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The Optimality of a Zero Inflation Rate with Menu Costs: Australia

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Abstract

This paper juxtaposes the policy trend towards a zero inflation rate against the theoretical standard of optimal deflation at the real interest rate. It extends an example monetary economy to include a simple form of nominal adjustment costs and calibrates the model with recent evidence on Australian money demand. There is a critical value that the calibrated parameter for menu costs must exceed in order for a zero inflation rate to be optimal. An inflation rate of –2 per cent to 0 per cent is found to be optimal. The quantitative results, of whether inflation-adjustment costs imply a zero inflation rate policy for Australia, are tempered by the abstraction of the model and its sensitivity to parameters. Qualitatively, the paper shows the effects of changes in the adjustment cost function and in the structural parameters.

1. Introduction: Menu Costs and Suboptimality of the Friedman Deflation

A near-zero inflation rate increasingly has become a focus of policy and research (Leigh-Pemberton 1992; Ireland 1993; Dowd 1994; Stemp 1996). Estimates of the welfare cost of inflation have been calibrated to show the gains from achieving a zero inflation rate (Carlstrom & Gavin 1992; Lucas 1994; Braun 1994a). Yet the accepted first-best optimum of monetary theory remains Friedman's (1969) deflation at the rate of time preference (deflation at the real rate of interest).[1]

Howitt (1987) suggests that 'menu costs' may make deflation unattractive. The menu cost literature has been strong on theoretical results but criticised for its dearth of empirical support. Levy et al. (1997) help fill this gap by providing new evidence that shows this cost to be significant for a set of supermarkets. Another management/accounting type of literature discusses how inflation requires reevaluation of cash flows, inventory values, and capital replacement in such a way that can distort optimal investment strategies (for example, as in Beaurepaire, Higgins & Mercovich 1974).[2] A zero inflation rate eliminates these adjustment costs that waste resources.

Alternatively, frictions and second-best considerations can alter the optimum. Taub (1989) allows informational externalities to drive the optimum above the Friedman rate. Gillman (1996a) introduces a positive externality from costly-credit use to get a similar result. In a

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Ramsey optimal tax framework, with inflation as one such tax, Braun (1994b) finds a positive inflation rate to be optimal. However, in a similar Ramsey framework, but with positive costs of using a cash alternative, Lucas (1994) finds a nearly trivial departure from the Friedman deflation.

This paper explores the route of menu costs in that they seem to be pervasive empirically, accepted intuitively, and a direct way to consider more fully the costs of government taxation through inflation. And they can imply an optimum with an exactly zero rate of inflation. Bringing these costs into a monetary general equilibrium, the paper starts from the first-best Friedman optimum and introduces an inflation-induced, menu-type, adjustment cost that reduces profits. The profit reduction is related to the non-monetary, profit maximisation, economies of Barro (1972), Mankiw (1985), and Parkin (1986), or more recently Fluet and Phaneuf (1997). Using a representative agent approach, the paper is able to show how a zero inflation rate can be optimal. This depends critically on the adjustment cost function. Here the paper assumes alternative forms including one similar to Mussa (1977) and Fender (1990). It extends such previous work by calibrating an adjustment cost parameter (based on Levy et al. 1997) and by using this to quantify the optimal rate of inflation.

1.1 A Baseline Case: Quantitative and Qualitative Results

Another advantage of monetary optimisation is that it shows, through the margins of substitution and an explicit welfare cost function, how the Friedman deflation is gradually made more suboptimal as the level of the inflation-adjustment cost increases. The explicit welfare cost function also allows a sensitivity analysis with respect to the model's structural parameters, the adjustment cost parameter, and the inflation-adjustment cost function. This gives qualitative results on what conditions make a zero inflation rate optimal because of inflation-adjustment costs.

The results are suggestive of policy directives, but remain preliminary. The paper's choice of model structure, parameter calibrations, and other assumptions gives a baseline case for whether menu costs cause a zero inflation rate to be optimal. To comfortably allow a policy recommendation, the results would need to be enhanced through expanded efforts to measure the inflation-adjustment costs and through refinements of the general equilibrium model and its calibration.

The abstraction of the model of the paper does not allow, for example, for an Ireland (1996)-type framing of the rules versus discretion debate, or for analysis of how to target a zero inflation rate (see, for example, Svensson 1997). Rather it gives a qualified representative agent formulation of the possibility in Australia of a zero inflation rate optimum as a result of menu-type costs due to inflation. The analysis can be extended to include capital, more general utility specifications, Ramsey-type taxation, relative price variability, and shocks to money supply, goods technology, and finance sector technology. It can be applied to other countries.

1.2 Costly Credit and a Zero Inflation Optimum

The paper uses an economy in the class with costly-credit technologies that avoid a bias in the results. A standard cash-in-advance economy has a relatively interest-inelastic money demand and its corollary of a less variable velocity, as in for example Cooley and Hansen (1995).[3] This causes an exaggerated effect of the inflation-adjustment cost factor, gives a lower critical value for the cost of adjustment, and makes it easier to accept the hypothesis that the optimum occurs at a zero inflation rate. The agent in the standard model finds a zero inflation rate optimal at a lower level of the adjustment cost factor.

This paper uses my 1993 economy as extended with inflation-adjustment costs. This model is within a group with costly exchange means that help make velocity realistically variable.[4] Here, velocity endogenously depends on the shadow cost of money versus the shadow cost of the exchange credit alternative. Gillman and Otto (1997) show that this explanation leads to a cointegrated Australian demand for money with error correction. And this velocity feature eliminates the bias towards finding a zero inflation rate as optimal, which is demonstrated by examining a special case of the economy that represents the standard model.

