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A Segmented Markets Model of Inflation

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Abstract

Models of inflation usually have monetary policy impacting the economy through either an interest rate or a monetary/credit quantity channel but not through both. We argue that policy is transmitted via two distinct types of agents – those that are and that are not liquidity constrained. The implication is that both channels must be seen as complementary, joint indicators of inflation and must both be incorporated in models of inflation. We provide a formal representation of price level determination and behaviour in this segmented markets framework and evaluate it econometrically using US data.

A SEGMENTED MARKETS MODEL OF INFLATION

1. Introduction

This paper puts forward a new, segmented markets model of inflation. It builds on two key propositions. The first is that inflation is the outcome of monetary policy actions, while the second is that inflation is transmitted to the economy by the central bank via two generically distinct channels. These two channels reflect the behaviour of two distinct types of agents in the economy, namely those that are liquidity constrained and those that are not liquidity constrained. This liquidity constraint distinction is the source of the segmented markets. The two channels describe the behaviour of these agents in response to monetary policy actions.

A monetary policy action has its effects on economic activity, and ultimately on inflation, by disturbing the portfolio equilibrium, and hence the expenditure behaviour, of the two agents. The sizes of the resulting disequilibria measure the amount of inflationary or deflationary tension in the economy arising from monetary policy actions. When portfolio equilibrium is restored for both sets of agents, the inflation generated from the monetary-policy-induced perturbation ceases and price stability is re-established.

In this segmented markets setting, a monetary policy action impacts on the first type of agent – denoted the liquidity-constrained agent – through changing the quantity of money balances available. It impacts on the second type of agent – denoted the non-liquidity-constrained agent – through its effect on the real rate of interest. In other words, monetary policy is transmitted to the rate of inflation through two channels: first, through its impact on the fraction of the money stock available to the liquidity-constrained sector for its purchase of goods and services and, secondly, through its effect on the real interest rate, which matters for the intertemporal expenditure decisions of the non-liquidity-constrained agents. The first channel, in effect, is the quantity channel through which the central bank affects prices while the second channel has an obvious familiarity to the Wicksellian interest rate channel. We estimate the model for the US economy and find it to have strong explanatory power.

Our model stands in contrast to the pattern in the literature where monetary policy is modelled as being channelled to the economy *either* through a financial price (i.e., an interest rate) *or* a financial quantity (i.e., a credit or a monetary aggregate), but not both at the same time.¹ Models of the first type usually focus on Taylor rules, which tend to summarise the stance of monetary policy exclusively in terms of a rate of interest. Models of the second type tend to look at financial quantity variables, of which a well-known example is the P-star model. There is little controversy about the interest rate effect in current economic discussion. It is the key aspect of the conventional wisdom about how monetary policy affects the economy. The financial quantity effect, which can be rationalised as stemming from the types of mechanisms stressed by monetarists (such as real balance effects) or from bank loan market imperfections (more popularly known as the credit channel), is subject to more debate. Yet, in an authoritative review, Kashyap and Stein (1997, p. 5) take the view that: “Overall the results suggest that monetary policy may have important real consequences, but not because of standard interest rate effects”.

What is less well established, and the core of the argument here, is that there is no choice to be made between the two channels. Rather, both are simultaneously operative and a complete explanation of inflation requires the inclusion of both channels. In our model, an expansionary monetary policy has the following effects. It reduces the real rate of interest relative to the equilibrium or natural rate, which stimulates the consumption expenditures of those non-liquidity constrained households for which the rate of interest is the binding constraint. And, *at the same time*, the *same* monetary policy action increases the money stock relative to its ex-ante demand and stimulates the consumption expenditures of those households for which the quantity of money is the binding constraint on expenditures. In our empirical analysis, we use the gap between the market and equilibrium real rate of interest, i.e., the real interest rate gap, to capture the first channel, while for the second channel we use an excess-money variable, or what we term the money gap.

In re-establishing their respective equilibrium positions following a monetary policy action, both sectors adjust and in doing so generate inflation. The private sector is

¹ For example, recently popular models proposed by, e.g., Woodford (2003) and Neiss and Nelson (2003) clearly indicate the “real interest rate gap” channel as an *alternative* to indices using financial quantity variables such as monetary or credit aggregates.

merely propagating, however, the inflationary pressures triggered by the central bank. The proposed model, therefore, suggests that to capture the determinants of inflation all one needs to focus on are the determinants of aggregate expenditures that are directly and fairly immediately amenable to manipulation by the central bank.

The immediate interface between the central bank and the non-bank private sector following a monetary policy action takes place in the commercial bank loan market. Since the central bank is the only source of inflation and since it interacts exclusively with banks in monetary policy operations, the first step then to understanding the inflation process is to focus on the behaviour of banks themselves in the wake of monetary policy actions. The most immediate repercussion of monetary policy is on banks' lending behaviour. And, in this respect, it is of key importance to distinguish between two types of borrowers who are assumed to populate the bank loan market, that is between agents that are usually, but not necessarily always, liquidity constrained and those that are *never* liquidity constrained. This is the source of market segmentation in our model and the basis for our theoretical and empirical modelling.

Since these two disequilibria arise in the bank loan market, where central banks' policy actions are first felt, they together convey a more complete measure of inflationary tensions, and, accordingly, explain better subsequent actual inflation than more conventionally used variables such as the output gap or the deviation of unemployment from its natural rate. The now almost standard model of inflation, the New Keynesian Phillips Curve model, focuses on the labour market. Although the labour market seems to play a key role in most models of inflation, regardless of which school of thought inspires the model, we believe that developments in that market are quite far removed in the transmission process from the actions of the central bank. Pressure points that arise earlier in the transmission process are much closer to the ultimate source of inflation, which after all is the central bank itself. They should, therefore, provide a much more accurate picture of the long-term inflation potential arising in the economy than are provided by other indicators based on product or labour markets which reflect aspects of private sector behaviour that are (much) less closely related to monetary policy.

The paper is organised as follows. In section 2, a graphical representation, emphasising the dichotomy among participants in the loans market, is used to motivate our segmented markets model of inflation. Section 3 provides a formal representation of price level determination and behaviour in the segmented markets framework. In section 4, the results of an econometric evaluation of the model, using US data, are given. Section 5 concludes.

2. The Segmented Markets Approach and the Impact of Monetary Policy

- Uses of the Segmented Markets Approach

In arguing that inflation operates through two channels, it is necessary to think of an economy in which agents are segmented into two groups with contrasting degrees of participation in financial markets. This kind of distinction has proven very useful in empirical applications, most familiarly in examining aggregate consumption and investment. In aggregate consumption research, the two types of agents have been described variously as maximising and rule-of-thumb agents (see Campbell and Mankiw, 1989, 1991) and non-liquidity constrained and liquidity-constrained agents (Zeldes, 1989). More recently, Christiano, Eichenbaum and Evans (1997) have popularised a model (the limited participation model) due to Rotemberg (1984). This model effectively rationalises liquidity constraints by arguing that individuals may be unable to adjust the levels of their cash balances quickly enough to enable them to smooth their expenditures over time since they have only limited opportunities to participate in financial markets. In a more recent paper, Alvarez, Lucas and Weber (2001) use a two-agent model, which they call a model of segmented markets, to generate the elusive liquidity effect of monetary policy and to examine other aspects of monetary policy. The segmented markets conceptual framework is, therefore, not just a convenient heuristic device but is also considered a sensible description of reality.

