Money Demand in General Equilibrium Endogenous Growth: Estimating the Role of a Variable Interest Elasticity

Max Gillman[a]

Cardiff University

Glenn Otto[b]

University of New South Wales

Institute of Economics, Hungarian Academy of Sciences

Abstract

The paper presents and tests a theory of the demand for money that is derived from a general equilibrium, endogenous growth economy, which in effect 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. The implied interest elasticity of money demand rises with the inflation rate and financial innovation rather than being constant as is typical in shopping time specifications. Using quarterly data for the US and Australia, we find evidence of cointegration for the money demand model. This money demand stability results because of the extra series that capture financial innovation; included are robustness checks and comparison to a standard money demand specification.

JEL Classifications: C23, E41, 042.

Keywords: Money demand, interest elasticity, exchange credit, cash-in-advance.

[a] Business School, Colum Drive, Cardiff, CF10 3EU; tel.: +44 (0)29 2087 6547, email: GillmanM@cardiff.ac.uk

[b] School of Economics, UNSW Sydney NSW 2052, Australia; tel.: +61 2 9385 3332, email: G.Otto@unsw.edu.au

1 Introduction

The paper offers a test of the money demand function, as derived from a general equilibrium endogenous growth model that includes financial sector productivity (Gillman and Kejak, 2005b). This model explains inflation as having a negative but diminishing effect on growth as the inflation rate is raised. Underlying the result is that the consumer becomes increasingly sensitive to inflation, as this tax is increased, substituting more from money to credit, and less from goods to leisure. Since the human capital utilization rate decreases as leisure use increases, the growth rate falls, but falls by lesser amounts as inflation increases. The implied money demand function is similar to a Cagan (1956) function, with a constant "semi-interest" elasticity, or rather an elasticity that rises in magnitude as the inflation rate rises.

An additional feature of the money demand is that its interest elasticity also rises with productivity increases in the credit production sector that outstrip aggregate productivity increases that are reflected in the real wage. This means that during a period of financial deregulation, as occurred in the US and Australia, starting in the late 1970s and early 1980s, the interest elasticity ceteris paribus would be expected to rise in magnitude due to the less expensive credit that acted as an alternative means of exchange. Decreases in the nominal interest rates that occurred during the later part of the deregulatory period, due to falling inflation, would cause by themselves the interest elasticity to decrease in magnitude. The net effect of these two opposing factors in a sense can be hinted at by what happened to velocity during this period. For example for the US, the income velocity of money continued to rise even after the fall in nominal interest rates. This is explained by the financial sector productivity increases dominating the nominal interest rate decreases, in Gillman and Kejak (2004). From this velocity experience, then, it would be expected that the interest elasticity would rise over the period.

This gives two central hypotheses for the paper. One, that a stable money demand function can be found for the Cagan-like model that also explains the inflation-growth profile (Gillman and Kejak, 2005b), as based on the inclusion of an "additional variable", reflecting financial sector productivity, as compared to standard money demand models. Second, that the interest elasticity as estimated would be found to rise over the period because of the importance of the post-deregulation productivity in financial services. Note that the deregulation generally took place in phases, with a series of banking laws that each contributed productivity shocks (see Benk, Gillman, and Kejak, 2005). Thus the financial productivity variable would be expected to reflect these increases over a period of time, thereby affecting the stationary estimation rather than being confined to a jump that could be netted out of the estimation using various procedures.

In Section 2, the general equilibrium money demand is presented, and in Section 3 a

testable model is derived. Section 4 describes the data to be used in the study. Section 5 provides empirical results for US and Australian money demand. Section 6 presents evidence of the robustness of the results. Discussion and conclusions follow in Sections 7 and 8, respectively.