2. Economy with Costly Inflation Adjustment: Reducing the Real Wage

Expressing profit as revenue minus costs, $R - C$, and letting the inflation-adjustment cost raise total costs by the factor $D(\pi)$, profit is given by $R - [1 + D(\pi)]C$.[5] With P the price of the good c, with linear production that depends only on labour n, and with w the constant marginal product of labour, the production function is $c = wn$. The revenues R are given by Pc and, with W the nominal wage, the costs are given by the nominal wages Wn. Profit maximisation in competitive markets implies that the adjustment cost $D(\pi)$ functions as a tax (with proceeds destroyed) that reduces the real wage w to $w/[1 + D(\pi)]$. The resource constraint becomes:

$$c = wn/[1 + D(\pi)] \tag{1}$$

Within the monetary economy, it enables an analysis of inflation rate optimality.

2.1 Choosing Cash or Credit to Purchase Goods at Stores

Goods differ across a store continuum that is indexed by s which takes on values from 0 to 1. Each store s sells a different colour of the same good $c(s)$ and the agent likes the different colours.[6] The agent uses either cash or credit at each store. The price of the good that is bought with cash at any store equals only the goods price P, since the production technology is the same for all goods. There remains the cost of using cash as the exchange medium, which is the interest foregone by carrying around cash. This is a cost borne implicitly by the agent when combining both exchange and goods in order to yield consumption of the goods. This exchange cost equals the product Pi, where i is the nominal interest rate. The total *shadow* cost of consuming the cash good is $P(1 + i)$, comprising the goods production cost plus the exchange cost.

The production cost of a good bought with credit is the same P at any store. This is also the case in Lucas and Stokey (1983) in which the cash good and credit good each enter as a separate argument in the utility function. There the shadow cost of using credit is zero because credit requires no production resources. Here, the shadow cost of exchange for a credit good is positive. The credit cost, just like the exchange cost of using cash, is not part of the goods market price because the exchange activity is being done by the agent rather than by the store selling the goods.

2.2 The Technology for Credit Production and the Cash Constraint

The agent acts in part like a bank (as Hicks, 1935, suggests) by inputing time into a given credit service technology for each store s, in order to then buy a good on credit at store s. Let $\tau(s)$ denote the average time required per good that is bought on credit at store s. The exchange cost of the good is the value of the time used in credit activity at the store: $Pw\tau(s)$. Just as $P(1 + i)$ is the shadow cost of goods bought with cash, $P[1 + w\tau(s)]$ is the shadow cost of goods bought on credit. Optimally, the agent provides credit services at stores where $w\tau(s) < i$. The agent uses cash at stores where $i \leq w\tau(s)$. In the example economy, $\tau(s)$ is specified to be linear in the store index: $\tau(s) = A(1 - s)$ where A is a positive constant. For example, at the store $s = 1$ the credit cost is lowest (zero) and the agent provides/uses credit there if $i > 0$. The highest cost store at which the agent uses credit services is the one indexed just above the marginal store $\bar{s}$. The marginal store $\bar{s}$ is determined by the equilibrium condition that results from optimisation with respect to $\bar{s}$. This condition weighs the exchange cost of cash against exchange cost of credit use at the marginal store (it is given by $i = w\tau(\bar{s})$).[7]

Given that cash is used at stores indexed from 0 to $\bar{s}$ where credit costs are relatively high, that $M(t)$ denotes the pre-transfer level of cash at time period t, and that $P(t)$ denotes the price of a good at any s store at time t, the cash constraint that gives rise to money demand is:

$$M(t) \geq P(t)\int_0^{\bar{s}} c(s,\, t)ds \qquad (2)$$

The composite cash good can be thought of as $\int_0^{\bar{s}} c(s,\, t)ds$. Next period's money supply $M(t + 1)$ equals this period's money supply $M(t)$ plus an end-of-period lump sum government transfer of cash denoted by $H(t)$:

$$M(t + 1) = M(t) + H(t) \qquad (3)$$

In order to get a closed-form solution, the paper assumes a constant rate of inflation π, defined by $\pi \equiv H(t)/M(t)$, so that $M(t + 1) = (1 + \pi)M(t)$.

2.3 Income Constraint and Equilibrium

At the end of the period the agent sets aside cash for trading next period, $M(t + 1)$, and pays off credit debt, $P(t)\int_{\bar{s}}^1 c(s,\, t)ds$, while receiving a cash transfer $H(t)$, an asset endowment, $P(t)a(t)$, and wages. Nominal wages equal the wage rate as decreased by the inflation-adjustment factor and multiplied by the time spent working: $\{P(t)w(t)/[1 + D(\pi)]\}[1 - x(t) - \int_{\bar{s}}^1 A(1 - s)c(s,\, t)ds]$, where 1 is the Beckerian (1965) time endowment, $x(t)$ is leisure, and the sum $\int_{\bar{s}}^1 A(1 - s)c(s,\, t)ds$ is the total Karni (1974)-type time used up in credit activity. During each period, the agent purchases, consumes, and produces goods, as well as producing credit services and incurring the inflation-adjustment cost.

Consider initially specifying the adjustment cost $D(\pi)$ so that it is symmetrically proportional to the level of inflation or deflation: with the parameter $d \geq 0$, let $D(\pi) = d|\pi|$. Discounting over the infinite horizon, by a market discount factor $q \geq 0$, makes the wealth constraint:

$$\sum_{t=0}^{\infty} \{[P(t)w(t)/(1 + d|\pi|)][1 - x(t) - \int_{\bar{s}}^1 A(1 - s)c(s,\, t)ds] + H(t) + P(t)a(t) - M(t + 1) - P(t)\int_{\bar{s}}^1 c(s,\, t)ds\} \geq 0 \qquad (4)$$

Setting $a(t) = 0$ and substituting in from equations (2) and (3), the time period t net revenue of equation (4) can be rewritten as the social resource constraint $\int_0^1 c(s)ds = [w(t)/(1 + d|\pi|)][1 - x(t) - \int_{\bar{s}}^1 A(1 - s)c(s,\, t)ds]$, corresponding to equation (1).