- Description of the Two Agents

Liquidity-constrained agents have inadequate access to financial markets. This is because they cannot, for example, easily mobilise their non-human assets as collateral in the loan market or cannot leverage on the basis of their human capital (future labour income). They, therefore, cannot always gain access to liquidity needed for consumption purposes. They are unable to participate fully in financial

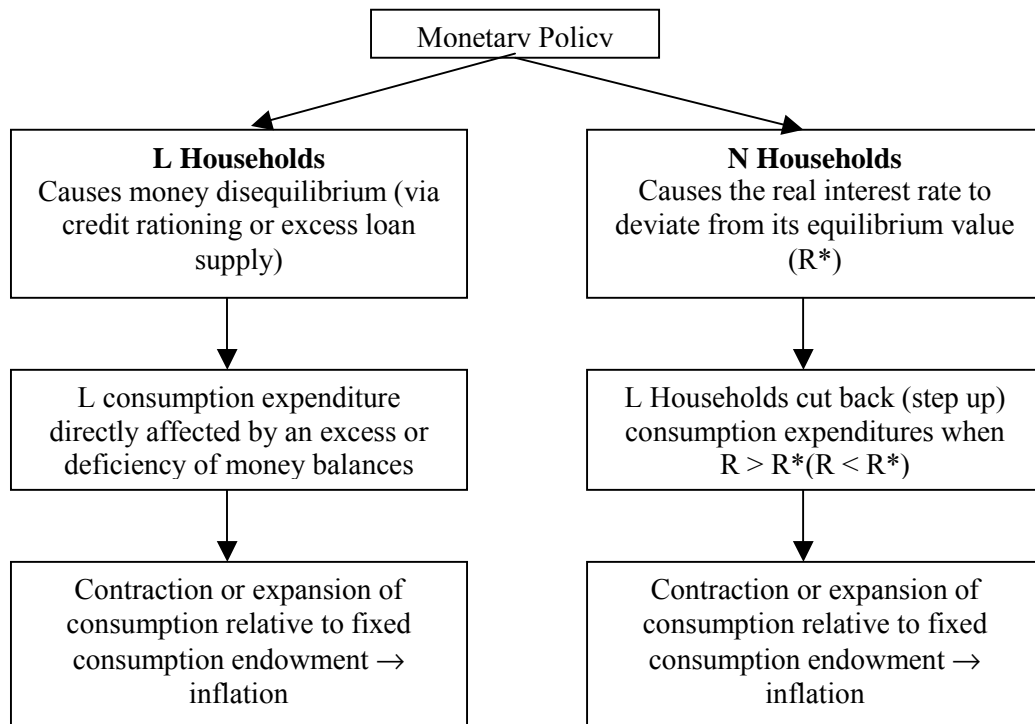
markets and could be said to experience “portfolio stickiness”. The binding constraint that is relevant to liquidity-constrained agents in undertaking spending and that is, at the same time, amenable to control by the central bank is the amount of the nominal money stock held by them. Although they do hold some fraction of the money stock, their holdings are not easily adjusted and so these agents are frequently constrained relative to their desired expenditure plans. The binding constraint they face then is the amount of liquidity rather than its price. Consequently, the expenditures of liquidity-constrained agents are not affected by the rate of interest.

The binding constraint for non-liquidity-constrained agents, which can simultaneously be manipulated by monetary policy, is the real rate of interest. Although these agents also hold a certain proportion of the money stock, their holdings do not constitute binding constraints in the sense that they can always borrow from banks at the prevailing loan rate. To have an impact on the expenditures of these agents, the central bank has to raise or lower the actual real rate of interest, which it can control in the short to medium term, relative to the corresponding natural or equilibrium rate, which it cannot control. These agents are only concerned about the price of liquidity and not its quantity, since they can always obtain whatever amounts of liquidity they want at the going rate of interest.

- Diagrammatic Illustration of the Impact of Monetary Policy on the Loan Market

Before providing a formal representation of price level determination in this two-agent economy in the next section, we provide a graphical analysis of how the two channels of monetary policy operate by looking at the market for bank loans. The well-known Stiglitz-Weiss (1989) model of credit rationing can be used to convey an intuitive understanding of how monetary policy operates simultaneously via both an interest rate and a financial quantity effect. In this segmented markets framework, changes in monetary policy operate through two generic channels, where those channels relate to the two types of agents already described. This is illustrated in the flow diagram in Chart 1, which is largely self-explanatory. L and N refer to liquidity-constrained and non-liquidity-constrained households, respectively. The existence of two channels does not mean that the central bank controls two things at

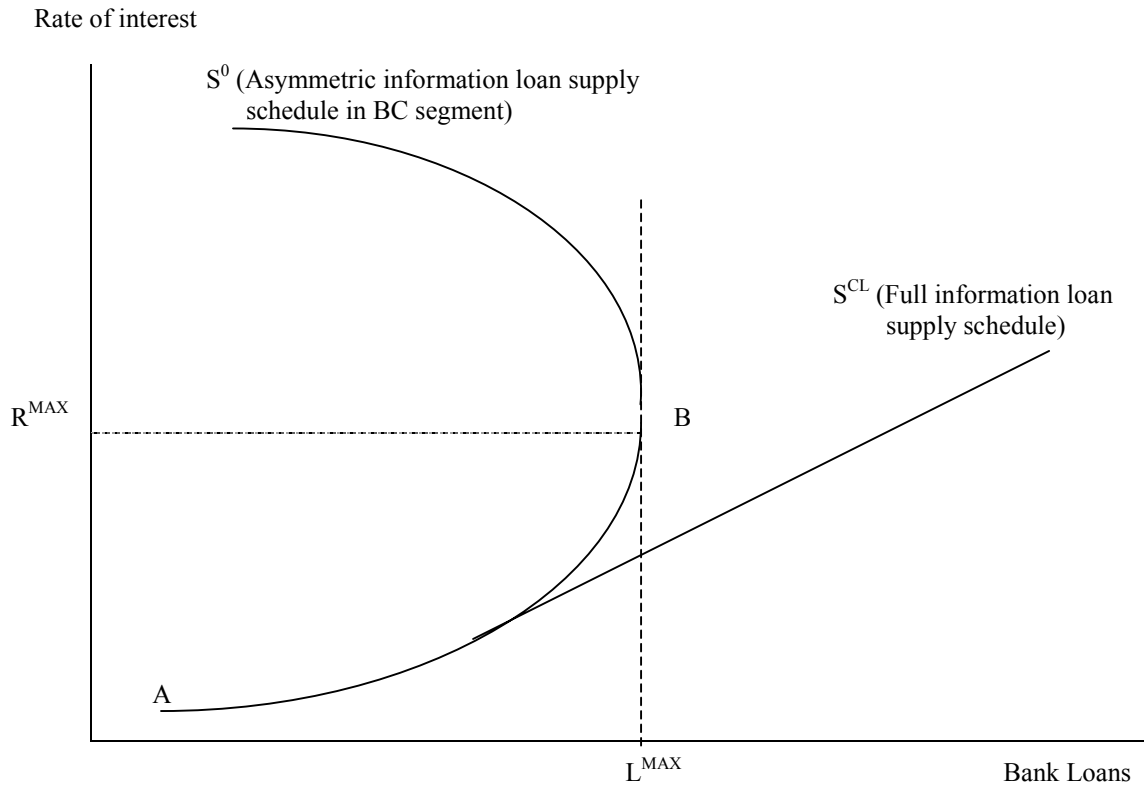
Chart 1: Flow Diagram of Monetary Policy Transmission



the same time but merely that its operations affect both types of agents differently, determined by their contrasting levels of success in raising funds in the bank loan market.

