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Money Demand in a Banking Time Economy

ABSTRACT

The paper presents a theory of the demand for money that combines a special case of the shopping time exchange economy with the cash-in-advance framework. The model predicts that both higher inflation and financial innovation - that reduces the cost of credit - induce agents to substitute away from money towards exchange credit. This results in an interest elasticity of money that rises with the inflation rate rather than the constant elasticity found in standard shopping time specifications. A number of the key predictions of the banking time theory are tested using quarterly data for the US and Australia. We find cointegration empirical support for the model, with robustness checks and a comparison to a standard specification.

JEL-Classification: O42, E13, E41, E51

Keywords: money demand, cointegration, financial technology, banking time

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1. Introduction

In recent years a growing number of countries have adopted inflation rate targeting policies. In 1989 New Zealand instituted the first inflation rate targeting policy and has subsequently been followed by Australia, Canada and the EU through its low-inflation Maastrich Treaty criterion. Eastern and Central European countries are also following, as they work towards accession to the EU, with the Czech Republic, Poland, and Hungary all adopting inflation targeting policies in recent years. One result of the spread of inflation rate targeting has been a waning interest in the modelling of money demand and in determining whether a stable specification for money demand can be found. The conventional wisdom is that an inflation rate targeting policy that in effect is close to a Taylor (1993) rule really does not require knowledge of the underlying money demand, or its stability.

McCallum (1999) challenges such conventional wisdom of the unimportance of money demand by arguing that when money supply rules are directly compared to Taylor rules they can sometimes do better. He provides an example, of Japan in the late 1990s, when a money supply rule seems to have better forewarned that Japanese monetary policy was too restrictive. McCallum suggests that money demand still may be important but that it needs to be considered from general equilibrium perspectives such as the shopping-time exchange models in order to develop policy models further.

In our view there are other reasons for continuing to understand better money demand. The ability of a general equilibrium model, such as the neoclassical endogenous growth model, to explain money demand is simply another test of the same model just as explaining the equity premium, business cycles, and growth. Given a general consensus of a unitary income velocity of money, the key remaining feature of money demand that general equilibrium models should be able to explain is the interest elasticity and its relation to the inflation tax. The interest elasticity of money demand is key to several central issues of monetary economics. (1) Hyperinflation: Cagan (1956) could only explain this with an interest elasticity of money that rises with the inflation rate (a constant semi-interest elasticity). The question is whether this model of money demand can also account for moderate and low inflation. (2) The cost of a suboptimal inflation rate policy: Lucas (2000) compares the Cagan model with a constant elasticity model using historical US data and shows how different are the welfare costs of a non-Friedman optimal rate of inflation under the two different money demand functions. (3) Growth rates: Bailey's (1956) static analysis of inflation as a tax has been extended to the endogenous balanced growth model. Increases in the tax cause decreases in the growth rate (Gomme, 1993, Chari, Jones, and Manuelli 1996). The degree to which the growth rate is decreased by the inflation tax also can depend on the degree to which the sensitivity to the tax is affected as the inflation rate rises. Gillman and Kejak (2002) demonstrate how a rising interest elasticity, and tax sensitivity, implies a smaller negative marginal effect on growth at high rates, as the inflation rate increases, and a bigger negative effect at low inflation rates. This is consistent with Cagan's model but not a constant interest elasticity model.

Different monetary models have been used in general equilibrium for introducing money into the neoclassical model, including money-in-the-utility function models of Eckstein and Leiderman (1992), and Lucas (2000), and the cash-in-advance models of Cooley and Hansen (1989), Gomme (1993), Gillman (1993), and Aiyagari, Braun, and Eckstein (1998). In all of those economies the interest elasticity varies with the inflation rate, generally with greater variations in economies where credit is not fixed into the preferences but rather is used according to its real resource cost relative to money in the purchase of any good. Another economy that requires resources for exchange is the shopping time model of McCallum and Goodfriend (1987). Lucas (2000) has used this model for measuring welfare costs, while Gavin and Kydland (1999) used it for analysing monetary shocks in the business cycle. In both of these applications, the shopping time function is specified so that the interest elasticity is constant. Thus the cash-in-advance economies and the shopping time economies make directly conflicting predictions about the nature of the interest elasticity of money demand.

This paper presents a way to resolve the interest elasticity conflict. It develops a monetary endogenous growth economy that uses a cash-in-advance constraint with Aiyagari et al (1998) type credit and at the same time is a special case of the McCallum and Goodfriend (1987) exchange technology. This combination of cash-in-advance with shopping time is done through the device of having both money and credit available for goods purchases, as in Gillman (1993) and Aiyagari et al (1998). However, rather than simply specifying that time is used up in credit activity, the time used in credit services is specified through a standard production function for such services with diminishing returns to labor. Such microfoundations for the banking time allows the Clower (1967) constraint to be rewritten in a form equivalent to a special case of the shopping time function, with the only restriction being a Cobb-Douglas production function for credit services with diminishing returns to banking time. Real resources are used in the economy when avoiding the inflation tax, a feature of the shopping time model emphasized by Lucas (2000). However in contrast to the standard shopping time the interest elasticity of money demand rises with the rate of inflation rather than being constant. This varying interest elasticity is not forced on the model, but rather follows in a direct way from the simple assumption that credit services are produced with a diminishing returns technology. Critically it is the inclusion of the productivity of credit services in the model, not found in the standard shopping time approach, that also leads us to find evidence of an empirically stable money demand function. The results show time series importance of a finance sector productivity variable, in a way related to Choi and Oh (2003).

The remainder of this paper has the following structure. In Section 2 the general equilibrium the money demand is outlined and a testable model is derived. The data to be used in the study are described in Section 3. Section 4 provides empirical results for US and Australian money demand. The relationship of our findings to some debates on modelling money demand is also presented in Section 6, along with our conclusions.

2. A Banking Time Model

Consider a representative agent who consumes the good $c(t)$ and leisure $x(t)$ and has a current period utility function given by,

(1) $$u = \ln c(t) + \alpha \ln x(t) .$$

Clower Constraint

The agent can purchase the good using either money, denoted by $M(t)$, or with exchange-credit. Letting $a(t) \in (0,1]$ denote the fraction of purchases of the aggregate consumption good that the agent chooses to make with money, the cash-in-advance, or Clower constraint is

(2) $$M(t) = a(t)P(t)c(t)$$

where $P(t)$ is the price of the consumption good. Defining real money balances as $m(t) \equiv M(t)/P(t)$, real money demand in equilibrium is $m(t) = a(t)c(t)$. It is apparent that the model predicts a unitary consumption elasticity and a (variable) consumption velocity of money equal to the inverse of the fraction $a(t)$.