2   Representative Agent Economy

Consider a representative agent who as consumer likes goods c_t and leisure x_t, and has a current period utility function given by

$$u = \ln c_t + \alpha \ln x_t. \tag{1}$$

The consumer can purchase the good using either money, denoted by M_t, or with exchange-credit. Letting a_t denote the fraction of purchases of the aggregate consumption good that the agent chooses to make with money, and with P_t as the goods nominal price, the cash-in-advance, or exchange technology, constraint is

$$M_t = a_t c_t P_t. \tag{2}$$

It is apparent that the model predicts a unitary consumption elasticity and a (variable) consumption velocity of money equal to $1/a_t$. Total exchange is equal to both money and credit purchases of the consumption goods. With q_t denoting the real quantity of credit used, the exchange constraint can be expressed as

$$M_t + P_t q_t = P_t c_t, \tag{3}$$

and combining equations (2) and (3),

$$q_t = (1 - a_t)\, c_t. \tag{4}$$

The fraction of time spent in each activity sums to one. With l_{Gt}, l_{Ft}, and l_{Ht} denoting the time spent in goods production, credit production, and human capital investment production, respectively,

$$1 = x_t + l_t + l_{Ft} + l_{Ht}. \tag{5}$$

Credit services are produced using only effective labour and total deposited funds, a constant returns to scale (CRS) function that follows the standard banking literature begun with the seminal contributions of Clark (1984) and Hancock (1985), except that

there is no physical capital as an input, for simplification.[1] The total funds deposited, if the financial intermediary is decentralized, are the money and credit given in equation (3); the deposited funds are set equal to c_t.[2] With h_t denoting the stock of human capital, the effective labor used in producing credit is $l_{Ft}h_t$; this can be thought of as the banking time of the agent. With $A_F \in R_+$, the CRS credit services production technology is given as

$$q_t = A_F(l_{Ft}h_t)^\gamma c_t^{1-\gamma}. \tag{6}$$

Solving for a_t in equations (4) and (6), and substituting this into the exchange constraint (2), the money constraint can be written in a way that includes the credit production technology:

$$M_t = \left[1 - A_F(l_{Ft}h_t/c_t)^\gamma\right] P_t c_t. \tag{7}$$

This version of the Clower constraint can be shown to be equivalent to a special case of the shopping time constraint, if the effective banking time $l_{Ft}h_t$ is solved for; then this banking time rises with c_t, and falls with M_t/P_t, just as does shopping time. But whereas in the typical shopping time specification, the interest elasticity is constant by design, here in contrast the CRS production function for credit crucially implies an equilibrium money demand interest elasticity that rises in magnitude with the inflation rate.

The consumer accumulates both human capital h_t and physical capital, denoted by k_t, renting both to the goods producer. The rate of human capital investment is assumed to be proportional to the effective time spent in human capital accumulation $l_{Ht}h_t$, as in Lucas (1988). With $A_H \in R_{++}$ and the depreciation rate δ_h,

$$\dot{h}_t = A_H l_{Ht} h_t - \delta_h h_t. \tag{8}$$

Physical capital investment i_t, given the depreciation rate δ_k, is given by

$$\dot{k}_t = i_t - \delta_k k_t. \tag{9}$$

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

$$Q_t = M_t + P_t k_t, \tag{10}$$

---

[1] See Gillman and Kejak (2005a) for specifications with capital.

[2] In a decentralized model, with bank deposits denoted by d_t, consider requiring that d_t is equal to the sum of money and credit, so that all means of exchange come from the bank deposits; then $d_t = a_t c_t + (1 - a_t) c_t = c_t$. And let the Clark (1984) production function be $q_t = A_F(l_{Ft}h_t)^\gamma d_t^{1-\gamma}$; then in equilibrium $c_t = d_t$ and equation (6) results.

making the flow of nominal financial wealth:

$$\dot{Q}_t = \dot{M}_t + P_t\dot{k}_t + \dot{P}_t k_t. \tag{11}$$

By the social resource constraint, or the allocation of goods constraint that is similar to the allocation of time constraint in equation (5), income is equal to investment plus consumption expenditures. With the real interest rate and real wage rate denoted by r_t and w_t, this can be written by solving for nominal investment as

$$P_t i_t = r_t P_t k_t + w_t P_t l_t h_t - P_t c_t. \tag{12}$$

Substituting from equations (9) and (11) into equation (12), the flow constraint (11) can be written as

$$\dot{Q}_t = r_t P_t k_t + w_t P_t l_t h_t - P_t c_t + \dot{M}_t + \dot{P}_t k_t - \delta_k k_t. \tag{13}$$