A diagrammatic exposition of the bank loan market is given in Figure 1. It displays two loan supply schedules. The first (S^{CL}) is an upward-sloping loan supply schedule in which banks increase loan supply for every increase in the loan rate of interest – i.e., the classical, full-information configuration. In other words, there is always an interest rate premium, which compensates the bank for supplying loans to increasingly risky borrowers. The market imperfection already alluded to is assumed to take the form of asymmetric information in the bank loan market. It is depicted in the figure as the asymmetric-information loan supply schedule (i.e., S^0). It shows the supply of loans reaching a maximum at R^{MAX} (the profit-maximising loan rate of interest from the point of view of the bank) and then becoming backward-bending. Beyond point B (corresponding to the loan amount L^{MAX} and the interest rate R^{MAX}), asymmetric information problems become so acute that the bank finds it no longer profitable to supply further loans. The reasons for the

Figure 1: Full Information and Asymmetric Information Loan Supply Schedules

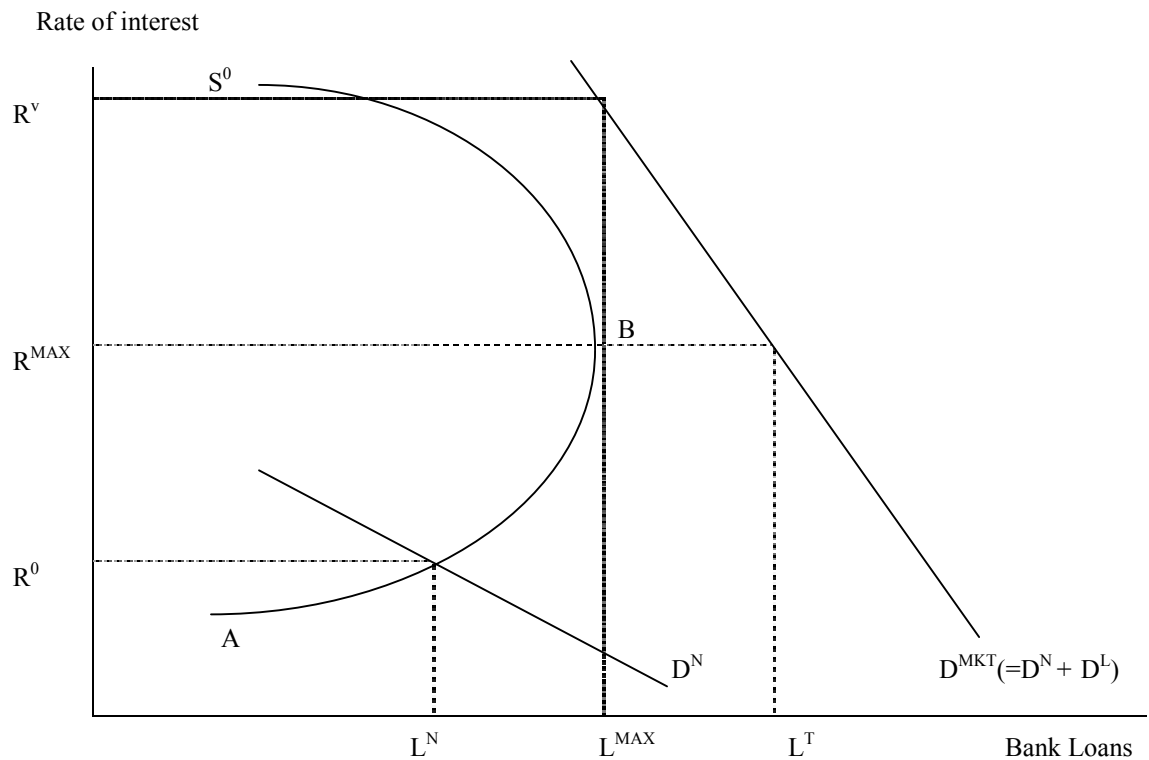


backward-bending supply schedule are well known.² They derive from traits of economic behaviour summarised in the terms moral hazard and adverse selection, reflecting the difficulties banks face in dealing with the limited information available to them about borrowers.

Henceforth we only deal with the more realistic backward-sloping loan supply curve. Turning to the demand side of the loan market, two demand schedules are shown in Figure 2. The first schedule, D^N , represents the loan demand schedule of the “full-information” N sector borrowers. These borrowers are always given priority by the bank. The demand schedule of the “full-information” borrowers has to intersect the loan offer curve in the upward-sloping AB segment of the curve as N agents are operating in a world that can be described by the classical loanable funds theory of the rate of interest.

The second schedule, D^{MKT} , represents the total market demand schedule for loans, comprising the demand schedules of the N and the L sectors (i.e., D^N and D^L , where

² The loan supply schedule is normally shown as backward bending but this is not necessary to demonstrate the credit rationing effect. It could truncate at the point corresponding to R^{MAX} .

Figure 2: Loan Supply and Loan Demand Schedules

D^L is the demand schedule of asymmetric information borrowers). It is, accordingly, positioned to the right of D^N . In general, we would expect D^N to intersect the supply schedule short of B so that the difference in loan supply (i.e. $L^{MAX} - L^N$) is available to the bank to distribute among “asymmetric information” borrowers at the maximum loan rate, R^{MAX} . Since this amount is less than the demand for loans by the L sector (i.e., $L^T - L^N$) at the rate R^{MAX} , the available loans are rationed among L borrowers. As banks grant more loans in moving from full-information to asymmetric information borrowers, their ability to screen accurately is reduced because they have to “go down the list” of borrowing prospects (see Stiglitz and Greenwald, 2003). These borrowers are, depending on the stance of monetary policy, liquidity-constrained at least some of the time.

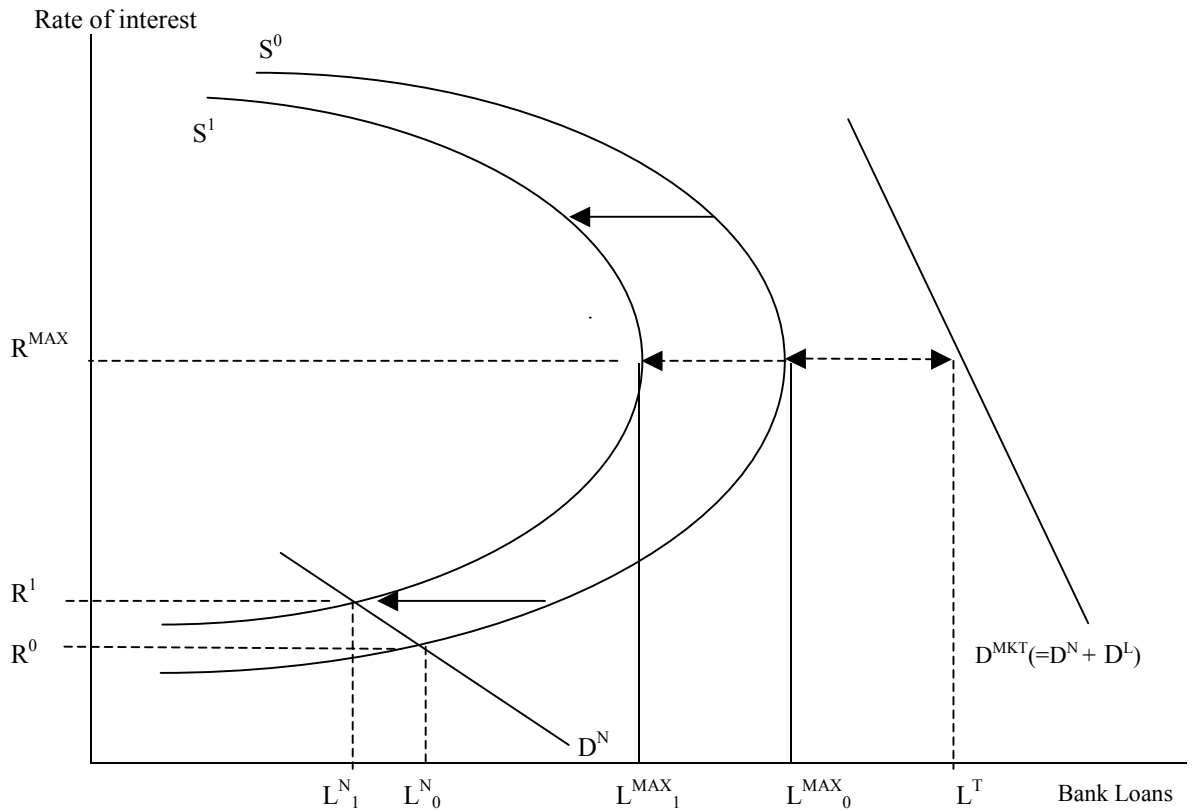
It is clear that the borrowing and expenditure decisions of “asymmetric information” borrowers are not affected by the loan rate of interest since the rate that they are willing to pay for additional funds (R^v in Figure 2) is in excess of the maximum rate being sought by the lender (i.e., R^{MAX}). For them, there is a pure credit-rationing, or quantity, effect. The L sector of the economy is, therefore, never constrained by the