Production of Goods, Credit and Human Capital

Goods are produced with a Cobb-Douglas technology involving physical capital, denoted by $k(t)$, and effective labour, which equals the human capital stock, denoted by $h(t)$, factored by the fraction of time spent in goods production, denoted by $l_G(t)$. With $A_G \in \mathbb{R}_{++}$ a shift parameter, $\beta \in (0,1)$ and $y(t)$ denoting the total output of goods that can be converted costlessly to capital, production of goods is given by

(3) $$y(t) = A_G \left[l_G(t) h(t) \right]^{\beta} k(t)^{1-\beta}.$$

Credit services are produced using only effective labour via a diminishing returns technology. In particular, let $l_F(t)$ denote the fraction of labour-time required per unit of goods that are purchased with credit. Then $l_F(t)h(t)$ is the effective, or human-capital indexed, labour required per unit of goods bought with credit, and $l_F(t)c(t)$ is he total banking time of the agent. The share of goods bought with credit is given by $1-a(t)$. With $\gamma \in (0,1)$ and with $A_F \in \mathbb{R}_{++}$ a shift factor, the credit services production technology is given as

(4) $$1-a(t) = A_F (l_F(t) h(t))^{\gamma}.$$

By making the credit service profit maximization problem explicit, it can be shown that $\gamma = w(t)h(t)l_F(t) \big/ \left[R(t)\left(1-a(t)\right) \right]$, and that $1-\gamma = \pi(t) / \left[R(t)\left(1-a(t)\right) \right]$, where $\pi(t) = \left(P_F(t)/P(t) \right)\left(1-a(t)\right) - w(t) l_F(t) h(t)$, and $P_F(t)/P(t) = R(t)$, given that $P_F(t)$ is the nominal price of credit services, $\pi(t)$ is the real profit that the credit services firm maximizes subject to the production technology (4), and $R(t)$ is the nominal interest rate. This implies that the share of effective labor in output is the constant γ, and the share of profit in output is the constant $1-\gamma$, similar to a Cobb-Douglas production function. This technology implies that as the share of goods bought with credit increases, for a given consumption basket, the per-unit credit cost rises marginally because of diminishing marginal returns to labour.

The rate of human capital investment is proportional to the effective time spent in human capital accumulation. The fraction of time spent accumulating human capital is obtained by subtracting the fraction of time in leisure, in goods production, and in credit services from unity, $1-x(t)-l_G(t)-l_F(t)c(t)$. With $A_H \in \mathbb{R}_{++}$ denoting a shift parameter, then human capital investment is given as

$$\dot{h}(t) = A_H(1-x(t)-l_G(t)-l_F(t)c(t))h(t) \tag{5}$$

Banking Time

Using equation (4) the agent's Clower constraint can be written as

$$M(t) = [1-A_F(l_F(t)h(t))^{\gamma}]P(t)c(t) \tag{6}$$

while the supply of money is assumed to grow at the constant rate $\sigma = \dot{M}(t)/M(t)$. The government returns its revenues to the agent in the form of a lump-sum transfer $V(t) = \sigma M(t)$. By solving the constraint (6) for the banking time, $l_F(t)c(t)$, there results a special case of the McCallum and Goodfriend (1987) shopping time constraint, as extended to the endogenous growth framework:

$$l_F(t)c(t) = \left[\left(1-m(t)/c(t)\right)/A_F\right]^{1/\gamma}\left[c(t)/h(t)\right]. \tag{7}$$ [1]

Income Constraint

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[1] Note that Love and Wen (1999) apply the shopping time model within the endogenous growth framework, in an interesting calculation of welfare costs, but exclude human capital from the shopping time function; in contrast here the derivation from the Clower and credit services production constraints implies the inclusion of human capital in the banking time term.

The nominal value of the financial capital stock, denoted by Q equals the sum of the money stock and the nominal value of the physical capital stock. It is given by

(8) $$Q(t) = M(t) + P(t)k(t).$$

The flow of nominal financial wealth is given by

(9) $$\dot{Q}(t) = \dot{M}(t) + P(t)\dot{k}(t) + \dot{P}(t)k(t).$$

This can be re-written in the following manner. The nominal value of the change in the physical capital stock is the value of nominal income minus consumption expenditure and depreciation of capital (assumed here to be zero). With $r(t)$ and $w(t)$ denoting the marginal product of capital and effective labour in goods production, the flow of nominal financial wealth becomes

(10) $$\dot{Q}(t) = r(t)P(t)k(t) + w(t)P(t)l_G(t)h(t) - P(t)c(t) + V(t) + \dot{P}(t)k(t).$$

2.1 Equilibrium Conditions and Money Demand

The agent is assumed to maximize the present value of utility given by (1) subject to the constraints given by (5), (6), (8) and (10) with respect to *c(t), x(t),* $l_G(t)$, $l_F(t)$, *h(t), k(t)* and *M(t)*. The Hamiltonian for this problem is given by,

(11) $$\begin{aligned} H = &\int_0^\infty e^{-\rho t}(\ln c(t) + \alpha \ln x(t)) \\ &+\phi(t)[M(t) - (1 - A_F(l_F(t)h(t))^\gamma)P(t)c(t)] \\ &+\varphi(t)[Q(t) - M(t) - P(t)k(t)] \\ &+\lambda(t)[r(t)P(t)k(t) + w(t)P(t)l_G(t)h(t) - P(t)c(t) + V(t) + \dot{P}(t)k(t)] \\ &+\mu(t)[A_H((1 - x(t) - l_F(t)c(t) - l_G(t))h(t)]. \end{aligned}$$

The agent's first order conditions can be expressed in the following form where the time subscripts are dropped, g is the balanced-path growth rate of output and R is the nominal interest rate.