Let preferences at time period t be given by the log-utility function: $u(t) \equiv \int_0^1 \{\ln[c(s,\, t)] + \alpha \ln[x(t)]\}$, where $\alpha \geq 0$. The representative agent maximises the time-preference discounted utility subject to the cash constraint (2), and subject to the interest-discounted wealth constraint (4). Combining the market clearing equation (3) with the first-order conditions yields the equilibrium $c^*(s,\, t)$, $0 < s \leq \bar{s}$; $c^*(s,\, t)$, $\bar{s} < s \leq 1$; $x^*(t)$; $[M(t)/P(t)]^*$; $\bar{s}^*$; and the marginal utility of real income $[\lambda(t)P(t)]^*$, where $\lambda(t)$ is the multiplier of the cash constraint. The deterministic Fisher (1907) equation of interest rates follows by introducing a bond market as in Lucas and Stokey (1983). Although suppressed here, the paper uses the resulting equilibrium condition in the form of $1/q \equiv (1 + i) = (1 + \pi)(1 + \rho)$, where ρ is the rate of time preference. The equilibrium is as in Gillman (1993) except that the marginal product of labour is everywhere reduced by the inflation-adjustment cost factor.

3. The Effect of Menu Costs on the Equilibrium

Consider first the cash-only economy without the implicit banking sector or the inflation-adjustment cost. This is the special case of $\bar{s} \equiv 1$. The marginal rate of substitution between goods and leisure shows how the inflation-adjustment cost creates pressure towards a zero optimal inflation rate. Denoted $MRS_{c1,\, x}$, this rate equals $(1 + \pi)(1 + \rho)/w$, as in Lucas and Stokey (1983) with leisure added. At $\pi = -\rho/(1 + \rho)$, the rate equals the marginal rate of transformation between goods and time, $1/w$ (from the goods production function), and the first-best Friedman optimum results. With the inflation-adjustment cost, the rate between a cash good and leisure is proportionately affected:

$$MRS_{c1,\, x} = [(1 + \pi)(1 + \rho)(1 + d|\pi|)]/w$$

For inflation rates above zero, the adjustment cost increases the inefficient substitution away from cash goods and towards leisure. For inflation rates below zero, there are opposing effects. As the inflation rate falls below zero, the adjustment cost becomes higher and pressures the agent away from cash. But also, the foregone interest cost of cash becomes lower and pressures the agent towards more cash. With a sufficiently high magnitude of d, the adjustment cost effect dominates and pushes the optimum towards a zero inflation rate.

3.1 Relatively Less Substitution from Credit to Leisure

With the availability of credit, and with $\bar{s} < 1$, the effect of the inflation-adjustment cost is partly diffused; the adjustment cost affects the shadow cost of cash goods proportionately but affects the shadow cost of the credit goods less than proportionately. Denoted $MRS_{c2,x}$, the rate of substitution between a credit good at store s and leisure is:

$$MRS_{c2,x} = [(1 + d|\pi|) + Aw(1 - s)]/w$$

In the first term, the ratio of the goods cost of the credit good relative to the real wage cost of leisure ($1/w$) is factored by $(1 + d|\pi|)$. However, in the second term, the shadow exchange cost of credit and the shadow price of leisure both are factors of the real wage. The inflation-adjustment distortion cancels out and leaves this term as $A(1 - s)$. Because of the first term, increasing or decreasing the inflation rate from a zero level induces substitution from credit goods towards leisure, and a zero inflation rate eliminates this marginal effect. Without this effect in the second term, the overall impact of the inflation-adjustment cost is less than proportional to its level.

In the Lucas and Stokey (1983) economy, the rate between a credit good and leisure is just $1/w$ as there is no cost of credit; the inflation-adjustment cost would affect the credit good in the same proportionate way as it would the cash good. In contrast, with credit use determined by its cost, an increase in the inflation-adjustment cost d induces less overall substitution from goods to leisure since the distortion is not as strong for each credit good as it is for each cash good. Further weakening the overall distortion of a given d, the agent also can substitute from using cash to using credit for the purchase of goods at any s store. This is seen in the other ‘external’ margin that decides the cash–credit ratio amongst the store continuum.

3.2 Additional ‘External’ Margin of the Costly Credit Economy

An added external margin as compared to Lucas and Stokey (1983), the agent solves also for $\bar{s}$ from the condition $i = w\tau(\bar{s})$. The solution is $\bar{s}^* = 1 - \{[\rho + \pi(1 + \rho)](1 + d|\pi|)\}/Aw$, where $i = \rho + \pi(1 + \rho)$. As the inflation rate increases above zero, the adjustment cost reinforces the direct effect of the inflation rate increase in causing a decrease in $\bar{s}^*$ and the use of cash at fewer stores. Reducing the inflation rate to a negative level from zero, the adjustment cost offsets the lower foregone interest cost and induces substitution towards credit use at more stores. Thus there are two qualitative features. First, at both internal and external margins the adjustment cost clashes with the low foregone interest cost of cash when the inflation rate is negative. Second, by making the costly credit option available to the agent, the effect of a given level of d is less since it affects the overall purchase of goods less than proportionately if some credit is used. With credit being used, it takes a higher level of d in order to imply the optimality of a zero inflation rate.

