effectiveness of this interaction in controlling inflation.

In summary, for both economies the evidence for low unemployment relative to umin causing accelerating inflation is mixed; being strong before the mid-1970s and muted after. Indeed for Australia, our estimates suggests that the period of low unemployment from 1972:2 to 1979:3 was not one of excess demand but of a battle between unions and employers with the latter aiming to keep wages down rather than increase wages to cope with labour shortages.

4.2.6 The natural rate model

The natural rate model assumes one regime with a single value for the unemployment-level effect. Estimates assuming just one regime are reported in Table 2. For both the US and Australia, these estimates show how the one-regime model fails to pick up the high sensitivity of inflation to unemployment at low rates of unemployment. Thus, the unemployment level effects in the unat model are -0.24 and -0.28 for US and Australia respectively, compared with, see Table 1, -4.31 and -1.07 for the low unemployment regimes. The influence of supply factors on unat is somewhat similar to their influence on umin. However, the average size of the 95% confidence interval on unat is much wider than on umin, being 8.41 and 6.13 percentage points of unemployment compared with 0.87 and 0.75 for umin.[11]

Table 2 Estimates of the natural rate and NAIRU models for US and Australia

Dependent variable: % change in ULC minus % change in CPI

green (light green)=sig diff from zero at 95% (90%) level

		US				Australia							
		US, 1966:2 to 2017:4				1967:4 to 2017:4				1967:4 to 2017:3			
		linear SRPC				linear SRPC				convex SRPC			
		coef	p value	coef	p value	coef	p value	coef	p value	coef	p value	coef	p value
unat equation	constant	-22.11	0.01	-22.90	0.00	0.46	0.87	-0.68	0.80	-2.96	0.18	-2.14	0.14
	un ben	0.32	0.02	0.33	0.01	0.22	0.03	0.17	0.09	0.35	0.01	0.26	0.00
	union density	3.70	0.02	3.83	0.01	0.05	0.16	0.06	0.09	0.02	0.61	0.02	0.45
	female/non-white	0.84	0.20	0.65	0.26								
	teen	0.52	0.08	0.59	0.04								
	sigma	1.14	0.00	1.14	0.00	1.46	0.00	1.46	0.00	1.42	0.00	1.42	0.00
SRPC	exp inf	0.18	0.07	0.16	0.09	0.12	0.01	0.12	0.02	0.12	0.01	0.12	0.01
	un level	-0.24	0.00	-0.26	0.00	-0.28	0.00	-0.28	0.00	-1.48	0.01	-1.89	0.00
	speed limit	-0.16	0.62	-0.24	0.43	-1.15	0.00	-1.22	0.00	-6.21	0.00	-6.42	0.00
	ldv	0.56	0.00	0.57	0.00	0.72	0.00	0.72	0.00	0.70	0.00	0.70	0.00
	qtly diffs	0.38	0.00	0.38	0.00	0.41	0.00	0.41	0.00	0.40	0.00	0.40	0.00
	% ch manu employment	0.07	0.43			0.21	0.17			0.16	0.33		
test statistics	Log likelihood		-320.91		-321.22		-359.23		-360.18		-353.76		-354.24
	Akaike info criterion		3.22		3.21		3.69		3.69		3.64		3.63
	Number of coeficients		12		11		10		9		10		9
average size of 95% CI on unat			8.41		7.58		6.13		2.70		8.11		1.76

Expected inflation as measured by surveys of opinion, has very little influence in either the two-regime model or the natural rate model. The coefficient on expected inflation is small, being 0.18 for the US and even smaller, 0.12, for Australia. Given our specification this implies lagged inflation dominates the expectations story.

For Australia we also report estimates with a convex SRPC, specified as

$$X_t = a_1\left(\Delta_4 \ln P_t^* - \Delta_4 \ln P_{t-1}\right) + a_2\left(\frac{u_t - u_t^{min}}{u_t}\right) + a_3\left(\frac{u_{t-1} - u_{t-2}}{u_t}\right) \qquad (4.2.1)$$
$$+ a_4\left(\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln P_{t-2}\right) + a_5\left(\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln ULC_{t-4}\right) + v_t$$

[11] Including the % change in the manufacturing employment share reduces the precision of the unat estimates by a large amount, in contrast to the effect on umin in the two-regime model.