(12) $$(1/c)/(\alpha/x) = (1 + aR + \gamma(1-a)R)/wh;$$

(13) $$g = r - \rho;$$

(14) $$-\dot{\mu}/\mu = A_H(1-x) = r;$$

(15) $$-\dot{\lambda}/\lambda = r + \dot{P}/P \equiv R;$$

(16) $$w = \beta A_G\left[A_H(1-x)/(1-\beta)\right]^{[(\beta-1)/\beta]};$$

(17) $$R = w\Big/\left[\gamma A_F(l_F h)^{\gamma-1}\right].$$

The first two conditions (12) and (13) describe substitution between goods and leisure and the balanced growth rate. Conditions (14) and (15) describe the real and nominal return on capital. Conditions (16) and (17) describe standard input price relations in the goods and credit service sectors. From the last equation (17) and the Clower constraint (6), the agent's money demand can be derived as

(18) $$m = [1-\gamma^{\gamma/1-\gamma}(R/w)^{\gamma/1-\gamma}A_F^{1/1-\gamma}]c.$$

Writing money demand in terms of its inverse income velocity,

(19) $$m/y = [1-\gamma^{\gamma/1-\gamma}(R/w)^{\gamma/1-\gamma}A_F^{1/1-\gamma}][c/y].$$

The solution for *c/y* follows from $c/y = 1/(i/y) = 1-(\dot{k}/k)(k/y) = 1-g(k/y)$. Since k/y is the average product of capital in the Cobb-Douglas production function of equation (3), $k/y = r/\beta$. Using this relation and substituting in for *g* from equation (13) gives that $c/y = \beta + (\rho/r)(1-\beta)$ and

(20) $$m/y = [1-\gamma^{\gamma/1-\gamma}(R/w)^{\gamma/1-\gamma}A_F^{1/1-\gamma}][\beta + (\rho/r)(1-\beta)].$$

Money demand depends negatively on the nominal interest rate R, with an interest elasticity of $\left[\gamma/(1-\gamma)\right]\left[(1-a)/a\right]$ that rises with *R*, positively on the real wage w (as in Karni, 1974, Dowd, 1990, and Goodfriend, 1997), and negatively on the level of productivity in the credit sector A_F. Although financial innovation has been considered as a factor of money demand in various ways, for example in Friedman and Schwartz (1982), Orden and Fisher (1994), Ireland (1995), Collins and Anderson (1998), and Mulligan and Sala-i-Martin (2000), the inclusion of A_F is a novel aspect of equation (20). A decrease in A_F increases the productivity of credit services and so decreases the demand for real money balances. Also novel is that the parameter γ, which determines the degree of diminishing returns in the credit sector, plays a key role in determining the magnitude of the interest elasticity.

The second factor in equation (20) depends on the real interest rate relative to the rate of time preference, in a way similar to the growth equation (13). An increase in the growth rate decreases the inverse money velocity through an interaction term $[1-\gamma^{\gamma/1-\gamma}(R/w)^{\gamma/1-\gamma}A_F^{1/1-\gamma}](\rho/r)(1-\beta)$ of part of the second factor with the first. This can be viewed as a procyclic influence on velocity that is reminiscent of Friedman's (1959) theory in which an increase in temporary income causes an increase in velocity in a procyclic fashion. Alternatively this might also be viewed as the way in which the equity premium possibly affects money demand, which Friedman (1988) allows for with the inclusion of stock prices in the money demand function.

2.2 Econometric Model Specification

The interaction term in equation (20) is assumed to be insignificant (or equivalently the assumption is $r \cong \rho$) although this presents an area for further research. Then using equation (20) without the interaction term as the basis for the empirical analysis in this paper, we can obtain a more tractable form for estimation with the approximation *(1-z) = -ln z*. This gives

(21) $$m/y = -\left([\gamma/(1-\gamma)] + [\gamma/(1-\gamma)]\ln R - [\gamma/(1-\gamma)]\ln w + [1/(1-\gamma)]\ln A_F\right).$$

For estimation purposes we write (21) as follows,

(22) $$(m_t / y_t) = \alpha_0 + \alpha_1 \ln R_t + \alpha_2 \ln w_t + \alpha_3 \ln A_{Ft} + u_{1t},$$

where u_{1t} is assumed to be a stationary error term, which reflects dynamic adjustment, measurement errors and (stationary) omitted variables. The comparative statics of equation (20) impose the following general sign restrictions on the parameters for the variables in (22): $\alpha_1 < 0, \alpha_2 > 0, \alpha_3 < 0$. Equation (21) and the Cobb-Douglas specification for credit production imply the additional variable restrictions that $-\alpha_1 = \alpha_2 = \gamma/(1-\gamma)$ and that $\gamma < 1$.

As an alternative to equation (22) we also consider a standard constant interest elasticity model for money demand:

(23) $$\ln(m_t / y_t) = \beta_0 + \beta_1 \ln i_t + \beta_2 \ln y_t + u_{2t}.$$

This is similar to the form estimated by Hoffman et. al. (1995), except that for comparability with (22) our dependent variable is inverse velocity. From standard theory we expect $\beta_1 < 0$, as it measures the interest elasticity of money demand, while the magnitude and sign of β_2 is ambiguous as it depends on the income elasticity of money demand. A unitary income elasticity (as implied by the exchange credit model) makes $\beta_2 = 0$, while an income elasticity less than (greater than) one makes β_2 negative (positive).

The key feature of this conventional specification is that it does not allow for the effect of changes in the cost of exchange credit on the demand for money. If for example the 1980s and 1990s represent a period during which the relative price of exchange credit fell sharply, due to the effects of deregulation and rapid technological progress in the financial sector, then according to the banking time model, the conventional specification should not be an adequate model of the demand for cash.

3. Data

A quarterly data set is constructed for the United States from 1976:1 to 1998:2 and for Australia from 1975:1 to 1996:2. These are periods when both of these countries experienced relatively high inflation, deregulation of the financial system and the growth of interest bearing exchange credit. The majority of series used in the paper are produced by government departments and official statistical agencies. However for some series we are forced to extrapolate or interpolate the available data. Definitions of the series used are provided in the Appendix A, while the full data set and the primary sources are available from the authors on request.

Two comments about the variables used in the paper are in order. In the theoretical model, money is a non-interest bearing means of payment that is costless to produce. Therefore in the empirical analysis we use a narrower monetary aggregate than M1 or M2, both of which have been widely used in previous empirical studies. These monetary aggregates include assets that we consider more like credit than our model's concept of money. The model suggests the use of a narrow monetary aggregate, which we measure as currency plus non-interest bearing bank deposits.