4. The Cost of Inflation with the Adjustment Cost

To sort out the exact effect of stationary inflation and its adjustment cost on utility, a function is derived that gives the Bailey (1956)-type welfare cost of inflation for different levels of the adjustment cost.[8] This welfare cost is defined as the amount of real assets, denoted here by a, that the agent must be compensated with in order to be indifferent to a rate of inflation above the optimal rate. With welfare costs defined as being equal to zero at the Friedman rate of deflation, the function can take on negative values as the inflation rate rises from the negative rate of time preference up towards the optimum. Where the welfare cost function is lowest, at a zero or negative value, the corresponding level of inflation is the optimal inflation rate.[9]

Let $v(\bullet)$ represent the level of utility at the economy's equilibrium, so that v is the indirect utility function. Consider setting indirect utility, with a zero level of real asset endowment and with a Friedman deflation at the rate of $-\rho/(1 + \rho)$, equal to indirect utility, with some positive level of real asset endowment a and with some level of inflation π above $-\rho/(1 + \rho)$. This gives $v[0, -\rho/(1 + \rho)] = v(a, \pi)$. Solving for a and dividing by full income $w \cdot 1$, the cost function for any given level of inflation is $a/w = f(\pi, \alpha, Aw, \rho, d)$.[10] The leisure preference parameter α is set as in Gillman (1993) at 2.27. Calibrations are then required for Aw, ρ and d.

4.1 Calibrating *Aw* and ρ with Australian Data

To calibrate the cost of credit parameter Aw, consider that the income velocity of money in the economy approximately equals $1/\bar{s}$. With $\bar{s}^* = 1 - i/(Aw)$ when adjustment costs are zero, Aw can be computed for a given velocity and an interest rate. First consider to which monetary aggregate the model economy corresponds. Money in the model economy is that which does not earn interest while being used in exchange. This suggests using currency plus non-interest bearing demand deposits, which Gillman and Otto (1997) call non-interest bearing money (NIBM). (This abstracts from the costs of the non-interest bearing demand deposits since the model includes no other costs for money but the foregone interest costs.) The average annual velocity of Australian NIBM over the 1975–96 quarterly period is 11.16 in the Gillman and Otto database. (This is the standard RBA database from 1984 onwards; it uses exponential interpolation for the non-interest bearing deposits from 1976–84.) The average 90-day government bond interest rate is 0.1142 over the same period. From the approximation to velocity given by $1/\bar{s}$ when adjustment costs are zero, this gives an average value of $Aw = 0.1254$. As a test of these parameter specifications, the interest elasticity of money demand can be calibrated with $Aw = 0.1254$ in the model economy and compared to the actual estimated elasticity in Gillman and Otto. From an approximation of equation (23) in Gillman (1993), the model gives an elasticity of –1.89.[11] This compares to the estimated time series elasticity of –1.06 in Gillman and Otto.

An alternative calibration gives a higher value of Aw, by equating the –1.06 elasticity estimate to the model's approximation of the interest elasticity (given in endnote 11). Given an interest rate of 0.1142, this gives a value of $Aw = 0.2335$. A lower value of Aw makes it harder to find optimal a zero inflation rate for any given adjustment cost parameter. This makes $Aw = 0.1254$ more conservative than $Aw = 0.2335$ relative to the experiments of the paper. Another approach is to start with a more conventional, lower, estimate of the interest elasticity, say, –0.5 (as is implied by the Baumol, 1952, model). Calibrating Aw again from the elasticity approximation given in Gillman (1993) implies that $Aw = 0.4015$.

A different alternative is to calculate Aw directly. Gillman (1993) interprets Aw in terms of the share of labour hours in the Finance sector. This again gives a value of Aw that is higher than 0.2335. Another option is to separate out A and w. The real wage in Australia can be measured but there is a problem in measuring A. This parameter is interpreted in Gillman as being proportional to the labour hours per unit of output in the Finance sector. The Australian Bureau of Statistics measure the Finance output by extrapolating from hours worked. The ratio of hours to output, or the inverse of productivity, is therefore based on only the hours series. Lowe (1995) concludes this measure contains significant error and so it is not used in this paper.

The rate of time preference is calibrated as the average real interest rate over the same 1975–96 period. The CPI Australian average inflation rate is equal to 0.0731 over the period. The real rate in a discrete model framework, with discretely observed data, is $(i - \pi)/(1 + \pi)$. With $i = 0.1142$, this gives a real rate of 0.0395.

4.2 Calibrating the *d* Factor

Calibrating the d factor of the function $D(\pi) = d|\pi|$ requires two sources of data, for the total menu cost $D(\pi)$, and for the inflation rate that corresponds to that cost. The total menu cost is taken from evidence reported by Levy et al. (1997) for four major US grocery store chains over the 1991–92 period. They find a 0.7 per cent reduction in revenue. To be able to use this as a measure of the model's per cent increase in cost, $D(\pi)$, it is necessary to state the model in terms of a reduction in revenue (instead of an increase in cost) as a result of menu costs, and then show how this corresponds to $D(\pi)$. Let revenue be given as $Pc[1 - \hat{D}(\pi)]$ and costs as wn. Then profit maximisation under perfect competition implies that the real wage equals $(\partial c/\partial n)[1 - \hat{D}(\pi)]$. Equating this alternative to the real wage embodied in equation (1) yields that $1/[1 + D(\pi)] = 1 - \hat{D}(\pi)$. With $\hat{D}(\pi) \equiv 0.007$ in our use of the evidence in Levy et al., we solve for $D(\pi)$ and find that it also equals 0.007.