2.1 Goods Producer Problem

Goods are produced, by the representative agent acting as a producer, with a Cobb-Douglas technology involving physical capital, k_t, and effective labour, which equals the human capital stock, h_t, factored by the fraction of time spent in goods production. With $A_G \in R_{++}$ 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

$$y_t = A_G \left(l_t h_t\right)^\beta k_t^{1-\beta}. \tag{14}$$

The firm maximizes the standard profit subject to rental capital and labor inputs, with the first-order conditions that

$$w = \beta A_G \left(l_t h_t\right)^{\beta-1} k_t^{1-\beta}, \tag{15}$$

$$r = (1 - \beta) A_G \left(l_t h_t\right)^\beta k_t^{-\beta}. \tag{16}$$

2.2 Government

It is assumed that the government supplies money through lump sum transfers V_t to the agent,

$$\dot{M}_t = V_t, \tag{17}$$

where $V_t = \sigma M_t$, so that the rate of money growth is constant at σ.

2.3 Equilibrium

Equilibrium is characterized by the firm's conditions (15) and (16), the money supply condition (17), and the consumer's equilibrium conditions from the following Hamiltonian problem: the consumer maximizes the present value of utility given by (1) subject to the constraints (7), (8), (10) and (13) with respect to c_t, x_t, l_t, l_{Ft}, h_t, k_t, and M_t :

$$
\begin{aligned}
H \;=\; & e^{-\rho t}\left(\ln c_t + \alpha \ln x_t\right) \\
& + \mu_t\left\{M_t - \left[1 - A_F(l_{Ft}h_t/c_t)^\gamma\right]P_t c_t\right\} \\
& + \varphi_t\left(Q_t - M_t - P_t k_t\right) \\
& + \lambda_t\left(r_t P_t k_t + w_t P_t l_t h_t - P_t c_t + V_t + \dot{P}_t k_t - \delta_k k_t\right) \\
& + \phi_t\left[A_H\left(1 - x_t - l_t - l_{Ft}\right)h_t - \delta_h h_t\right].
\end{aligned}
\tag{18}
$$

2.4 Balanced Growth Path

The agent's equilibrium conditions along the balanced growth path can be expressed, with the time subscripts dropped, with g denoting the balanced-path growth rate, and with R denoting the nominal interest rate (made explicitly the interest rate for nominal bonds, if bonds are included in the problem), as

$$
\frac{x}{\alpha c} = \frac{1 + aR + \gamma\left(1 - a\right)R}{wh},
\tag{19}
$$

$$
g = r - \delta_K - \rho,
\tag{20}
$$

$$
-\dot{\phi}_t/\phi_t = A_H\left(1 - x\right) - \delta_H = r - \delta_K,
\tag{21}
$$

$$
-\dot{\lambda}_t/\lambda_t = r + \dot{P}/P \equiv R,
\tag{22}
$$

$$
w = \beta A_G\left[A_H\left(1 - x\right)/\left(1 - \beta\right)\right]^{-(1-\beta)/\beta},
\tag{23}
$$

$$
R = w/\left[\gamma A_F\left(l_F h/c\right)^{\gamma-1}\right].
\tag{24}
$$

The first equilibrium equation (19) describes substitution between goods c and leisure x, as being dependent on the real wage w as discounted the by nominal interest rate R, whereby the discount is smaller the greater is the use of credit (a larger $1 - a$); put differently, a rise in R causes substitution from goods to leisure. The second condition (20) gives the balanced growth rate g as being equal to the return on physical capital $r - \delta_K$ minus time preference ρ, as well as equaling, by the third equation (21), the return on human capital minus time preference ρ; human capital's utilization rate $(1 - x)$ goes down, and the growth rate goes down, when leisure x goes up because of inflation.