One problem that we face in estimating equation (22) for Australia is the lack of a useful measure of labour productivity in the finance sector. In Australia the official measure of aggregate output in the finance sector aggregate is obtained adding the value of inputs and assuming a zero growth rate for labour productivity. In the absence of a direct productivity measure for the Australian finance sector we use the real wage for that sector as a proxy. Provided factor markets are reasonably competitive, changes in the real wage will reflect productivity changes. It is apparent from equation (4) that the marginal product of labour in credit production depends on A_F. Lowe (1995) provides some empirical evidence, which suggests that the real wage in the Australian financial sector is a plausible indicator of productivity in that sector.

In proxying the productivity of the credit services sector by the real wage in the finance sector, as well as using the economy-wide real wage in the estimation, we are including two real wage rates. At first look this may appear counter-intuitive in that a single wage must prevail in the model economy. However, the single wage rate is that for homogenous labour. The actual wages vary between sectors as the effective human capital is different across sectors since the wages for the goods and credit services sectors are $wl_G h$ and $wl_F ch$, which are in general different

4. Empirical Results

The two models that we consider are given by equations (22) and (23). We view these models as alternative equilibrium relationships that potentially describe the long-run influences on money holdings. It is apparent from looking at plots of the variables that the series are non-stationary. Moreover the augmented Dickey-Fuller test for a unit root implies that it is not unreasonable to characterise the variables in the two models as integrated of order one[2]. Given the non-stationary nature of the data, our econometric strategy is to employ the cointegration techniques developed by Johansen (1995) to estimate the two alternative models.

Banking Time Model

Tables 1 and 2 present the results for United States and Australian data obtained from estimation of the banking time model using the Johansen procedure. The results for both countries are based on a VAR in levels with four lags, however

[2] The results from these tests are available on request.

(as indicated below) our results are not particularly sensitive to choice of lag length[3]. The trace and the λ-max statistics are used to test for the number of cointegrating vectors. Using a 5 percent level of significance the trace test points to a single cointegrating relationship among the four variables in the banking time model for both the United States and Australian data. The λ-max test is consistent with this finding for Australia, but provides slightly weaker support for a cointegrating vector for the United States (about the 10 percent level). However, on balance there does seem to be reasonable evidence of a cointegrating relationship among the four variables in the banking time model for both countries.

Conditional on the existence of a single cointegrating vector we normalize by setting the coefficient on *(m/y)* equal to unity and then interpret the other coefficient estimates in the vector as the long-run coefficients in model (22). The unrestricted point estimates of the α coefficients along with 95 percent confidence intervals are reported in the tables. For both countries the signs of the unrestricted point estimates are consistent with the predictions of the model. Equilibrium holdings of money are negatively related to the nominal interest rate and to productivity in the credit sector, while they are positively related to the aggregate real wage rate. However one problem with the unrestricted estimates for both countries is that the estimated standard errors are large. This can be seen from the reported 95 percent confidence intervals, which typically include zero.

More precise estimates can be obtained by imposing the restriction on the cointegrating vector that $-\alpha_1 = \alpha_2$. A likelihood ratio test indicates that this restriction is not rejected by the data for either country and the respective restricted

[3] Since the individual series appear to display trends an unrestricted constant is included in the VAR model. Three seasonal dummy variables were initially included in the VAR models for both the United States and Australia, but are only found to be significant in the Australian case.

estimates are reported in Tables 1 and 2. For Australia the coefficient estimates for the restricted model are all statistically significant. From equations (21) and (22), $|\alpha_1| = \alpha_2 = \gamma/(1-\gamma)$, and the implied point estimate of γ is 0.26. For the United States data imposing the restriction reduces the coverage of the 95 percent interval estimate, but all intervals still include zero. The implied point estimate on the interest rate and real wage is γ =0.21. The point estimates of γ for both countries provide strong empirical support for the assumption of decreasing marginal returns to time spent in credit production.

The estimated coefficients on the measure of productivity in the credit sector are negative for both sets of data. This is consistent with model's prediction that productivity improvements in the credit sector will lower the price of credit (as a means of exchange) and result in substitution away from cash. One difference between the point estimates for the United States and Australia is the absolute magnitude of the coefficients. In fact the results for Australia provide greater support for our particular parameterization of the banking time model than those for the United States. It is apparent from equations (21) and (22) that $\alpha_3 = -(1/1-\gamma)$ and that we can recover another estimate of γ from the point estimate of α_3. For Australia the implied value of γ is 0.66, which is an intuitively plausible number, however for the United States the implied value for γ is negative. The results for Australia are consistent with long run movements in the financial sector real wage providing a good proxy for productivity changes in the credit sector[4]. For the United States the small estimated (absolute) value for α_3 may reflect the fact that labour productivity in the Finance, Insurance and Real Estate sector is not a completely satisfactory measure of A_F.

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[4] This is not true for the United States data. Attempts to use the real wage in the United States finance sector as a proxy for productivity in the credit sector were unsuccessful.

An important objective of any money demand study is obtaining an estimate of the interest elasticity of money demand. From equation (21) it is apparent that the (approximate) interest elasticity implied by our specification of the banking time model is given by $-(\gamma/1-\gamma)/[m/y]$. Thus the interest elasticity of money is time varying and given the time series properties of *(m/y)* is actually non-stationary. Figure 1 presents a plot of the interest elasticity for the United States and Australia implied by the restricted estimates. In both countries the demand for money has tended to become more elastic over time. The estimates of the interest elasticity are at the high end of the range of international evidence, particularly for the United States; a result which is consistent with the prediction in Gillman (1993) that including the cost of credit services makes money demand more interest elastic.

On preliminary analysis, the results in Tables 1 and 2 suggest that the banking time model is able to capture key aspects of the long run behaviour of the non-interest bearing money in the United States and Australia. In particular, productivity growth in exchange credit production and the consequent fall in the cost of exchange credit services does appear to be an important influence on the transactions demand for cash.

A Conventional Model of Money Demand

If the cost of credit services is an important determinant of the demand for money, then a conventional money demand should not be able to explain the trend behaviour of cash. We now examine this hypothesis formally by estimating equation (23). This specification is equivalent to the model for log-velocity that has been estimated by Hoffman et. al. (1995) for a number of countries, with some degree of success[5]. The results obtained are reported in Tables 3 and 4.

For the United States both the trace and the λ-max test point to the existence of a single cointegrating vector, however the estimated long run interest elasticity is positive. The Australian results provide even less support for the conventional model, since there is strong evidence that the velocity of money is not cointegrated with real

[5] Hoffman et. al. (1995) use broader measures of money than our measure of cash.

income and the nominal interest rate. What these results indicate is that real income and nominal interest rates are not sufficient to explain the trend behaviour of money in the United States and Australia over the last twenty-five years.