Second, the relevant inflation rate must be inserted into $D(\pi) = d|\pi| = 0.007$ in order to solve for d. The adjustment cost function should use the inflation rate that corresponds to the time period during which Levy et al. report 0.007. This period is 1991–92 and the average annual US CPI inflation rate over 1991–92 is 0.0354. Then $0.007 = d|0.0354|$; and $d = 0.1977$ is the calibrated level for d. Notice that this level of inflation is close to the Australian rate in recent years, which averaged 0.0253 over 1990–96. Also making the data comparable to Australia, the technology of grocery store chains presumably is not very different in Australia from the United States since both countries are 'first-world'. There appear to be few if any alternative sources of data from which d can at present be calibrated.

4.3 Results for the Linear Inflation-Adjustment Cost Technology

Substituting $Aw = 0.1254$ and $\rho = 0.0395$ into the welfare cost function $f(\pi)$, a critical level of d can be found. In particular, a zero inflation rate is optimal for values of d that exceed 0.3341. It is found that an interest rate of 0.0395 (a zero inflation rate) becomes optimal once d rises above the critical level of $d^* = 0.3341$. Table 1 shows, at $d = 0.1977$ the optimal rate of inflation turns out to be a deflation of 1.70 per cent, more than halfway towards a zero rate from the Friedman deflation of 0.0395 (the calibration for ρ). This result is sensitive to the value of Aw, ρ and d. As Aw goes up, the critical d^* goes down. At a value of $Aw = 0.2271$, the critical level of d^* just falls down to the level equal to the calibrated level of $d = 0.1977$, and makes a zero inflation rate optimal. Therefore, at the higher, alternative, calibrated value of $Aw = 0.2335$, which exceeds 0.2271, a zero rate of inflation is optimal. A decrease in ρ also causes the critical d^* to go down.

5. Alternative Adjustment Cost Functions

More generally, the adjustment cost function can be specified as $D(\pi) = d|\pi|^{\beta}$, where β is equal to one for the linear case, less than one

Table 1 Optimal Inflation Rate under Alternative Adjustment Cost Functions (ρ = 0.0395)

Adjustment cost function	*Actual d calibrated*	*d* critical Aw = 0.1254*	*Optimal interest rate Aw = 0.1254*	*Optimal inflation rate Aw = 0.1254*	*Minimum Aw at which π = 0 is optimal at calibrated d*	*Optimal inflation rate Aw = 0.2335*
$d\|\pi\|^{0.67}$	0.0657	0.0694	0.0175	–0.0220	0.1333	0.0000
$d\|\pi\|^{0.78}$	0.0948	0.1087	0.0201	–0.0194	0.1458	0.0000
$d \ln(1 + \|\pi\|)$	0.2012	0.3341	0.0225	–0.0170	0.2226	0.0000
$d\|\pi\|$	0.1977	0.3341	0.0225	–0.0170	0.2271	0.0000
$d\pi^2$	5.59	∞	0.0235	–0.0160	**	–0.0111

Note: ** Raising Aw to 0.467 for this cost function gives an optimal inflation rate of –0.0071.

for concave cases, and greater than one for convex cases. Research into the form of this cost function appears to be scarce and so the linear case is used as a baseline example. Theory suggests both concave and convex specifications. Fender (1990) derives a concave function, with the cost depending on the inflation rate raised to the (2/3) power (β = 0.67). Derived from a partial equilibrium with menu costs from changing prices, Fender suggests that menu costs will at first be high as inflation starts up from a zero level. Then the adjustment cost will rise at a decreasing rate with the level of the inflation rate. Mussa (1977) considers a similar case in which he derives the same (2/3) power. He additionally considers relative price changes, or 'relative demand pressures'. Here some prices need to be, say, raised while the inflation rate is already raising the general price level, and this decreases the menu cost of the inflation adjustment. For this case, Mussa derives convexity in the adjustment cost function for low levels of the inflation rate, and concavity for higher levels of the inflation rate. Empirically, it is only possible to report a β on the basis of calibrations made from an unpublished thesis by Beaurepaire et al. (1974); this gives a power coefficient of 0.78 (see Gillman 1996b), which is not very different from Fender's and Mussa's 0.67.

5.1 Sensitivity to Concavity versus Convexity

To show how both concave and convex specifications affect the results, Table 1 presents four more specifications, of β = 0.67, 0.78 and 2.0, and a natural log case (which is concave but close to linear at near-zero levels of the inflation rate). For *Aw* = 0.1254, all of the alternatives, as with the linear case, imply an optimal deflation rate near the 2 per cent level. This deflation is greatest for the most concave case of β = 0.67, and least for the convex quadratic case of β = 2.0. However while the most concave case implies the optimum furthest away from the zero inflation level, it also implies the greatest sensitivity of the optimal deflation rate to the *Aw* calibration level. For β = 0.67, *Aw* need rise less than 10 per cent to imply an optimum of a zero inflation rate. For the convex case of β = 2.0, a near-infinite rise in *Aw* would still leave a slight deflation as the optimum. With *Aw* = 0.2335 in the concave and linear cases, a zero inflation rate is optimal; the convex case implies an optimal deflation of 1.1 per cent. In general, the more convex is the specification, the more sensitive is the level of the optimal inflation rate to the calibration of *d*. For β = 0.67, a 10 per cent increase in *d* pushes the optimum to a zero inflation; for β = 2.0, a 10 per cent increase in *d* slightly changes the optimal deflation rate.

5.2 Skewness and the Model without Costly Credit

Another type of sensitivity analysis would be to skew the $D(\pi)$ functions towards a higher relative cost from either inflation or deflation. Mussa (1977) reasons that wage decreases are more problematic than price increases (which can decrease customer goodwill), and that wage changes are passed through to price changes. He interprets this as a higher inflation-adjustment cost for negative rates of inflation than for positive rates of inflation. Such skewness means for our analysis that the optimal inflation rate would be further pushed up towards zero.