Equation (22) presents a form of the Fisher equation of interest rates, by which the real interest rate and the inflation rate sum up to the nominal interest rate; while equation (23) from the producer problem shows that the real wage rises with an increase in leisure when inflation increases.

2.4.1   Money Demand

Equations (23) and (24) describe the standard input price relations in the goods and credit service sectors, with the price of labor equaling its marginal product in (23), and with the marginal cost of credit equaling the ratio of the marginal factor price w to the marginal factor product $\gamma A_F \left(l_F h/c \right)^{\gamma - 1}$ in (24). From this latter equation, and the exchange constraint (7), the agent's real money demand can be derived as

$$M/P = m = \left[1 - \left(\frac{\gamma R}{w} \right)^{\gamma/(1-\gamma)} A_F^{1/(1-\gamma)} \right] c. \tag{25}$$

Writing money demand in terms of its inverse income velocity,

$$m/y = \left[1 - \left(\frac{\gamma R}{w} \right)^{\gamma/(1-\gamma)} A_F^{1/(1-\gamma)} \right] (c/y). \tag{26}$$

The solution for c/y follows from

$$c/y = 1 - (i/y) = 1 - \left(\dot{k}_t + \delta_K k_t \right)/y = \left(\dot{k}/k + \delta_K \right)(k/y) = 1 - \left[(g + \delta_K) \cdot (k/y) \right].$$

Since k/y is the inverse of the average product of capital in the Cobb-Douglas production of goods, $k/y = (1 - \beta)/r$. Using this relation and substituting in for g from equation (20) gives that $c/y = \beta + (\rho/r)(1 - \beta)$, so that

$$m/y = \left[1 - \left(\frac{\gamma R}{w} \right)^{\gamma/(1-\gamma)} A_F^{1/(1-\gamma)} \right] \left[\beta + (\rho/r)(1 - \beta) \right]. \tag{27}$$

The money demand per output depends negatively on the nominal interest rate 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 (1993), and Collins and Anderson (1998), the inclusion of A_F is more novel as a time series variable. An increase in A_F increases the productivity of credit services and so decreases the demand for real money balances. The parameter γ determines the degree of diminishing returns to effective labor per unit of consumption in the credit sector, a measure of development that changes

only gradually over long periods of time and that is treated as a constant for the money demand estimation.

2.4.2 Interest Elasticity

From equations (2) and (27), the interest elasticity of m/y, denoted by $\eta_R^{m/y}$, is

$$
\begin{aligned}
\eta_R^{m/y} &= -\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{1-a}{a}\right) \\
&= -\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\left(\frac{\gamma R}{w}\right)^{\gamma/(1-\gamma)} A_F^{1/(1-\gamma)}}{1-\left(\frac{\gamma R}{w}\right)^{\gamma/(1-\gamma)} A_F^{1/(1-\gamma)}}\right).
\end{aligned}
$$

It is immediately clear that $\partial \mid \eta_R^{m/y} \mid /\partial R > 0$; given the Fisher equation (22), this implies that the elasticity increases as inflation goes up. Increases in credit productivity, A_F, similarly increase the elasticity magnitude.

2.5 Basis for Testing

The nature of the interest elasticity will be tested by an approximation to the money demand in (27). The second factor in equation (27), $[\beta + (\rho/r)(1-\beta)]$, which depends on the real interest rate, will be assumed to be constant. This assumption effectively is ignoring cyclical income effects on inverse income velocity coming through changes in consumption relative to income as a result of temporary income effects.[3] Here, with an emphasis on the trends in the interest elasticity over time, the assumption that this term is constant implies that temporary income effects are absent, as is consistent with the model's deterministic setting.[4]

3 Econometric Model Specification

Applying the approximation $(1-z) = -\ln z$ to equation (27), a more tractable form for estimation is

$$
m/y = -B\left\{[\gamma/(1-\gamma)](1+\ln R - \ln w) + (1/\gamma)\ln A_F\right\}, \tag{28}
$$

---

[3]Such changes are possible and dealt with in Friedman (1959), Friedman and Schwartz (1963), and Benk, Gillman, and Kejak (2006), in which an increase in temporary income causes an increase in velocity in a procyclic fashion; and this is investigated econometrically in Gillman, Siklos, and Silver (1997).