Sensitivity of the Estimates of the Banking Time Model

While the results reported in Tables 1 and 2 provide *prima facie* support for the predictions of the banking time model it is important to provide some evidence of the robustness of our estimates. To do this we consider how the results obtained from estimating equation (24) change as we vary first the sample size and then the number of lags of the VAR model (Hoffman et al. 1995). Tables 5 and 6 present some recursive estimates for equation (22). These are obtained by fixing the starting point of the sample and then estimating the model over progressively longer sample periods. Each set of estimates adds an extra four quarters. All of the recursive estimates are based on VAR with four lags.

For each of the recursive estimates we report the trace statistic for testing the null of no cointegration, the unrestricted estimates of (22), the likelihood ratio statistic for testing $-\alpha_1 = \alpha_2$ and the restricted estimates. The results suggest that there is strong evidence of at least one cointegrating vector for all of the sample lengths considered. In addition the parameter estimates, particularly the restricted estimates, are quite robust to the changes in the sample size considered, particularly for the Australian data. In the restricted model for Australia the point estimate of γ varies from 0.22 to 0.26, while the estimate of α_3 ranges from -3.39 to -1.53. Overall these recursive estimates suggest that our theory yields a relatively stable model for money in Australia. With the United States data there is somewhat more variation in both the restricted and unrestricted estimates, until about 1995.

Finally we consider the sensitivity of our estimates of (22) to changing the lag length of the VAR model used in the Johansen estimator. Table 7 presents a comparison of the results obtained from estimation of equation (22) for VAR models with lags lengths of 3, 4 and 5. The results for the United States are quite robust to this variation in lag length. For Australia with the VAR(3) and VAR(5) specifications there is considerably less support for a cointegrating relationship, although the coefficient estimates obtained from these specifications are consistent with the predictions of the banking time model and are qualitatively similar to those from the VAR(4) model.

Short Run Dynamics

The cointegration analysis is concerned with testing for long run relationships and estimating the long run coefficients. We now consider the short run dynamics. Given the existence of a cointegrating relationship we can model the dynamic behaviour of money by an error correction model. Tables 8 and 9 report our attempts to obtain a relatively parsimonious error correction model for money. The models are obtained by the usual general-to-specific strategy. Initial models included two lags of the following variables; $\Delta(m/y)$, $\Delta \ln w$, $\Delta \ln A_F$ and the error correction mechanism lagged once. When statistically insignificant variables were omitted, on the basis of t-tests, we are left with the models reported in Tables 8 and 9. For both countries a reasonably parsimonious dynamic model can be obtained. Diagnostic tests on the residuals of the models indicate no evidence of serial correlation or ARCH effects up to five lags. To ensure that our inference is robust to the presence of heteroskedasticity, the reported t-statistics are computed using White's (1980) heteroskedasticity-consistent covariance matrix estimator.

For Australia the dynamic model explains about 75 percent of the variation in $\Delta(m/y)$. The significant variables are two lags of $\Delta(m/y)$, the lagged change in the interest rate and the error correction term. Notice the error correction term is the most significant of all the variables in the dynamic model, providing some additional evidence that the banking time model is a valid cointegrating relationship. Lagged changes in the economy-wide real wage and in the finance sector real wage are not important in explaining $\Delta(m/y)$ despite their key role in explaining the trend in non-interest bearing money. For the United States the dynamic model explains about half the variation in $\Delta(m/y)$. In this case ΔA_{Ft-1} is found to be a significant explanatory variable.

M1, M2, and M3 Estimation Results

As a final test of the banking time model we estimated it using broader some measures of money. While we have not included tables of the results in this paper the main findings can be summarised as follows. We estimate the model using M1 for both the United States and Australia and using M2 for the United States and M3 for Australia. All of the measures of money provide some support for the existence of at least one cointegrating vector. However in the case of M1 the restriction $-\alpha_1 = \alpha_2$ is strongly rejected for both countries, while the unrestricted coefficient estimates typically have the wrong signs. For the broader aggregates M2 and M3 the coefficient restriction is not rejected, but the estimated coefficient on productivity is found to be small and statistically insignificant.

5. Qualifications and Conclusions

The paper's results suggest that some of the problems in money demand estimation may arise from using too broad an aggregate, perhaps in an attempt to try to explain the shifting use of the different money instruments. In the cash-in-advance models, money is a non-interest bearing means of payment that is costless to produce. We therefore use, as our baseline aggregate for the theory, money plus non-interest bearing demand deposits, assuming away the cost of such deposits. In addition to this definition of money as non-interest bearing instruments, we investigate whether the theory might unexpectedly also explain the broader aggregates, of M1 and M2, and even M3. These broad aggregates contain features of both the non-interest bearing aggregates that in our model acts as money as well as the interest-bearing aggregates that in our model acts as exchange credit, and so are not as well-suited to being explained by standard exchange-based general equilibrium monetary models. Including the productivity of the finance sector is expected to capture the shift away from non-interest bearing money into interest-bearing aggregates. So it is not surprising that it does not help explain for example Australian M3 demand, which includes interest-bearing aggregates. The M3 results do indicate cointegration with significance for the real wage, also a theorized cost of using exchange credit.

Alternatively, a contrasting approach to estimating money demand is to change the definition of the monetary aggregate so that it contains the non-interest bearing elements of all of the monetary instruments. Barnett (1980) does this with the "Divisia" application of index theory to monetary aggregates, and Lucas (2000) suggests this may be a useful direction. Here when a shift in the price of interest-bearing credit activity leads to a different relative usage of the various monetary instruments, the definition of the Divisia aggregate is changed to re-weight the different instruments in reflection of their new usage. For example, a lowering of the cost of interest bearing accounts, like "checkable" interest-bearing money market accounts, may induce an increased use of such accounts. During the moderately high-inflation and financial-deregulation environment of the industrial countries in the 1980s, the Divisia index increased the weight of such partially interest-bearing aggregates in the Divisia aggregate, while reducing the weight given to aggregates like currency. Changing the definition of the aggregate so that it captures the non-interest bearing parts of all of the monetary instruments can enable the aggregate to remain responsive only to the nominal interest rate, the own-price of money, in a stable function. It avoids a shift in its demand during changes in the substitute prices, such as in the cost of the interest-bearing instruments, by instead shifting the weights that define the aggregate.