This is a prominent form in Australia, see especially Gruen, Pagan and Thompson (1999), and follows the original specification of Phillips (1958). As in Gruen, Pagan and Thompson (1999), the speed limit is also specified in convex form. From our theoretical perspective, a convex SRPC is a way of capturing the deflation puzzle although neither Phillips (1958) nor Gruen, Pagan and Thompson (1999) offer a microeconomic foundation for this form.

The estimates with a convex SRPC show less-precise estimates of NAIRU compared with the estimates of umin. The average size of the 95% confidence interval on NAIRU is 8.11% points of unemployment compared with 0.75 percentage points for umin. However, the NAIRU is more precisely estimated when the % change in the manufacturing employment share is excluded, being reduced to 1.76 percentage points of unemployment.

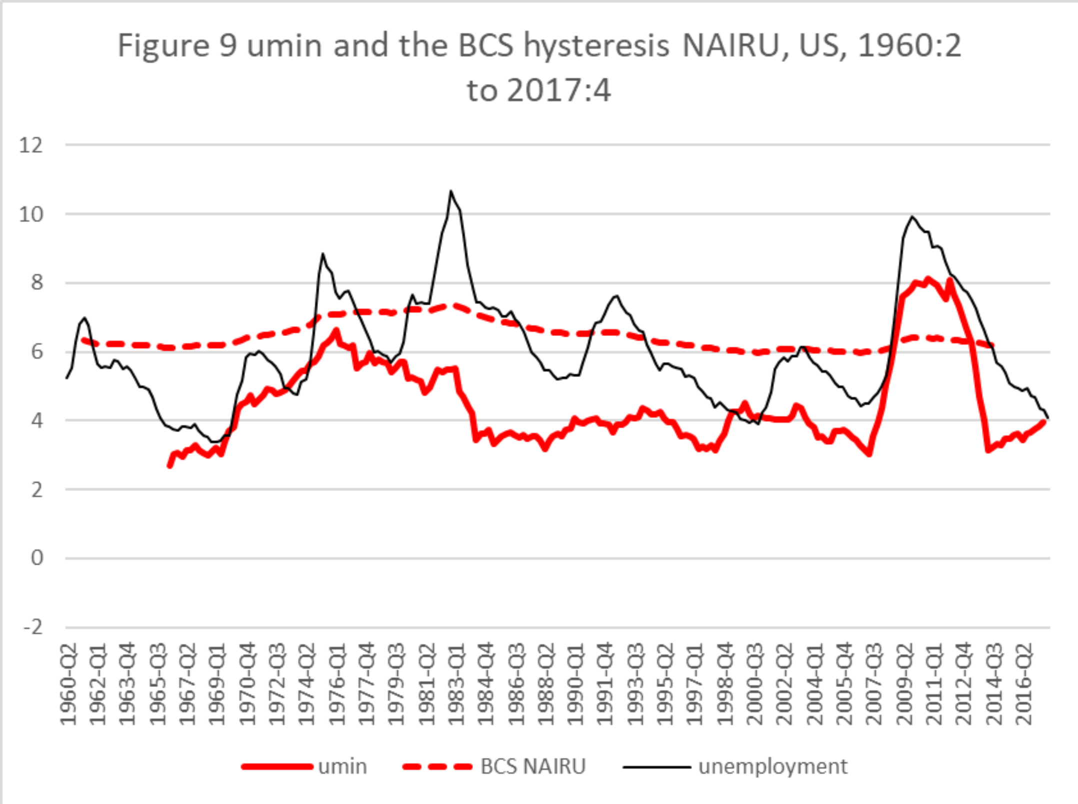
4.2.7 BCS hysteresis

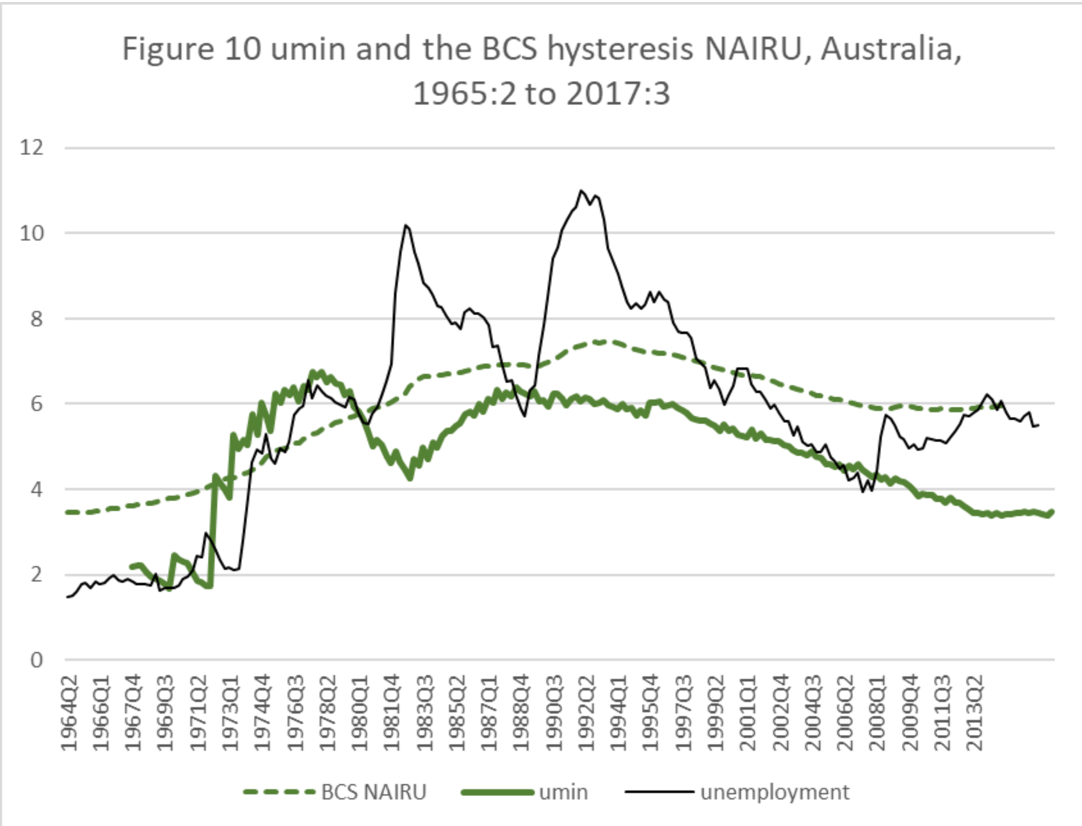
Figures 9 and 10 compare the umin estimates with the estimates of the BCS hysteresis NAIRU for the US and Australia.[12] The degree of precision of the BCS NAIRUs is lower than for umin: the average size of the 95% confidence interval for the US is 1.65 compared with 0.87 and 1.06 compared with 0.75 for Australia.

The striking contrast between umin and the BCS NAIRU is the relative smoothness of the latter. This reflects the strong influence on the former of the labour supply factors. Using the knowledge created by the umin estimates, one can discern from the pattern of the BCS NAIRU a muted and somewhat lagged influence of labour supply factors. Thus, for the US, the substantial increase in umin up to 1976, reflecting the labour supply factors, is echoed in an accompanying gradual and slight increase in the BCS NAIRU. After 1976, when the labour supply factors were pushing umin down, the BCS NAIRU continued to increase, peaking in 1983. Given the downward influence of supply-side effects suggested by the direction of umin, the continuing increase in the BCS NAIRU presumably reflected the increase in actual unemployment during this period.