loan rate of interest. Rather, their effective constraint is the amount of loans obtainable by them. The N sector, on the other hand, is never constrained by a nominal quantity variable since for them the effective constraint is the cost of funds as they can always obtain whatever funding they want in the bank loan market, subject to paying the going rate of interest. In other words, N's consumption does not depend on the level of credit or money.

How does a change in monetary policy impact on the loans market and, specifically, on the behaviour of N and L consumers? Consider a tightening of the stance of monetary policy conducted in the traditional manner of the central bank selling bonds to their monetary policy counterparts, which are exclusively banks. This implies a reduction in the supply of bank reserves and a corresponding reduction in the availability of funds to supply as loans. It shifts the loan supply schedule to the left throughout its full range, i.e., from S^0 to S^1 (see Figure 3). The tightening of monetary policy has two effects. First, it raises the rate of interest for N sector borrowers (from R^0 to R^1) reducing the quantity of loans demanded by them by $(L^N_0 - L^N_1)$. The lower demand for loans reflects decisions by N sector borrowers to defer consumption. That is, they make a downward revision in their real expenditure plans for the current period on account of the higher rate of interest with a view to consuming more in the future. The decline in their demand for loans is purely endogenous, reflecting a lower desired level of consumption in the current period. In other words, these consumers still attain their desired consumption levels on account of their unlimited access to bank loans but their level of borrowings has declined due to the rise in the interest rate (from R^0 to R^1). The second effect of the leftward shift in the loan supply schedule is to increase the level of rationing experienced by L agents from $(L^T - L^{MAX}_0)$ to $(L^T - L^{MAX}_1)$. The lower level of loans available to L agents forces them to retrench on their consumption expenditures.

Figure 3 then illustrates, to paraphrase Stiglitz and Greenwald (2003, p.38), that with credit rationing, monetary policy exerts its effects not only through interest rates, but also through credit availability. This twin effect could be generalised to refer to loan market disequilibrium, with the effects of a monetary policy change on the consumption spending of L and N agents reinforcing each other.

Figure 3: The Loans Market and a Change in the Stance of Monetary Policy



All funds raised in the loan market by L and N agents are assumed to be credited instantaneously to the borrower's overnight deposit account at the lending bank where it is available as immediate liquidity to be used for consumption purposes. They are added to whatever money balances the agents will already have accumulated. The provenance of these other money balances is explained in the next section of the paper. This, conveniently, allows us to talk of liquidity constraints in terms of money balances despite the fact that the source of the constraints is to be found in the bank loan market, as just explained.

3. Price Level Determination and Adjustment in a Segmented Loans Market Economy

- Description of the Economy

Both types of agent, or household, are assumed to receive the same endowment of goods, y , each period. The economy's resource constraint is written as:

$$y = \lambda c_{Lt} + (1 - \lambda) c_{Nt} \quad (1)$$

The parameters λ and $(1 - \lambda)$ represent the fractions of households (where λ is less than or equal to one) that are liquidity constrained (L) and non-liquidity constrained (N), respectively, and c_{Lt} and c_{Nt} their respective real consumption bundles in period t .³

The N consumers are assumed to have identical preferences as encapsulated in the following utility function:

$$E_t \sum_{i=0}^{\infty} (1 + \delta)^{-i} U(c_{Nt+i}) \quad (2)$$

Where c is consumption, δ is the subjective rate of discount, and E_t is the expectation conditional on information available at time t . If the representative consumer can borrow and lend at the real interest rate, r , then the first-order condition necessary for an optimum is:

$$E_t U'(c_{Nt+1}) = \left(\frac{1 + \delta}{1 + r} \right) U'(c_{Nt}) \quad (3)$$

This implies that, given the interest rate and the discount rate, each N consumer seeks to consume a particular utility-maximising bundle of goods in the current period, which we denote as c_{Nt} .

No household consumes its own endowment but rather each trades its own endowment so as to acquire funds to purchase goods. Exchange is governed by a cash-in-advance constraint. This implies that there is a need to hold transactions balances in equilibrium. Each of the L and N households consists of a seller and a shopper. The seller's function is to sell the household's endowment for cash in the goods market and hand over the cash to the household's shopper who then buys goods in the same market. As in ALW, the cash-in-advance constraint is modified to allow for shocks to velocity, v , which has a value range of greater than zero and less than unity. These arise from the fact that the amount of cash available to the shopper from the till of the seller is variable since it is affected by the randomness of

³ Although we use some of the parable and terminology of Alvarez, Lucas and Weber (henceforth referred to as ALW) (2001), the model specified here is quite different in a number of respects. One difference in assumption is crucial, which is that in ALW all agents are at times liquidity constrained

buyers' visits and purchases from a seller's shop. This means that velocity can vary from period to period.

The funds available to shoppers for consumption can come from three sources: a variable fraction of current period sales (i.e., $v_t P_t y$), unspent receipts from sales in the previous period ((i.e., $(1-v_{t-1})P_{t-1}y$ or, equivalently, M_{t-1}), and from banks following monetary policy measures. With the velocity of money, the goods endowment and the price level common to all agents, consumption expenditure will differ between N and L agents depending on how they interact with the banking system. Both types of household can supplement their money balances by borrowing from banks.

N households have unlimited access to bank loans and do not encounter any funding difficulties in the sense that they can obtain as much funding as desired provided they are willing to pay the going interest rate. They need funding to bridge the gap between the consumption that can be funded from the two sources just noted and that required to fund their desired consumption bundle in the current period, c_{Nt} . But since this required funding is always forthcoming, it is never a binding constraint on their level of consumption. L households, however, are often rationed in the loan market because of unresolved asymmetric information problems. Although they can raise loans from banks, they end up getting less than they need to attain the desired consumption bundle. The implication is that for both types of households, the cash-in-advance constraint exists, but for N households it does not impose a constraint on consumption since they can acquire as much transactions balances (via the loan market) as they need to carry out their consumption plans.⁴

In this setting, N agents, who are always capable of accessing the loan market for additional funding, are always on their money demand schedules. L agents, on the other hand, are often rationed in the loan market but at other times can experience excess money supply. In contrast to N agents, they are therefore almost never on their money demand schedules.

while in the model being proposed here only L agents are sometimes liquidity constrained while N agents are *never* liquidity constrained.