[4]Note that other major dimensions of this model have been tested. Gillman and Nakov (2004) find support for the implied general equilibrium Tobin effect, whereby inflation causes the capital to effective labor ratios across sectors to rise, because of a higher input price ratio of w/r; Gillman, Harris, and Matyas (2004) find support for the negative effect of inflation on growth.

where $B \equiv [\beta + (\rho/r)(1-\beta)] \leq 1$, for $g \geq 0$, is treated as a constant.[5]

3.1 Baseline Money Demand Specification

From the equilibrium money demand approximation in equation (28), the model for estimation can be directly expressed as

$$(m_t/y_t) = \alpha_0 + \alpha_1 \ln R_t + \alpha_2 \ln w_t + \alpha_3 \ln A_{Ft} + u_{1t}. \qquad (29)$$

u_{1t} is assumed to be a stationary error term, which reflects dynamic adjustment, measurement errors and (stationary) omitted variables. As described in the Data section below and in the Appendix, the nominal interest rate is measured by the government short term interest rate, the real wage is measured by the economy-wide hourly wage rate, and the productivity in the credit sector is measured by either the output divided by hours worked in the Finance sector, or by the real wage in the Finance sector; real GDP is used for output, a narrow measure of M1 is used as the baseline money stock measure, and broader monetary aggregates are also employed in the robustness analysis.

The comparative statics of equation (28) impose the following general sign restrictions on the parameters for the variables in (29):

$$\alpha_1 < 0, \ \alpha_2 > 0, \ \alpha_3 < 0. \qquad (30)$$

Equation (28) and the Cobb-Douglas specification for the credit production imply the additional variable restrictions:

$$-\alpha_1 = \alpha_2 = \gamma/(1-\gamma), \ \alpha_3 = (1/\gamma)\alpha_2, \ \gamma < 1. \qquad (31)$$

3.2 Alternative Standard Money Demand Specification

As an alternative to equation (29) we also consider a standard constant interest elasticity model for money demand:

$$\ln(m_t/y_t) = \beta_0 + \beta_1 \ln i_t + \beta_2 \ln y_t + u_{2t}. \qquad (32)$$

This is similar to the form estimated by Hoffman, Rasche, and Tieslau (1995), except that for comparability with (29) 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 whether the income elasticity

---

[5]This approximation is best for low values of the variables in the (0,1) range; and all variables are less than 0.15, allowing for a good approximation.

of money demand is greater or less than one. A unitary income elasticity (as implied by the exchange credit model) makes $\beta_2 = 0$, while an income elasticity, for example, of less than one makes β_2 negative.

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.

4   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 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 (29) 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 (6) 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.

5   Results

The two models that we consider are given by equations (29) and (32). 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. Given the non-stationary nature of the data, our econometric strategy is to employ the cointegration techniques developed by Johansen and Juselius (1990) and Johansen (1995) to estimate the two alternative models.

5.1   Baseline 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 (as indicated below) our results are not particularly sensitive to choice of lag length.[6] 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 seems 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 equation (29). 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.

---

[6]There is an unrestricted intercept, with drift in the levels.

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.

5.1.1   Restrictions

More precise estimates can be obtained by imposing the restriction on the cointegrating vector that

$$-\alpha_1 = \alpha_2. \tag{33}$$

A likelihood ratio test indicates that this restriction is not rejected by the data for either country and the respective restricted estimates are reported in Tables 1 and 2. For Australia the coefficient estimates for the restricted model are all statistically significant. From equation (31), $|\alpha_1| = \alpha_2 = \gamma/(1-\gamma)$, 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. These 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. Since equation (31) implies that $\alpha_3 = -[1/(1-\gamma)]$, another estimate of γ can be recovered from the point estimate of α_3. For Australia the implied value of γ is 0.66, which is within the $(0,1)$ assumed bounds; however for the United States the implied value for γ is negative, which violates the bounds. This forces reliance only upon the estimate of γ as given by the α_1 and α_2 joint estimate.