However, central banks engaged in inflation-rate targeting may need to understand the demand for the very narrowly defined money that they actually supply and how it can shift when inflation variability induces financial innovations. The Divisia approach provides a brilliant exposition of how the nominal interest rate acts as the own-price of money. But it cannot explain the demand for narrowly defined money.

Dixon (1997) suggests that Barnett (1997) "makes a strong case for the Divisia approach as the only model that can successfully provide a stable money demand based on indisputably rigorous microeconomics".[6] Our paper offers an exception by deriving the demand for money from the production of credit services. Modelling the banking sector is our key to finding a stable money demand without "missing money" and without changing the definition of the aggregate in order to do so.

Further, another partial equilibrium approach, the "lagged dependent variable" (ldv) model for example of the buffer stock approach or the "P Star" model also relate to our results. Cuthbertson (1997), in discussing deficiencies of the ldv models in explaining money demand, suggests that the error-correction model is "taking lags seriously", and "has proved useful in modelling 'lags' in a single equation context" (p.1194). We provide not only cointegration estimation of a single equation model, but also include error correction dynamics that provide a theory of the short run as based on our long run model, and that compares to the ldv models. However Cuthbertson also claims that the microfoundations of the Baumol (1952) model involves lump sum costs and "are inconsistent with an ldv (at the micro level)." Our model is a general equilibrium intricately based on Baumol's theory of setting the costs of exchange equal at the margin, without the need for lump sum costs to generate a stable equilibrium. This is done (in our equation (17)) as in Gillman

[6] Dixon (1997), p. 1169.

(1993) and Aiyagari et al (1998) by having increasing marginal costs of credit production in a way motivated by Hicks (1935) and Becker (1965), whereby the representative agent acts in part as a bank.

Explaining money demand is another facet that general equilibrium models can be put to test over. If they cannot explain money demand when deregulation in the financial sector occurs, then they would seem to require extension so that they can internalise such related factors within the money demand function. This is a central argument of the paper. The paper provides a micro-founded paradigm of banking time as a special case of shopping time, with the result being an interest elasticity that varies significantly with the inflation rate in a way similar to the Cagan model. And it gives a less unrestricted money demand function as compared to shopping time models, money-in-the-utility function models, and cash-good, credit-good models, in that there are no unrestricted utility and "transactions cost function" parameters. Indeed it is the attempt to restrict such parameters with some basis in outside data that has lead researchers to impose a constant interest elasticity within the shopping time framework. Here, only the two technology parameters of the credit services sector are added. By using a time series for a measure of the productivity of the credit services sector, the estimation implies an estimate of the other parameter for the degree of diminishing returns. Thus the technology parameter is constant, while the behavioural "parameter" of the interest elasticity is allowed to vary endogenously.

Further, the meeting of shopping time and cash-in-advance approaches through the banking time approach suggests merit not only for money demand, but also because of its other implications. First it provides an explanation of velocity. Gillman and Kejak (2003) show that this approach can explain trends in the velocity of various monetary aggregates. Changes in the velocities that are not explained by nominal interest rate movements can at times be explained by shifts in the productivity of the finance sector because of banking deregulations. It allows for proof of the Friedman optimum in a second-best Ramsey framework without any assumption except diminishing returns to labor in the credit services sector (Yerokhin, 2001), for explaining the growth of the size of banking sectors in step with inflation rates (Aiyagari et al 1998, English, 1999, Frenkel and Mehrez, 2000), and for explaining a non-linear, negative, nature of the effect of inflation on growth (Ghosh and Phillips, 1998, Khan and Senhadji, 2000, Gillman, Harris and Matyas, 2003). And it may serve to help develop central bank policy models by endogenizing velocity in a single-good economy, a task that Alvarez, Lucas, and Weber (2001) leave as an extension in their "Taylor rule" model, thereby showing the importance of money demand in the policy rule setting.

Another part of the lack of interest in an empirically valid general equilibrium model of money is that in real business cycle models with money, sticky price models produce a liquidity effect without any focus on the underlying money demand, as for example in Ohanian, Stockman, and Kilian (1995) and Cooley and Hansen (1998). However by including a credit production technology, it is possible to investigate how shocks to the productivity of credit can affect output, and even explain episodes when velocity is “shocked” due to changes in banking laws. Li (2000) uses a production technology of credit that is similar to the model of this paper. And by requiring banks to receive the open market purchases of money through government bond purchases, Li’s model yields a significant liquidity effect. It may be possible to develop the endogenous money demand of this paper in a real business cycle with credit shocks, and possibly even with a Li-type liquidity effect, that can explain a fuller range of experience than nominal rigidity models.

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Table 1: Banking Time Model 1976:1-1998:2 – United States

Hypothesis	**Trace**	**λ-max**
$\rho \leq 3$	0.36	0.36
$\rho \leq 2$	9.84	9.48
$\rho \leq 1$	24.09	14.25
$\rho = 0$	49.36*	25.27

Unrestricted Estimates: Point and 95 percent Interval Estimates

α_1	α_2	α_3
-0.23 (-0.62 to 0.16)	0.34 (-0.48 to 1.17)	-0.18 (-0.57 to -0.21)

Restriction: $-\alpha_1 = \alpha_2$

Likelihood Ratio Test of Restriction:

LR = 0.04

Restricted Estimates: Point and 95 percent Interval Estimates

α_1	α_2	α_3
-0.26 (-0.63 to 0.12)	0.26 (-0.12 to 0.63)	-0.22 (-0.47 to 0.04)

Notes: Critical values for the Trace and λ-max test statistics are from Johansen and Juselius (1990. Table A2). A * indicates the null hypothesis can be rejected at the 5 percent level of significance. The LR test of the coefficient restriction is distributed as a Chi-squared with one degree of freedom.