For Australia, one can also discern a muted and lagged response of the BCS NAIRU to umin. The mute is strong enough for the BCS NAIRU to completely miss the supply-side dip in potential activity in the period 1977:4 to 1988:1.

[12] The sample period for BCS is 1961:2 to 2014:4.





Generally, for the US, the BCS NAIRU is well above umin, with the exception of the temporary bump during the Great Recession. This demonstrates the point made above that the hysteresis model as specified does not define a lower limit to the unemployment rate consistent with hysteresis and so gives little guidance to policymakers on the potential level of activity.

BCS (2015, p. 20) conclude from their hysteresis NAIRU estimates that the unemployment level effect has become smaller over time, “with nearly all of the decline taking place from the mid-1970s”. For Australia, our umin estimates reveal a similar pattern, but goes further in providing an explanation, which is that before the mid-1970s the Australian economy was mainly in the low unemployment regime, indeed for 39 of the 42 quarters from 1965:3 to 10975:4. For 1976:1 to 2017:3 the Australian economy spent a mere 33 quarters in the low unemployment regime, out of a total of 167 quarters. Thus, the pattern of unemployment level effects found by BCS is explained by the restraining influence of loss aversion on wage deflation at high rates of unemployment.[13]

As noted above, the US spent very little time in the low unemployment regime, indeed only 12 quarters in total. Half of these occurred in the 64 quarters up to 1975:4 and half in the 169 quarters after 1975:4. So the, albeit somewhat subdued, movement from low unemployment regime to low unemployment regime is consistent with the restraining influence of loss aversion on wage deflation at high rates of unemployment.

5 Conclusion

The estimates of the relationship between real unit labour cost inflation and unemployment reported in this paper suggest that loss aversion by workers with respect to wages offers a resolution to the deflation puzzle. The loss aversion approach implies a resistance to reductions in the rate of money wage inflation. This resistance implies a very flat short run Phillips curve (SRPC) at rates of unemployment above a supply-side determined level that we call umin. Our estimates for the US and Australia find this. For the US, the short run Phillips curve has a negative slope for unemployment rates above umin, but this slope is very small. For Australia, the slope of the short run Phillips curve for unemployment rates greater than umin is flat, and so at high unemployment there is no statistically significant force to cause inflation to decelerate. Instead, high unemployment is consistent with ongoing low inflation.

[13] As reported by BCS (2015, p. 22, Laurence Ball argued that to use of the Kalman filter to infer the unemployment-level effect might confuse changes in the unemployment level effect with changes in the NAIRU. In our approach, umin, being determined by labour supply factors, is not subject to this criticism.

In fact, for both economies during the sequences of quarters of low unemployment, we find no evidence of deceleration of unit labour costs. Thus, the slight negative slope of the SRPC for the US was not enough to lead to deceleration. This slight negative slope implies that a reduction of one percentage point in unemployment would increase the rate of inflation by 0.18 percentage points. Such an increase would be hardly noticeable and so provides a very weak statistical counter-argument to our conclusion that loss aversion can explain the deflation puzzle. Furthermore, the dynamics of wage inflation implied by the loss aversion approach to wage determination suggests a muted deceleration effect. With loss aversion the supply price of labour is determined by the reference wage and so the downward dynamic depends upon the downward adjustment of reference wages. If the short run Phillips curve has some negative slope then any tendency to a deceleration of wages would be held up by sluggishness in the rate of reference wage inflation. Barring any dramatic circumstances that would cause workers to take a good look at their conditions, such as a threat of plant closure, it seems reasonable to expect that downward adjustment of reference levels is sluggish because the literature suggests that reference wages are influenced by past actual wages, other workers actual wages and the firm's capacity to pay.

Compare the dynamics implied by reference wage determination with the dynamics of the neoclassical approach. In the neoclassical approach, workers are concerned with their supply price of labour and that price is determined by their preferences, "set in concrete" so to speak. Workers will be prepared to work at wages which exceed their supply price and so will be prepared to participate in a process that, in response to a plentiful supply of labour, chases down wages. Workers by assumption are not influenced by their past wages, their idea of the wages of others or by the firm's capacity to pay. The lack of deceleration in periods of high unemployment casts doubt on the neo-classical approach.