⁴ L agents in this model differ, therefore, from "non-traders" in ALW in that they *do* participate indirectly in monetary policy operations via the bank loan market although they may not be successful in garnering the desired level of funding. It would seem to be preferable to have L households participating in monetary policy because it is via some kind of financial markets imperfection (e.g., the liquidity constraints of the L households) that monetary policy has its effects on the economy.

- Price Level Determination

We denote the total amount of bank lending following a monetary policy action by $\overline{\Delta M}$. The bar indicates that M is exogenously determined to the private non-banking sector of the economy by monetary policy action and the portfolio decisions of commercial banks. An M variable without a bar means that it is endogenously determined by the relevant sector of the economy. The differences between the two sets of households are modelled by assuming that, following a monetary policy-driven expansion of the money stock, N households have first call on the change in the money stock (taking ΔM_N of it, which is assumed to be always sufficient to satisfy N 's consumption needs), with the remaining amount, $(\overline{\Delta M} - \Delta M_N)$, being rationed among L households.

Nominal consumption expenditure by L households in period t is determined as follows:

$$\begin{aligned}
 P_t c_{Lt} &= \overline{M}_{Lt-1} + v_t P_t y + [\overline{\Delta M}_t - \Delta M_{Nt}] \\
 &= [\overline{M}_{t-1} - M_{Nt-1}] + v_t P_t y + [\overline{M}_t - \overline{M}_{t-1}] - [M_{Nt} - M_{Nt-1}] \\
 &= [\overline{M}_t - M_{Nt}] + v_t P_t y
 \end{aligned} \tag{4}$$

This says that the level of L households' consumption spending in the current period is *constrained* by the amount of money available to them. This, in turn, is equal to the exogenous amount which can be borrowed from banks following any central bank monetary policy operation in the current period after the loan demand of N agents, who get priority access to bank funding is satisfied, plus the varying amount that may become available from the efficiency or productivity of money as reflected in velocity (v), which is proportional to current sales [i.e., $v_t P_t y$ in total].

In contrast, the consumption of N agents is the outcome from the optimising framework in equations (2) and (3) above. We denote it by c_N and their nominal

expenditures in period t is $P_t c_{Nt}$, or C_{Nt} . The consumption spending of N households is, therefore, completely independent of the level of funding.⁵

Multiplying equation (1) by P_t , and substituting in for the nominal expenditures of L and N households, we obtain the following:

$$\begin{aligned} P_t y &= \lambda P_t c_{Lt} + (1 - \lambda) C_{Nt} \\ &= \lambda (\bar{M}_t - M_{Nt}) + \lambda v_t P_t y + (1 - \lambda) C_{Nt} \end{aligned}$$

Therefore,

$$P_t = \left[\frac{\lambda}{(1 - \lambda v_t) y} \right] (\bar{M}_t - M_{Nt}) + \left[\frac{1 - \lambda}{(1 - \lambda v_t) y} \right] C_{Nt},$$

and

$$P_t = \left[\frac{\lambda}{(1 - \lambda v_t) y} \right] \bar{M}_{Lt} + \left[\frac{1 - \lambda}{(1 - \lambda v_t) y} \right] C_{Nt}(r_t) \quad (5)$$

Equation (5) indicates the determination of the price level in this segmented markets model. In this representation, the price level is determined at any point in time, firstly, by that part of the money stock held by L households, \bar{M}_L , which is exogenously determined by the monetary policy actions of the central bank and the loan supply behaviour of commercial banks in an asymmetric information setting, and, secondly, by the (realised) consumption plans of N households which, according to the optimising framework in equations (2) and (3), is only a function of the real rate of interest (i.e., r) as shown in equation (5).⁶

Equation (5) can be described as a modified quantity theory equation. In taking account of the difference between L and N households, it says that the strict version of the quantity theory only holds when $\lambda = 1$, i.e., in a financially repressed and/or

⁵ In ALW, the consumption of traders depends on the change in the money supply that occurs in open market operations. Our specification differs from ALW in that the consumption of N agents does not in any way depend on funding availability. N agents' consumption spending is the outcome of the unconstrained optimising framework in equations (2) and (3) in the text.

⁶ For convenience, it is only written explicitly as a function of r in the last equation.

highly regulated financial system where liquidity constraints are pervasive.⁷ When λ is less than one, only that part of the money stock held by L agents impacts on the price level. N agents are able to adjust their money balances passively and smoothly to whatever level is needed to fund their desired level of expenditure. It is monetary policy's effect on the real interest rate that allows it impact N's optimal level of consumption spending relative to the fixed consumption endowment and, in turn, impacts the price level.

- *Price Level Disequilibrium*

Equation (5) indicates the determination of the price level at any given time. It is not necessarily, however, a price level consistent with long-run equilibrium. For L consumers, their money holding, \bar{M}_{Lt} , may exceed or fall short of their demand for money. For N consumers, the real interest rate, r , may deviate from its long run equilibrium value. Price stability (denoted here by P^*) only occurs in the (possibly rare) event when both agents are in portfolio equilibrium simultaneously. This happens when L households have their demand for money fulfilled exactly and N households are not subject to any incentive to adjust their consumption levels arising from a gap between the actual and equilibrium real rates of interest. The equilibrium version of equation (5) is written as follows:

$$P_t^* = \left[\frac{\lambda}{(1-\lambda v_t)y} \right] M_{Lt} + \left[\frac{1-\lambda}{(1-\lambda v_t)y} \right] C_{Nt}(r_t^*) \quad (6)$$

Price stability occurs when L households have their demand for money satisfied exactly (i.e., $\bar{M}_{Lt} = M_{Lt}$) and the actual real interest rate is equal to its natural or equilibrium level (i.e., $r = r^*$), obviating any incentive for either L or N households to alter their level of consumption.

Subtracting equation (6) from (5) then gives the following:

$$P_t - P_t^* = \left[\frac{\lambda}{(1-\lambda v_t)y} \right] (\bar{M}_{Lt} - M_{Lt}) + \left[\frac{1-\lambda}{(1-\lambda v_t)y} \right] [C_{Nt}(r_t) - C_{Nt}(r_t^*)] \quad (7)$$

⁷ If the segmentation assumption is dropped and all agents are assumed to be liquidity-constrained (i.e., λ set equal to 1) in equation (5) we get the standard quantity theory equation identical to ALW's equation (4).

Equation (7) indicates that deviations of the price level, P , from its equilibrium value, P^* , are owing to actual money balances deviating from desired levels and the real interest rate differing to the equilibrium rate. These deviations occur as a result of monetary policy actions upsetting the portfolio equilibrium of both L and N households at the same time. They leave L agents with either a deficiency of money balances (forcing them to cut consumption expenditure) or a surplus (encouraging them to spend more than they had planned), while N agents face a real rate of interest which is either in excess of the equilibrium rate (thereby causing a retrenchment in consumption) or falls short of it (inducing N agents to increase consumption spending). As portfolio equilibrium is restored, consumption spending is driven above or below the fixed endowment driving the price level above or below P^* . As can be seen from equation (7), only when portfolio equilibrium is fully restored (i.e., $\bar{M}_{Lt} = M_{Lt}$ and $r_t = r_t^*$) is price stability re-established (i.e., $P_t = P_t^*$).