Table 2: Banking Time Model 1975:1-1996:2 – Australia

Hypothesis	Trace	λ-max
$\rho \leq 3$	1.05	1.05
$\rho \leq 2$	7.59	6.54
$\rho \leq 1$	18.28	10.69
$\rho = 0$	49.11*	30.83*

Unrestricted Estimates: Point and 95 percent Interval Estimates

α_1	α_2	α_3
-0.49 (-0.93 to -0.04)	1.31 (-1.13 to 3.76)	-4.30 (-8.18 to -0.42)

Restriction: $-\alpha_1 = \alpha_2$

Likelihood Ratio Test of Restriction:

LR = 0.75

Restricted Estimates: Point and 95 percent Interval Estimates

α_1	α_2	α_3
-0.36 (-0.53 to -0.18)	0.36 (0.18 to 0.53)	-2.98 (-4.06 to -1.89)

Notes: Critical values for the Trace and λ-max test statistics are from Johansen and Juselius (1990. Table A2). A * indicates the null hypothesis can be rejected at the 5 percent level of significance. The LR test of the coefficient restriction is distributed as a Chi-squared with one degree of freedom.

Table 3: Conventional Model 1976:1-1998:2 – United States

Hypothesis	Trace	λ-max
$\rho \leq 2$	0.03	0.05
$\rho \leq 1$	10.27	10.21
$\rho = 0$	30.73*	20.46*

Unrestricted Estimates: Point and 95 percent Interval Estimates

β_1	β_2
2.41 (-4.98 to 9.80)	1.82 (-6.01 to 9.65)

Notes: See Table 1.

Table 4: Conventional Model 1975:1-1996:2 – Australia

Hypothesis	**Trace**	**λ-max**
$\rho \leq 2$	0.44	0.44
$\rho \leq 1$	7.80	7.80
$\rho = 0$	19.06	11.25

Unrestricted Estimates: Point and 95 percent Interval Estimates

β_1	β_2
0.09 (-0.02 to 0.19)	1.13 (0.94 to 1.31)

Notes: See Table 1.

Table 5: Recursive Estimates of the Banking Time Model – United States

	Unrestricted Estimates				Restricted Estimates		
Sample End	Trace	α_1	α_2	α_3	LR	γ	α_3
91:2	52.10*	0.00	1.23	0.15	6.72*	0.74	1.17
92:2	59.16*	-0.01	1.14	0.10	8.93*	0.12	-0.29
93:2	50.43*	-0.06	0.89	0.00	4.96*	0.09	-0.25
94:2	56.07*	-0.09	0.52	-0.11	1.00	0.11	-0.25
95:2	50.58*	-0.46	-3.88	-1.66	1.55	0.25	-0.22
96:2	51.71*	-0.27	0.23	-0.23	0.00	0.21	-0.22
97:2	50.80*	-0.26	0.17	-0.25	0.00	0.19	-0.22
98:2	49.36*	-0.23	0.34	-0.18	0.04	0.20	-0.22

Notes: See Table 1. All samples in the recursive models end in the year and quarter indicated.

Table 6: Recursive Estimates of the Banking Time Model – Australia

	Unrestricted Estimates				Restricted Estimates		
Sample End	Trace	α_1	α_2	α_3	LR	γ	α_3
89:2	52.58*	-0.19	-0.33	0.94	0.52	0.22	-1.55
90:2	51.54*	-0.44	0.95	-2.31	1.02	0.26	-1.53
91:2	50.64*	-0.55	1.76	-4.47	2.12	0.25	-2.61
92:2	50.33*	-0.64	2.70	-7.07	3.04	0.24	-3.37
93:2	50.86*	-0.63	2.52	-6.80	2.73	0.24	-3.39
94:2	52.61*	-0.59	2.14	-5.87	2.24	0.26	-3.18
95:2	53.67*	-0.59	2.14	-5.75	2.34	0.26	-3.12
96:2	49.11*	-0.49	1.31	-4.30	0.75	0.26	-2.97

Notes: See Table 1. All samples in the recursive models end in the year and quarter indicated.

Table 7: Estimates of the Banking Time Model for Alternative Lag Lengths

	Unrestricted Estimates				Restricted Estimates		
VAR(k)	Trace	α_0	α_1	α_2	LR	γ	α_2
United States							
k=3	50.33*	-0.32	0.76	-0.09	0.38	0.40	-0.28
k=4	49.36*	-0.23	0.34	-0.18	0.04	0.20	-0.22
k=5	47.47*	-0.30	0.15	-0.24	0.08	0.21	-0.20
Australia							
k=3	31.20	-0.59	1.15	-4.68	0.08	0.32	-3.67
k=4	49.11*	-0.49	1.31	-4.30	0.75	0.26	-2.98
k=5	41.35	-1.46	5.24	-11.96	1.30	0.38	-4.45

Notes: See Table 1.

Table 8: Dynamic Banking Time Model – United States

	Dependent Variable: $\Delta(m_t / y_t)$	
	Unrestricted Model	**Restricted Model**
Constant	0.003 (1.54)	0.004 (1.63)
$\Delta(m_{t-1} / y_{t-1})$	0.288 (2.49)	0.290 (2.48)
$\Delta \ln i_{t-1}$	-0.007 (3.87)	-0.007 (3.84)
ΔA_{Ft-1}	0.026 (3.17)	0.026 (3.17)
ECM_{t-1}	-0.005 (1.87)	-0.005 (1.87)
$\bar{R}^2$	0.484	0.483
LM1 (5)	0.114	0.112
LM2 (5)	0.515	0.530