Turning to the other dynamic, acceleration, the steepness of the SRPC at low rates of unemployment, at rates less than umin, is a force for acceleration. However, we find that past experience of accelerationist tendencies in wages at rates of unemployment less than umin, that is low-unemployment periods, reveal mixed tendencies. For both the US and Australia there were pronounced tendencies for nominal unit labour cost inflation to be increasing in low-unemployment periods before the mid-1970s, consistent with the acceleration hypothesis. However, this tendency does not show up for the low-unemployment periods after the mid-1970s, which are 1972:2 to 1979:3 for Australia and 1993:3 to 2000:4 for the US.

The tendency towards acceleration is usually inferred from positing a sustained excess demand for labour, under which both employers and employees see advantage in increasing wages. However, if unions are setting the inflationary pace when unemployment rates are less than umin then employers will not have a direct benefit from increasing wages; it is a battle with the unions. Thus, rates of unemployment below umin may not be as accelerationist as suggested by the implications of sustained excess demand. This consideration is particularly relevant for the Australian economy in its low-unemployment period in the 1970s.

In addition to the benefit of resolving the wage deflation puzzle, allowing for loss aversion in our specification of the wage inflation-unemployment process results in an improved understanding of the role of labour supply factors. The loss aversion approach implies that umin would be influenced by labour supply factors. We consider the unemployment benefit replacement ratio and union density, a proxy for worker power. Our estimates of these influences are well-determined.[14] The average size of the 95% confidence interval on umin over our estimation periods is 0.87 and 0.75 for the US and Australia respectively compared with 1.65 and 1.06 for the BCS NAIRU, and 8.41 and 6.13 for the natural rate model. Furthermore, the influence of labour supply factors on umin are substantial. For example, over the sample period, variation in the labour supply factors causes a range of values of umin of 5.4 percentage points for the US and 5.1 percentage points for Australia. Finally, at the current time (end of 2017) umin, the potential rate of unemployment, is estimated for the US and Australia at about 4% and 3.3% respectively.

[14] Our estimates show that for the US, umin is also influenced by demographic factors, that is the proportions of teen, female and black in the labour force.

Appendix: A simple model of the range of equilibria combining bargaining and efficiency wages

To capture bargaining specify the union's objective as the difference between utility from working and the utility from the reservation wage, that is:

$$\Xi^{i} = U^{i} - U^{RES} = W^{\beta_1}\left(W / W^{REF}\right)^{\beta_2^{i}} - \left(W^{RES}\right)^{\beta_1} \text{ for i=\{+, –\}} \qquad \text{(A1)}$$

where these two utilities are determined by:

$$\left\{\begin{array}{l} U^{+} = W^{\beta_1}\left(W / W^{REF}\right)^{\beta_2^{+}} \text{ for } W \geq W^{REF} \\ U^{-} = W^{\beta_1}\left(W / W^{REF}\right)^{\beta_2^{-}} \text{ for } W<W^{REF} \\ U^{RES} = \left(W^{RES}\right)^{\beta_1} \end{array}\right\} \text{with } 0 < \beta_1 < 1 \text{ and } 0 < \beta_2^{+} < \beta_2^{-} < 1 \qquad \text{(A2)}$$

where W= money wage, W^{REF}= reference money wage and W^{RES}= reservation money wage. Loss aversion influences the utility from working. $0 < \beta_2^{+} < \beta_2^{-} < 1$ implies that the sensitivity of utility to wages below the reference wage is greater than the sensitivity of utility to wages above the reference wage. There is a kink in the utility function at $W = W^{REF}$. Note that for simplicity, following Layard, Nickell and Jackman (1991), the union cares only about the wage.