Lastly, suppose that cash is the only means of exchange ($\bar{s} \equiv 1$). Given *Aw* = 0.1254, the zero rate of inflation would be optimal in all specifications of the inflation-adjustment cost function except for the quadratic specification. For β = 2.0, the optimal inflation rate would be –0.002, only slightly different from zero. These results are biased towards finding a zero inflation rate in that the model without credit overemphasises the role of the adjustment cost factor. With costly credit included, the model in a sense automatically indexes the payment to inflation when the purchase is made by credit. Or more exactly, using credit foregoes the interest cost of cash and the adjustment to a different inflation rate.

6. Conclusions and Qualifications

The paper finds some cases in which a zero inflation rate is optimal for Australia. For a lower-valued calibration of *Aw*, a deflation of around 2 per cent is found to be optimal across the alternative specifications of the inflation-adjustment cost function. For the alternative higher-valued *Aw*, a zero inflation rate is found to be optimal for the linear and concave adjustment cost specifications; a 1.1 per cent deflation is found for the convex specification. These results are more sensitive to the calibration for the menu cost parameter the more concave is the inflation-adjustment cost function.

The study gives estimates of the optimal inflation rate that are designed to be at the low end. An extension could look beyond just the cost of changing prices. There are likely to be tax-like effects of inflation adjustment on the firm's capital and labour demand, and goods supply, as well as on the consumer's capital and labour supply and goods demand, that would increase the inflation-adjustment cost above that of the menu cost interpretation. Much of these added costs conceivably come from uncertainty of the inflation rate, and are an increasing function of the absolute value of the mean inflation rate (as in Lourenco & Gruen 1995). Incorporating such costs would give a higher cost parameter that would push the optimal inflation rate farther towards zero. Further research on the empirical magnitude of menu costs or other inflation-adjustment costs, as well as refinement of the model, would be useful.

The comparative static results can be applied to a given country over time and across countries. For example, a decrease in the real rate of time preference implies a decrease in the critical value that the calibrated adjustment cost parameter *d* must exceed in order for a zero inflation rate to be optimal. Slightly extending the model conceptually so that the rate of time preference is set equal to the real marginal product of capital, we can think of what has happened to the real interest rate in Australia over time. The not-fully anticipated, early 1990s, inflation deceleration apparently contributed to an increase in the ex post real interest rate until the low inflation rate became more fully expected. By the mid-1990s, it is plausible that a low rate was expected and that a lower inflation risk premium was built into real interest rates. Ceteris paribus, a decrease in the real interest rate makes the optimality in Australia of a zero inflation rate more likely. And with the inflation rates of the United States, European Union and Japan now hovering near 1 per cent, this comparative static result adds weight to the argument for keeping the Australian dollar internationally competitive by maintaining a near-zero inflation rate.

Or consider illustratively the transition European and Asian economies that still are experiencing high and variable inflation rates that can make the real rates high (Gillman, 1998, computes these rates for eleven transition countries). Second, because of newly evolving financial sectors, and with a limited dispersion of information technologies, the menu costs would seem to be relatively high in such economies. The less advanced financial sectors also imply a higher cost of the credit services, which in the model corresponds to a higher *Aw*. In sum, there are opposing effects. A higher ρ makes a zero inflation rate less likely to be optimal, while a higher *d* and a higher *Aw* make the zero rate more likely to be optimal.

Over the secular trend in any given country, the real interest rate tends to be stable, while the cost of credit services, *Aw*, seems likely to trend down. The menu cost parameter *d* might seem likely to fall because of technological advance in information technology. However a scale effect on *d* from a growth in the number of products for sale could make *d* rise. It is even more difficult to discern a trend for a broader definition of *d* that includes other costs of inflation in distorting the production/consumption process.

The model's assumption of a zero marginal cost of producing money is a pillar of monetary theory, and is assumed in this model as in most. In qualification, if a government, or a private bank, uses resources to generate the credit necessary to instill confidence for using their debt as a means of exchange, then the marginal cost of money could be positive. Should the marginal cost of all sovereign debt including currency be driven to the competitive real interest rate, then the first-best optimal inflation rate would be zero. In such as optimum, seigniorage would be a competitive return for a stable fiat supply. And menu costs from non-zero inflation would be merely a symptom of departures from the optimum. Assuming zero marginal costs, this paper clarifies how an adjustment friction empirically can make zero the optimal inflation rate in Australia. This result should be strengthened by a theoretical marginal cost of money that is above zero and no greater than the market cost of capital.

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Endnotes

1. Irving Fisher wrote pervasively of 'price stability' with respect to the aggregate price level and not relative prices (for example, Fisher 1920), and helped develop the price index literature (see Persky 1998). He advocated a zero inflation rate policy and was criticised for this (Schumpeter 1952).

2. Harberger (1998) analyses in a growth context 'real cost reduction' as is 'on the mind of most business executives'. He reasons that 'people must perceive real costs in order to reduce them', and that 'inflation is the most obvious, probably the most pervasive, and almost *certainly the most noxious of such policies*' that 'impede the accurate perception of real costs' (italics in original).

3. Gillman, Siklos and Silver (1997), Collins and Anderson (1998), and Gillman and Otto (1997) find a larger-than-standard estimated interest elasticity of money when including cash alternatives. Ireland (1994) uses the costly credit feature to simulate the u-shaped US historical velocity path.