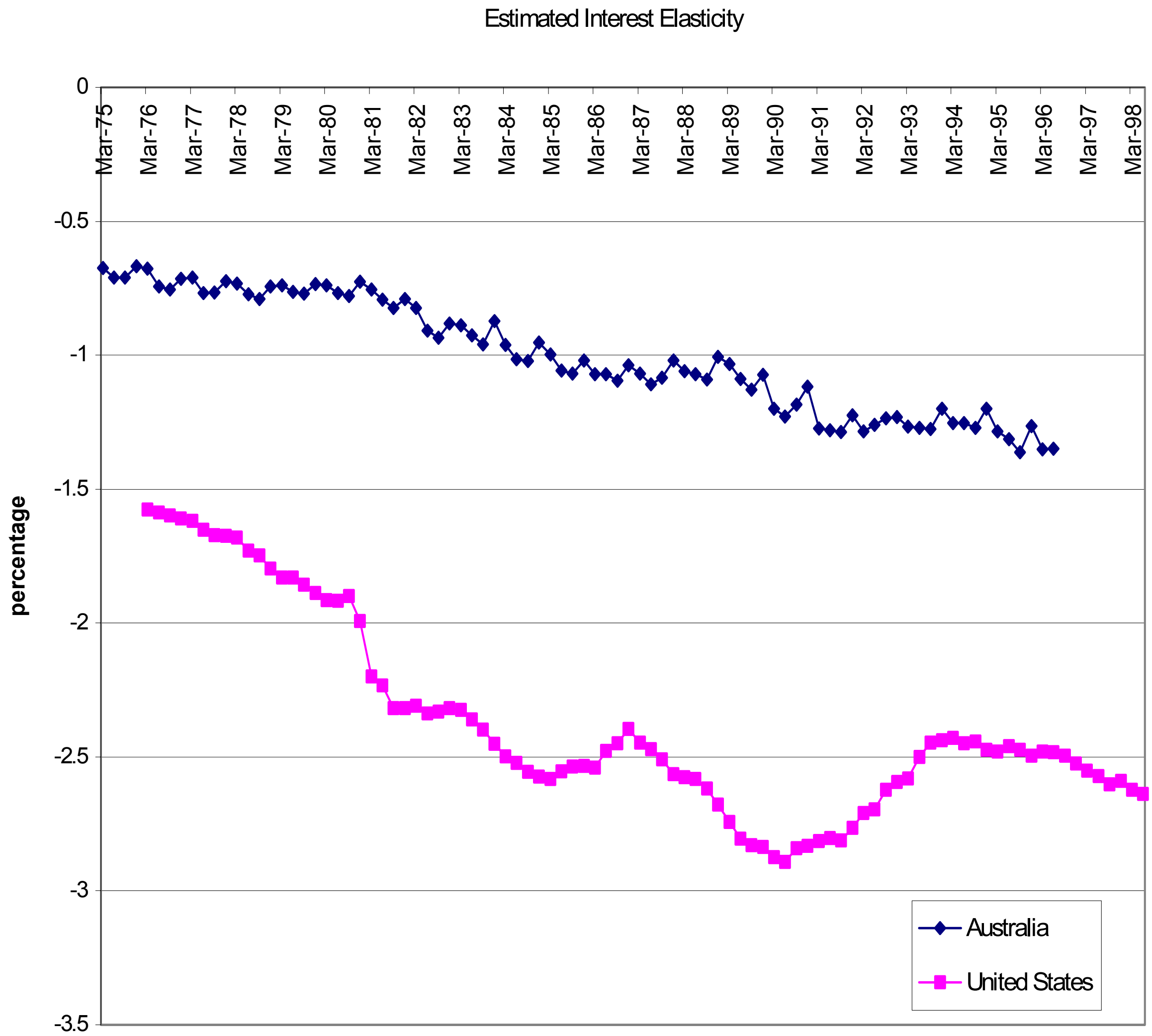
Notes: The t-statistics are computed using White's (1980) heteroscedasticity-consistent covariance matrix estimator. LM1 is a Lagrange multiplier test for serial correlation and LM2 is a test for ARCH effects. Both allow for possible effects up to fifth order.

Table 9: Dynamic Banking Time Model – Australia

	Dependent Variable: $\Delta(m_t / y_t)$	
	Unrestricted Model	**Restricted Model**
Constant	0.236 (3.58)	0.260 (3.51)
$\Delta(m_{t-1} / y_{t-1})$	-0.182 (2.04)	-0.184 (2.04)
$\Delta(m_{t-2} / y_{t-2})$	-0.295 (2.94)	-0.302 (3.00)
$\Delta \ln i_{t-1}$	-0.010 (1.37)	-0.010 (1.30)
ECM_{t-1}	-0.026 (3.79)	-0.033 (3.60)
$\bar{R}^2$	0.737	0.736
LM1 (5)	0.548	0.439
LM2 (5)	0.817	0.754

Notes: The t-statistics are computed using White's (1980) heteroscedasticity-consistent covariance matrix estimator. LM1 is a Lagrange multiplier test for serial correlation and LM2 is a test for ARCH effects. Both allow for possible effects up to fifth order.

Figure 1


Estimated Interest Elasticity
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
percentage
Mar-75
Mar-76
Mar-77
Mar-78
Mar-79
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Mar-96
Mar-97
Mar-98
Australia
United States

Appendix A: Data

Money

Non-interest bearing money is measured as currency plus non-interest bearing current deposits and M1 is the sum of currency and total current deposits.

United States

Money is measured as M1 less other checkable deposits.

Australia

Data on currency holdings (not seasonally adjusted) are available from 1975:1. The Reserve Bank of Australia publishes a series for total current (ie. demand) deposits with banks over the same period, however a decomposition of this series into interest and non-interest bearing components is only available from 1984:3 to 1996:2. An estimate of non-interest bearing deposits for the period 1975:1 to 1984:2 is obtained by simply extrapolating interest bearing deposits from 1984:2 back to 1975:1 (assuming a constant growth rate of 10 percent per quarter) and subtracting these from total current deposits.

Real Income

United States

Constant price income in 1992 prices is measured as nominal GDP deflated by the price index for GDP.

Australia

Constant price income in 1989-90 prices is measured as nominal GDP deflated by the implicit price deflator for GDP.

Nominal Interest Rate

United States

The interest rate is the 3 month T-bill rate.

Australia

The interest rate used is the 90 day bank-accepted bill rate.

Economy-Wide Real Wage

United States

The economy-wide real wage is measured as total private sector average hourly earnings in 1982 dollars.

Australia

The economy-wide hourly wage rate is obtained by dividing average weekly earnings of males in all industries by the average weekly hours by males in all industries. This is deflated by the implicit price deflator for GDP to obtain a real hourly wage rate.

Productivity in Credit Production

United States

An index of productivity in finance is computed as constant price GDP in the Finance, Insurance and Real Estate (FIR) sector divided by total hours worked in FIR.

Australia

In the absence of a suitable productivity measure for the credit sector, the real wage in credit production is used as a proxy for labour productivity. This is measured as the nominal hourly wage in the Finance and Insurance (FI) sector. It is computed by dividing average weekly earnings in FI by average weekly hours in FI and deflating by implicit price deflator for GDP. We note that quarterly data for the average weekly earnings per employee in FI is available only from 1984:4. For the period 1975:1 to 1984:3 we are forced to interpolate annual data for this series to get a quarterly series. Quarterly data on average weekly hours is based on the numbers for the FI sub-sector from 1984:4 to 1996:2. For the earlier period 1975:4 to 1983:3 quarterly hours data are only available for the sector the more general sector Finance, Insurance, Property, and Business Services (FIRB). Finally for the three quarters 1975:1 to 1975:3 we interpolate from annual data for the FIPB sector.