To capture efficiency wages, the production function is written:

$$Y = AeL^{\alpha} \qquad \text{(A3)}$$

where Y= output, A= base level efficiency, L= employment and e= the impact of wage outcomes on the efficiency of labour, which is specified to follow:

$$e = \left(\frac{W}{W^{REF}}\right)^{\theta^{i}} - K \text{ for i=\{+, –\} as } W \geq W^{REF} \text{ or } W < W^{REF} \text{ with } 0<\theta^{+}<\theta^{-}<1 \text{ and K<1}$$

(3.4)

Due to loss aversion, the efficiency function is kinked at $W=W^{REF}$.

The profits of the firm, Π, is:

$$\Pi = PY - WL = C\bar{P}\left(A\left[\left(\frac{W}{W^{REF}} \right)^{\theta^i} - K \right] \right)^{1-h} L^{\alpha(1-h)} - WL \tag{A5}$$

where the demand function for the firm's output is

$$P = C\bar{P}Y^{-h} \tag{A6}$$

where P=firm's price and $\bar{P}$ =the aggregate price level.

The wage is chosen to maximise the Nash maximand

$$\Omega = \Xi^{\phi}\Pi^{1-\phi}$$

$$= \left[W^{\beta_1}\left(W / W^{REF} \right)^{\beta_2^i} - \left(W^{RES} \right)^{\beta_1} \right]^{\phi} \left[C\bar{P}\left(A\left[\left(\frac{W}{W^{REF}} \right)^{\theta^i} - K \right] \right)^{1-h} L^{\alpha(1-h)} - WL \right]^{1-\phi} \tag{A7}$$

subject to the "right to manage" constraint

$$W = \alpha(1-h)C\bar{P}\left(A\left[\left(\frac{W}{W^{REF}} \right)^{\theta^i} - K \right] \right)^{1-h} L^{\alpha(1-h)-1} \tag{A8}$$

This choice constrains the equilibrium wage to lie between limits determined by two values, $\{k^+, k^-\}$ of the mark-up of the wage on the reservation wage, that is:

$$\frac{W^i}{W^{RES}} = \left(\frac{1}{1 - \frac{\phi}{1-\phi} \frac{\left(\beta_1 + \beta_2^i\right)\frac{1}{\alpha(1-h)} - 1}{1 - \frac{\theta^i}{\alpha(1-K)}}} \right)^{\frac{1}{\beta_1}} = k^i \text{ for i=\{+, –\}} \tag{A9}$$

Note that through $0 < \beta_2^+ < \beta_2^- < 1$ and $0 < \theta^+ < \theta^- < 1$, loss aversion implies $k^- > k^+$.

In general equilibrium, macroeconomic closure implies a range of equilibria and rates of unemployment. To derive the range of equilibria, specify the reservation wage as a linear function of alternative wage, W^A, and the unemployment benefit, B, weighted by the probability of getting employment, r, as follows:

$$W^{RES} = \rho W^{A} + (1-\rho)B \tag{A10}$$

In general equilibrium, W^A=W. Assuming that the unemployment benefit is set as a proportion, b, of the wage, as B=bW, then $\frac{W}{W^{RES}} = \frac{1}{\rho(1-b)+b}$ and so $W^i = k^i W^{RES}$ implies

$$\rho^i = \frac{\frac{1}{k^i} - b}{1-b} \leq 1 \text{ as } k^i \geq 1 \text{ for } i = \{+,-\} \text{ and } k^+ < k^- \rightarrow \rho^+ > \rho^- \tag{A11}$$

Using $u = 1 - \frac{L}{L^S}$, where L^S = aggregate labour supply, $\rho = 1-u$ and so

$$u^i = 1 - \rho^i = \frac{1 - \frac{1}{k^i}}{1-b} \text{ for } i = \{+,-\} \rightarrow u^i \geq 0 \text{ as } k^i \geq 1 \tag{A12}$$

Thus, loss aversion implies a range of equilibrium rates of unemployment given by $k^+ < k^- \rightarrow u^{min} = u^+ \leq u \leq u^- = u^{max}$.

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