4. Examples are the McCallum and Goodfriend (1987) and Lucas (1994) 'shopping time' economies that do not specify credit explicitly, and the Bansal and Coleman (1996) 'transaction cost' economy that explicitly includes credit. Related is the Lacker and Schreft (1996) economy in which the use of explicit credit is decided before optimisation on the basis of distance.

5. Balvers and Ran (1997) include within their profit function a related adjustment cost due to the time change in the price, yielding price stickiness. Mussa (1977) and Fender (1990) derive from a monetary setting of costly price changes an adjustment cost function that depends explicitly on the inflation rate. See Christiano, Eichenbaum and Evans (1997) for a comparison of a mark-up sticky-price model and a monetary model with a (costless) financial intermediary.

6. Lucas (1980) uses such a continuum of similar goods that can be aggregated together. Gillman, Siklos and Silver (1997) and Gillman and Otto (1997) use a one-good version of a costly credit model that is similar to the one here.

7. Note that the banking sector is implicit in how the time supplied for producing the credit enters into the optimisation problem. Alternatively, and with identical equilibrium conditions, the banking sector can be made explicit by specifying a separate bank profit maximisation problem and transferring bank profits to the agent's income. To simplify the model's structure, this explicit version is not presented (for a related explicit bank model, see Aiyagari, Braun & Eckstein 1995).

8. See for example Lucas (1994), Braun (1994a) and Gillman (1995) for such welfare cost measures.

9. Lucas (1994, sec. 6) and Gillman (1996a) similarly allow for negative values of the welfare cost function of inflation at the optimum.

10. Writing the welfare cost function in terms of the nominal interest rate for presentation purposes:

$$a/w = \{[Z(\{1 + d|\pi|\}/\{1 + d[0.0395]/[1.0395]\}) \text{ exponent}(1/\{1 + \alpha\})] - 1\}\{1/(1 + d|\pi|]\}$$

where:

$$Z \equiv \{1 - [(i\{1 - [i(1 + d|\pi|)/Aw]/[(1 + i)(1 + \alpha])]\}\cdot\{([1 + i] \text{ exponent}[1/(1 + \alpha)])/(e \text{ exponent}[([i - \ln(1 + i)][1 + d|\pi|])/(Aw[1 + \alpha])])\}$$

11. The formula used for the interest elasticity is $-\{[(1 - \bar{s})/\bar{s}] + i/(1 + i)\}$, which approximates equation (23) given in Gillman (1993) by omitting the last negligible term that is due to changes in the marginal utility of income.

References

Aiyagari, S. R., Braun, R. A. & Eckstein, Z. 1995, 'Transactions services, inflation, and welfare', Working Paper 27/95, Tel Aviv Sackler Institute of Economic Studies, Tel Aviv.

Bailey, M. J. 1956, 'The welfare costs of inflationary finance', *Journal of Political Economy*, vol. 64, no. 2, pp. 93–110.

Balvers, R. & Ran, J. 1997, 'Price stickiness under menu and convex adjustment costs', *Journal of Economic Research*, vol. 2, no. 2, pp. 269–78.

Bansal, R. & Coleman, W. J. 1996, 'A monetary explanation of the equity premium, term premium, and risk-free rate puzzles', *Journal of Political Economy*, vol. 104, no. 6, pp. 1135–71.

Barro, R. J. 1972, 'A theory of monopolistic price adjustment', *Review of Economic Studies*, vol. 39, pp. 17–26.

Baumol, W. J. 1952, 'The transactions demand for cash: An inventory theoretic approach', *Quarterly Journal of Economics*, vol. 66, no. 4, pp. 545–66.

Beaurepaire, R. A., Higgins, P. J. & Mercovich, P. C. 1974, 'A study into the impact of continuing inflation–With particular reference to Shell (Australia) Ltd., 1974–1985', Research Report, Master of Business Administration, University of Melbourne.

Becker, G. S. 1965, 'A theory of the allocation of time', *Economic Journal*, vol. 75, pp. 493–517.

Braun, R. A. 1994a, 'Another attempt to quantify the benefits of reducing inflation', *Federal Reserve Bank of Minneapolis Quarterly Review*, vol. 18, no. 4, pp. 17–25.

Braun, R. A. 1994b, 'How large is the optimal inflation tax?', *Journal of Monetary Economics*, vol. 34, no. 2, pp. 201–14.

Carlstrom, C. T. & Gavin, W. T. 1992, 'Zero inflation: Transition costs and shoe leather benefits', *Contemporary Policy Issues*, vol. 11, no. 1, pp. 9–17.

Christiano, L. J., Eichenbaum, M. & Evans, C. L. 1997, 'Sticky price and limited participation models of money: A comparison', *European Economic Review*, vol. 41, no. 6, pp. 1201–49.

Collins, S. & Anderson, R. 1998, 'Modeling U.S. households' demands for liquid wealth in an era of financial change', *Journal of Money, Credit, and Banking*, vol. 30, no. 1, pp. 83–101.

Cooley, T. F. & Hansen, G. D. 1995, 'Money and the business cycle', in *Frontiers of Business Cycle Research*, ed. T. F. Cooley, Princeton University Press, Princeton.

Dowd, K. 1994, 'A proposal to end inflation', *Economic Journal*, vol. 104, no. 425, pp. 828–41.

Fender, J. 1990, *Inflation: Welfare Costs, Positive Theory, and Policy Options*, University of Michigan Press, Ann Arbor.

Fisher, I. 1907, *The Rate of Interest*, Macmillan, New York.

Fisher, I. 1920, *Stabilizing the Dollar*, Macmillan, New York.

Fluet, C. & Phaneuf, L. 1997, 'Price adjustment costs and the effect of endogenous technique on price stickiness', *European Economic Review*, vol. 41, no. 2, pp. 245–58.