- Price Level Adjustment

The price disequilibrium embodied in equation (7) is resolved through the price level adjusting to the equilibrium level. The inflation (deflation) of the price level required to resolve the disequilibrium, in turn, must be generated by the nominal money gap and real interest rate gap on the right-hand-side of (7). The implication for empirical work is that inflation can be modelled as a function of these two gaps.

We note that the money gap can be expressed as follows: since,

$$\bar{M}_{Lt} = \bar{M}_t - M_{Nt},$$

then

$$\begin{aligned} \bar{M}_{Lt} - M_{Lt} &= \bar{M}_t - (M_{Lt} + M_{Nt}) \\ &= \bar{M}_t - M_t \end{aligned} \tag{8}$$

This, intuitively and conveniently, allows L household money disequilibrium to be replaced by economy-wide money disequilibrium since the N households are always in equilibrium with respect to money holdings.

We invoke the mean-value theorem to rewrite part of the second term on the right hand side of equation (7), as follows:⁸

$$C_{N_t}(r) - C_{N_t}(r^*) = C'_{N_t}(\rho)(r - r^*) \quad (9)$$

We assume that adjustment of the price level to its equilibrium value in the next period takes place, at a fraction, θ , of the current period discrepancy.

Accordingly, inflation in period $t+1$, can be expressed as:

$$\begin{aligned} \Delta P_{t+1} &= P_{t+1} - P_t = \theta(P_t - P_t^*) \\ &= \left[\frac{\theta\lambda}{(1 - \lambda v_t)y} \right] (\bar{M}_t - M_t) + \left[\frac{\theta(1 - \lambda)C'_{N_t}(\rho)}{(1 - \lambda v_t)y} \right] (r_t - r_t^*) \end{aligned} \quad (10)$$

4. An Empirical Assessment of the Segmented Markets Model

- Measures of Inflation and Two Gap Variables

We use US data, covering the period 1961q2 to 2005q1, to test the segmented markets model of inflation embodied in equation (10). The measure of inflation used is the quarter-to-quarter change in the natural log of CPI, which we denote by the familiar notation, π , while the aforementioned two gap variables are the explanatory variables.⁹

Given equation (10), the appropriate two gap variables are, respectively, a nominal money gap and a real interest rate gap. The nominal money gap, which we denote as MGAP, is the residual term from a money demand equation, of the following form:

$$M_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t \quad (11)$$

⁸ The mean-value theorem (see Chiang, 1984) states that the difference between the value of a function ϕ evaluated at x_0 and at any other x value can be expressed as the product of the difference $(x - x_0)$ and the first derivative, ϕ' , of the function evaluated at some point, ρ , between points x and x_0 , i.e., $\phi(x) - \phi(x_0) = \phi'(\rho)(x - x_0)$. Proceeding analogously here gives us the right-hand-side of equation (9) in the text.

⁹ The data used in the paper are described in Appendix 1.

where M is the nominal money stock ($M2$), P is the price level (CPI) and Y is real GDP, with these variables also measured in natural logs. This money demand specification captures a pure transactions demand for money in the spirit of cash-in-advance with money demand specified, therefore, as a function of a constant and nominal income. The residual term represents the deviation of money balances in the economy from that demanded. Given that all N households are *always* on their money demand schedules, it is exclusively the L sector of the economy that experiences an excess or deficiency of real balances. Accordingly, MGAP provides the appropriate measure of the extent of portfolio (or monetary) disequilibrium facing the L sector. It provides our indicator of the inflationary pressures emanating from the liquidity-constrained sector of the economy. MGAP then is the residual from the full-sample OLS regression of (11) above:

$$M_t = -3.59 + 0.895 P_t + 0.819 Y_t$$

The real interest rate gap, $r_t - r_t^*$, captures the other channel of inflationary pressures that originate in monetary policy and which are transmitted via the actions of the non-liquidity-constrained sector of the economy. The actual real interest rate is the only variable which the central bank can affect which is simultaneously a binding constraint on the consumption expenditures of the N sector. A fall in the actual real interest rate brought about by monetary policy drives a wedge between the actual real rate and the equilibrium real rate, which is assumed to remain unaffected by monetary policy. This stimulates expenditures by N sector agents but, given the fixed endowment of goods and services, this can only result in a pick-up in inflation.

To estimate the equilibrium real interest rate, we use the consumption-based capital asset pricing model (CCAPM). We invoke equations (2) and (3) above. Since N households are assumed to be able to borrow (and lend) without restriction at the real interest rate, r , the first-order condition for optimum consumption is given by equation (3). A generalised Fisher equation is derived from the CCAPM. An estimate of the equilibrium real interest rate facing N households is embedded within this equation. There are three steps involved in the derivation of the equilibrium real interest rate. First, an equilibrium condition between the nominal and real rates of interest is derived. Secondly, an expression for the equilibrium real rate is obtained from the condition that the one-period real rate of interest must equal the ex-ante

marginal rate of substitution between the consumption of N households now and in the next period. In the third step, this expression for the equilibrium real rate is substituted back into the equilibrium condition derived in the first step above to obtain, after some algebra, the following generalised Fisher equation:

$$i_t = \gamma E_t \Delta c_{t+1} - \frac{1}{2} \gamma^2 \text{Var}_t(\Delta c_{t+1}) + \delta + E_t \Delta p_{t+1} - \frac{1}{2} \text{Var}_t(\Delta p_{t+1}) - \gamma \text{Cov}_t(\Delta c_{t+1}, \Delta p_{t+1}) + \Delta M_{t+1} \quad (12)$$

This is an equation relating the nominal rate of interest to a number of terms.¹⁰ The equilibrium real rate of interest comprises the first three terms in equation (12), namely the sum of the discount rate (δ), the coefficient of relative risk aversion (γ) times expected consumption of N households ($E(\Delta c)$), less one-half times the product of the square of the coefficient of relative risk aversion times the variance of expected consumption of N households ($\text{Var}(\Delta c)$).

Note that in equation (12) the N subscript on c has been dropped. Since the consumption expenditures of N households are not observed in the data, we are constrained to use total household consumption expenditures, c, in place of c_N in the empirical implementation of the model. This does not pose a problem. This is because the model's parameter estimates in equation (12) will only reflect the behaviour of N households since the consumption expenditures of L households do not impact on the rate of interest. In other words, under the hypothesis that the consumption expenditures of L households have no impact on the loan rate of interest (refer back to Figure 2), the effect of the consumption of N households on the interest rate will be the same as that of total consumption on the interest rate. As shown in Figure 2, the borrowing and expenditure decisions of L households are not affected by the loan rate of interest because the rate they would be willing to pay is well in excess of the cap the banks place on the actual rate. It is also clear from this diagram that the variation in the consumption expenditures of L households do not impact on the rate of interest.¹¹

¹⁰ The detailed derivation of equation (12) and explanation of all terms is presented in Appendix 2.

¹¹ Or do so only very slightly in the $L^{\text{MAX}} - L^{\text{N}}$ range.

The method for estimating equation (12) is described in Appendix 2, with the sum of the first three terms above giving us an estimate of the equilibrium real interest rate. The difference between this and the actual real rate (i.e., the nominal rate minus the expected inflation rate) is then our estimate of the real interest rate gap.