Friedman, M. 1969, 'The optimum quantity of money', in *The Optimum Quantity of Money, and Other Essays*, Aldine, Chicago.

Gillman, M. 1993, 'The welfare cost of inflation in a cash-in-advance economy with costly credit', *Journal of Monetary Economics*, vol. 31, no. 1, pp. 97–116. Reprinted in *The Theory of Inflation* 1994, ed. M. Parkin, Edward Elgar, Brookfield, Vermont.

Gillman, M. 1995, 'Comparing partial and general equilibrium estimates of the welfare cost of inflation', *Contemporary Economic Policy*, vol. 13, no. 4, pp. 60–71.

Gillman, M. 1996a, 'Optimality of exchange credit restrictions', Research Paper no. 519, Department of Economics, University of Melbourne.

Gillman, M. 1996b, 'Price stability as optimal policy: Costly nominal adjustment in general equilibrium', Research Paper no. 515, Department of Economics, University of Melbourne.

Gillman, M. 1998, 'Macroeconomic analysis of the transition economies', in *Handbook on the Globalisation of the World Economy*, ed. A. Levy-Livermore, Edwin Elgar, Cheltenham, United Kingdom.

Gillman, M. & Otto, G. 1997, 'The velocity of non-interest bearing means of payment during a period of financial innovation: Australia, 1975–96', mimeo, University of New South Wales, & Economics Institute, Academy of the Sciences of the Czech Republic.

Gillman, M., Siklos, P. & Silver, J. L. 1997, 'Money velocity with costly credit', *Journal of Economic Research*, vol. 2, pp. 179–207.

Harberger, A. C. 1998, 'A vision of the growth process', *American Economic Review*, vol. 88, no. 1, pp. 1–32.

Hicks, J. R. 1935, 'A suggestion for simplifying the theory of money', *Economica*, vol. 2, no. 5, pp. 1–19.

Howitt, P. 1987, 'The optimum quantity of money', in *The New Palgrave: Money*, eds J. Eatwell, M. Milgate & P. Newman, Macmillan, New York.

Ireland, P. N. 1993, 'Price stability under long-run monetary targeting', *Federal Reserve Bank of Richmond Economic Review*, vol. 79, no. 1, pp. 25–45.

Ireland, P. N. 1994, 'Economic growth, financial evolution, and the long-run behavior of velocity', *Journal of Economic Dynamics and Control*, vol. 18, no. 3/4, pp. 815–48.

Ireland, P. N. 1996, 'The role of countercyclical monetary policy', *Journal of Political Economy*, vol. 104, no. 4, pp. 704–23.

Karni, E. 1974, 'The value of time and the demand for money', *Journal of Money, Credit, and Banking*, vol. 6, pp. 45–64.

Lacker, J. M. & Schreft, S. L. 1996, 'Money and credit as means of payment', *Journal of Monetary Economics*, vol. 38, no. 1, pp. 3–24.

Leigh-Pemberton, R. 1992, 'The case for price stability', *Bank of England Quarterly Bulletin*, vol. 32, no. 4, pp. 441–8.

Levy, D., Bergen, M., Dutta, S. & Venable, R. 1997, 'The magnitude of menu costs: Direct evidence from large U.S. supermarket chains', *Quarterly Journal of Economics*, vol. 107, no. 3, pp. 791–825.

Lourenco, R. D. & Gruen, D. 1995, 'Price stickiness and inflation', Research Discussion Paper 9502, Reserve Bank of Australia, Sydney.

Lowe, P. 1995, 'Labour-productivity growth and relative wages: 1978–1994', Research Discussion Paper 9505, Reserve Bank of Australia, Sydney.

Lucas, R. E. Jr 1980,'Equilibrium in a pure currency economy', in *Models of Monetary Economies*, eds J. H. Kareken & N. Wallace, Federal Reserve Bank of Minneapolis, Minneapolis.

Lucas, R. E. Jr 1994, 'On the welfare costs of inflation', Working Paper, University of Chicago.

Lucas, R. E. Jr & Stokey, N. L. 1983, 'Optimal fiscal and monetary policy in an economy without capital', *Journal of Monetary Economics*, vol. 12, pp. 55–93.

McCallum, B. T. & Goodfriend, M. S. 1987, 'Demand for money: Theoretical studies', in *The New Palgrave: Money*, eds J. Eatwell, M. Milgate & P. Newman, Macmillan, New York.

Mankiw, N. G. 1985, 'Small menu costs and large business cycles: A macroeconomic model of monopoly', *Quarterly Journal of Economics*, vol. 100, no. 2, pp. 529–37.

Mussa, M. 1977, 'The welfare cost of inflation and the role of money as a unit of account', *Journal of Money, Credit, and Banking*, vol. 9, no. 2, pp. 276–86.

Parkin, M. 1986, 'The output–inflation trade-off when prices are costly to change', *Journal of Political Economy*, vol. 94, no. 1, pp. 200–24.

Persky, J. 1998, 'Price indexes and general exchange values', *Journal of Economic Perspectives*, vol. 12, no. 1, pp. 197–205.

Schumpeter, J. A. 1952, *Ten Great Economists from Marx to Keynes*, Allen & Unwin, London.

Stemp, P. J. 1996, 'The role of monetary policy in Australia: A minimalist approach', *Australian Economic Review*, 1st quarter, pp. 10–28.

Svensson, L. E. O. 1997, 'Inflation forecast targeting: Implementing and monitoring inflation targets', *European Economic Review*, vol. 41, no. 6, pp. 1111–47.

Taub, B. 1989, 'The optimum quantity of money in a stochastic economy', *International Economic Review*, vol. 30, no. 2, pp. 255–73.