- Unit Root Properties of Inflation and Two Gap Variables

We first consider the unit root properties of the three variables, π , MGAP and $r - r^*$, used in the empirics. We use Augmented Dickey-Fuller (ADF) and the non-parametric Phillips-Perron (PP) statistics to test the order of integration of the level and first-difference of each variable. The lags for the ADF statistics are selected using the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC). For the PP statistic, we follow Greene (2003, p.267) in using the smallest integer greater than or equal to the sample size to the power of $1/4$ in choosing the truncation point for the Newey-West adjustment required for calculating the PP statistic.

Table 1: Augmented Dickey-Fuller and Phillips-Perron Statistics, 1961q2-2005q1

	π	MGAP	$r - r^*$
<i>LEVELS</i>			
ADF (AIC)	-2.45	-2.47	-2.64
ADF (SBC)	-2.45	-2.03	-2.38
Phillips-Perron	-3.46	-1.47	-2.40
Critical 95 per cent value	-2.88	-2.88	-2.88
<i>FIRST DIFFERENCE</i>			
ADF (AIC)	-15.64	-5.38	-5.35
ADF (SBC)	-15.64	-9.65	-12.06
Phillips-Perron	-22.56	-8.35	-11.58
Critical 95 per cent value	-2.88	-2.88	-2.88

The statistics, reported in Table 1, are unequivocal in indicating each of the two gap variables to be integrated of order one. The evidence is more mixed for the rate of inflation, π , with both ADF statistics indicating a unit root process, while the PP statistic points to a stationary series. We found that the autocorrelation function for the rate of inflation was significant up to seven lags and a plot of the autocorrelation function dies away quite slowly, an indicator of a non-stationary process, while the

autocorrelation of the first difference of the inflation rate falls away to zero rapidly.¹² This can be taken as indicating that the inflation process is an I(1) process. We, therefore, choose to take the inflation rate to be a unit root process, a conclusion that has been drawn previously (for example, by Hallman, Porter, and Small, 1991). We do not see anything awry in the inflation rate and two gap measures, which are all dependent on the practice of monetary policy over time, not being mean-reverting in practice.

- *Cointegration Analysis*

With the three variables, π , MGAP and $r - r^*$, each integrated of order one, the Johansen procedure provides an appropriate estimation method to discern whether there is a long run cointegrating relationship between these variables and whether the signs on the two gap variables are consistent with our theoretical expectation. It also provides a basis for examining the short-run dynamic movements of π .

We first run unrestricted VARs up to lag 24, adding a constant and time trend term to the three variables, in order to select the appropriate lag for the cointegrating VAR estimations. The SBC favours a second-lag ordering but the underlying equations at this lag have serially correlated error terms and so this lag length is discounted. The AIC selects lag 18 and in this case all three equations have serially *uncorrelated* terms. This is also the first lag length suggested suitable by a Likelihood Ratio test. In contrast to the lag ordering suggested by the SBC, this longer lag length also gives, as we shall see, economically sensible results. We are unsurprised at a longer lag length giving better results as we would expect both gap terms to be subject to long and variable lags in transmitting to inflation, given our earlier discussion of how the gap variables will be chronologically close to monetary policy actions and therefore at some remove from the ultimate outturn of those actions, i.e. inflation/deflation.

A VAR ordering of eighteen is then chosen. The time trend is insignificant in the unrestricted VARs and, accordingly, we estimate the cointegrating VARs with a restricted intercept but no trend in the cointegrating VARs. In the econometric estimations, we stipulate the two gap variables as the exogenous or long-run forcing

¹² A similar exercise for MGAP and $(r-r^*)$ yielded similar findings for those two variables.

variables and π as the endogenous variable. The trace and maximum eigenvalue statistic are identical in this case and reject the null hypothesis of no cointegrating relation among the three variables in favour of one cointegrating relationship, as we would expect, with the reported statistic of 25.97 being well above the 95 percent critical value of 15.27.

We normalise this cointegrating VAR on π and find the estimated coefficients, with t-statistics in brackets, on the two gap variables to be significant and of the expected sign:

$$\pi_t = 0.0098 + 0.0678 \text{MGAP}_t - 0.0025 r_t - r_t^*$$

(16.72) (5.30) (5.21)

The nominal money gap has a positive value, indicating that when nominal money balances exceed the amount consistent with real demand for them, inflation will rise to remove this discrepancy. The sign on the real interest rate gap is negative: when the actual real rate is less than the natural rate, inflation will increase.

- Short-Run Dynamic Analysis

With favourable cointegration results, we proceed to examining the short-run dynamics of inflation. The first-difference of π , $\Delta\pi$, is the dependent variable and is regressed on seventeen lags of itself, seventeen lags of the first difference of each of the two gap variables, and the error term, ECM, from the cointegrating VAR, lagged one quarter. This error correction term is the difference between actual inflation and fitted inflation. The latter, of course, depends on the two gap variables and is, accordingly, the measure of monetary policy-driven or, for shorthand, “monetary” inflation. For space considerations, we report only the estimate of the coefficient on the ECM term in Table 2, along with relevant diagnostic results for the regression equation.

The results are very satisfactory: the error correction term (the difference between actual and fitted/“monetary” inflation) has the correct sign and the speed-of-adjustment coefficient has an absolute value of 0.52, indicating a fast correction of actual inflation to its long run, monetary determinant. Diagnostic tests reveal the error terms to be serially uncorrelated and not to display ARCH. Some non-normality, however, is present but this should not be unexpected when dealing with

the rate of change in inflation. CUSUM and CUSUMQ tests, not shown, are also comfortably passed and the RESET statistic is supportive of the functional form specification. Finally, the regression equation has an R-square value of 0.70.

Table 2: Short-Run Dynamic Equation Results for Inflation, 1966q1 – 2005q1

$\Delta\pi_t = \dots -0.52 \text{ ECM}_{t-1}$ <p style="text-align: center;">(4.34)</p> <p>(t-statistics in brackets)</p>
$R^2 = 0.70;$ LM test for serial correlation (χ^2 , 4 DF) = 5.59; Bera-Jarque normality test (χ^2 , 2 DF) = 15.66 RESET test for functional form (χ^2 , 1 DF) = 1.19 ARCH test (χ^2 , 4 DF) = 2.78

- Other Econometric Analysis

We conclude our empirical analysis with two exercises. First of all, the robustness of the cointegration and short-run dynamic equation results is checked by reestimating for a shorter sample period, from 1961q2 to 2000q1. The results do not differ qualitatively from our baseline, full-sample results. Secondly, we examine whether π is cointegrated with each individual gap variable on its own. The maximum eigenvalue/trace statistic indicate the absence of any cointegrating relationship in either case – results that point to the need for both gap variables to be used together in explaining inflation.

5. Conclusion

In this paper, we have proposed a theory of inflation based on the distinction between two types of agent, or household, who populate the non-financial sector of the economy. The distinction is based on the idea that households fall into one or other of two categories. They are either liquidity constrained or not liquidity constrained. This implies that monetary policy is transmitted to the economy and impacts on the price level exclusively via two generically different channels, which correspond to the distinct behaviour of these two types of households.

Our model provides a richer representation of price level determination than standard Quantity Theory or Wicksellian explanations. It shows the price level being determined by the actions of both types of household and, accordingly, monetary policy affecting the price level through two channels, i.e., via the money stock available to liquidity-constrained households and via the real interest rate which matters to the intertemporal allocation of consumption expenditures by non-liquidity constrained households. The first channel is similar to the monetarist explanation of the process of inflation while the second is in line with Wicksellian descriptions. Yet, because each channel relates only to one of the two sectors, neither on its own gives a complete account of the inflation process.

A key implication of the model then is that there is no choice to be made between modelling inflation as being channelled either through a financial price (i.e., an interest rate) or a financial quantity (i.e., a credit or monetary aggregate) as both channels operate simultaneously. This is because any monetary policy action impacts on the two types of households differently arising from their contrasting experiences in the bank loans market. Two tension variables are derived which capture the portfolio disequilibria of the two types of households following a change in the monetary policy stance. The expenditure patterns of the two sets of households are affected in different ways as they endeavour to re-attain their respective portfolio equilibrium positions. In the assumed fixed-endowment economy, these actions generate inflation or deflation depending on the direction of the monetary policy action driving the process.

Accordingly, we believe that a complete picture of the inflation generated by the central bank requires that both channels be accounted for. On the empirical front, it means that the two channels of transmission corresponding to the Wicksellian real interest rate gap (i.e., the difference between the actual and equilibrium real interest rates affecting the consumption patterns of non-liquidity constrained agents) and the quantity-theoretic money gap (i.e., the difference between the demand for money balances and the stock of money balances outstanding affecting the consumption of liquidity-constrained agents) are joint indicators of inflationary pressures arising from monetary policy actions. Empirically, the segmented markets model then indicates that the nominal money gap and the real interest rate gap are joint indicators of

inflationary pressures arising from monetary policy actions and that neither on its own is a sufficient indicator. This is supported by our econometric results for the US.

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Appendix 1: Data Description

Consumer Price Index for All Urban Consumers: All Items,
1982-84=100, Seasonally Adjusted.

Source: U.S. Department of Labor: Bureau of Labor Statistics.

M2 Money Stock,

Billions of Dollars, Seasonally Adjusted.

Source: Board of Governors of the Federal Reserve System.

Real Gross Domestic Product,

Billions of Chained 2000 Dollars, Seasonally Adjusted Annual Rate.

Source: U.S. Department of Commerce, Bureau of Economic Analysis.

3-Month Treasury Bill: Secondary Market Rate,

Non-Adjusted.

Source: Board of Governors of the Federal Reserve System.

Real Personal Consumption Expenditure,

Billions of Chained 2000 Dollars, Seasonally Adjusted Annual Rate.

Source: U.S. Department of Commerce, Bureau of Economic Analysis.

Consumer Price Index for All Urban Consumers: All Items less Energy,
1982-84=100, Seasonally Adjusted.

Source: U.S. Department of Labor: Bureau of Labor Statistics.

Total Reserves, Adjusted for Changes in Reserve Requirements,

Billions of Dollars, Seasonally Adjusted.

Source: Board of Governors of the Federal Reserve System.

Appendix 2: Estimation of Equilibrium Real Interest Rate

Assume a single consumption good and that utility is isoelastic and time separable. An individual representative N-household consumer maximises expected utility over an infinite horizon:

$$E_t \sum_{i=0}^{\infty} \Phi^i \frac{1}{1-\gamma} C_{t+i}^{1-\gamma} \quad 0 < \Phi < 1, \gamma > 0 \quad (i)$$

where E_t represents expectations conditional on information available in period t , Φ is the discount factor, and γ is the coefficient of relative risk aversion.¹³

Equilibrium asset returns are established from the first-order condition of the representative consumer's maximisation problem. The first-order condition is:

$$C_t^{-\gamma} = \Phi E_t [C_{t+1}^{-\gamma} Q_{t+1} / Q_t] \quad (ii)$$

where Q_t is the value of an asset stated in terms of consumption goods in period t .

If it is assumed that the asset is a nominal bond, with a nominal interest rate of I_t , then the ex-post real return, R_t , on investing in nominal bonds between periods t and $t+1$ is:

$$(1 + I_t) P_t / P_{t+1} = Q_{t+1} / Q_t$$

where P_t is the nominal price of a good at time t and where

$$1 + R_t = Q_{t+1} / Q_t$$

Therefore,

$$(1 + I_t) P_t / P_{t+1} = 1 + R_t$$

Optimal portfolio choice requires expected yields on nominal and real bonds of identical maturity be equivalent when considered in terms of expected utility.

¹³ Unlike the main text of the paper, where upper-case is used to denote nominal variables and lower-case to refer to real variables, in this annex upper-case denotes a non-log variable and lower-case is used for log variables.

Adding expectations and the marginal utility of consumption in $t + 1$ establishes the equilibrium condition for an individual consumer:

$$E_t [U'(C_{t+1})(1 + I_t)(P_t / P_{t+1})] = E_t [U'(C_{t+1})(1 + R_t)]$$

where P_t / P_{t+1} is the change in purchasing power of money over one period, and $U'(C_t)$ the marginal utility of consumption in period t .

The first-order condition for nominal bonds is:

$$C_t^{-\gamma} = \Phi E_t [C_{t+1}^{-\gamma} (1 + I_t) P_t / P_{t+1}] \quad (\text{iii})$$

Applying log normality allows equation (iii) to be rewritten as the equilibrium asset-pricing condition:

$$i_t = r_t + E_t \Delta p_{t+1} - \frac{1}{2} \text{Var}_t (\Delta p_{t+1}) - \gamma \text{Cov}_t (\Delta c_{t+1}, \Delta p_{t+1}) \quad (\text{iv})$$

A separate expression for the equilibrium real rate of interest, i.e., r_t in expression (iv), is obtained from the condition that the one-period real rate must equal the ex-ante marginal rate of substitution between consumption now and consumption in the next period. This can be derived by considering the return on a real bond. If the known real rate of interest at time t is R_t , then the purchase of a real bond in period t for Q_t consumption goods entitles the holder to $Q_t(1 + R_t) = Q_{t+1}$ goods in $t + 1$.

The first-order condition for a real bond is found by substituting this relationship into equation (ii):

$$C_t^{-\gamma} = \Phi E_t [C_{t+1}^{-\gamma} (1 + R_t)] \quad (\text{v})$$

Equation (v) is the equilibrium relationship between the real rate of interest and the ex-ante intertemporal marginal rate of substitution. Applying the assumption of log normality and rearranging defines the log of the real rate:

$$r_t = \gamma E_t \Delta c_{t+1} - \frac{1}{2} \gamma^2 \text{Var}_t (\Delta c_{t+1}) - \phi \quad (\text{vi})$$

where $\phi = \log \Phi$. If the future is heavily discounted (i.e., a high value of discount factor, Φ), current consumption is greater and savings are lower.

We are now in a position to derive a relationship between the nominal interest rate and its proximate determinants. By substituting equation (vi) into (iv) and adding Δm to capture a liquidity effect on the nominal rate of interest, as first modelled by Fuerst (1992), we can derive the following generalised Fisher equation:

$$i_t = \gamma E_t \Delta c_{t+1} - \frac{1}{2} \gamma^2 \text{Var}_t(\Delta c_{t+1}) + \delta + E_t \Delta p_{t+1} - \frac{1}{2} \text{Var}_t(\Delta p_{t+1}) - \gamma \text{Cov}_t(\Delta c_{t+1}, \Delta p_{t+1}) + \Delta m_{t+1}$$

Note that the discount rate (δ) is minus the log of the discount factor (Φ), i.e., $\delta = -\ln \Phi$ and Δm_{t+1} represents a liquidity effect.¹⁴ An OLS estimation of this final equation rendered values of 1.5 for δ and 0.16 for γ .¹⁵ These were then used to generate the equilibrium real interest rate estimate.

¹⁴ We proxy the liquidity effect, Δm , by the change in total bank reserves (monetary base less notes and coin).

¹⁵ The basic data for i , c , p and m used in this estimation are, respectively, the last four variables described in Appendix 1.