5.1.2   Interest Elasticity Estimate

From equation (29) 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 results in Tables 1 and 2 suggest that the baseline 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 appear to be important influences on the transactions demand for cash.

Figure 1

Estimated Interest Elasticity
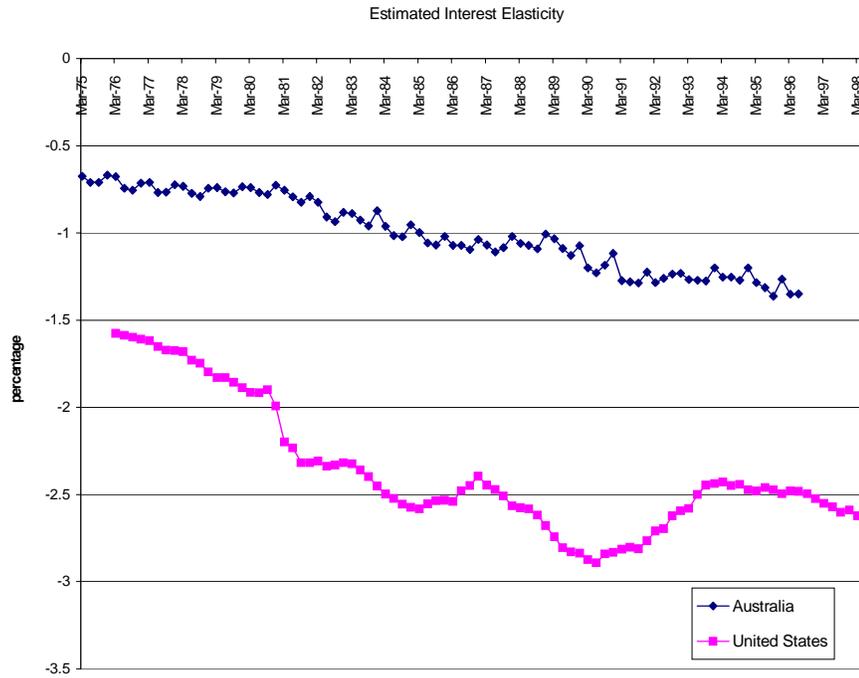
5.2   Conventional Model

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 (32). This specification is equivalent to the model for log-velocity that has been estimated by Hoffman, Rasche, and Tieslau (1995) for a number of countries. The results 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 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.

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.

6 Robustness

6.1 Sensitivity of the Estimates of the Baseline 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 (29) change as we vary first the sample size and then the number of lags of the VAR model (Hoffman, Rasche, and Tieslau, 1995). Tables 5 and 6 present some recursive estimates for equation (29). 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 (29), 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 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 (γ) 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 (29) 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.

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

Sample End	Unrestricted Estimates				Restricted Estimates		
	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.

6.2   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: $\Delta\left(m/y\right), \Delta\left(\ln w\right), \Delta\left(\ln A_F\right),$ 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 (1980) heteroskedasticity-consistent covariance matrix estimator.

For Australia the dynamic model explains about 75 percent of the variation in $\Delta\left(m/y\right)$. The significant variables are two lags of $\Delta\left(m/y\right)$, 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 $\Delta\left(m/y\right)$ 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 $\Delta\left(m/y\right)$. In this case $\Delta\left(\ln A_{Ft-1}\right)$ is found to be a significant explanatory variable.

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.

6.3   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.

7   Discussion

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, but do not report the results here. 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 to 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". Our paper offers up a demand for money derived from a fairly fully specified model, including one based upon the microeconomic structure of banking services production. 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.

Money demand is another facet of general equilibrium models that can be tested. 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 (1956) model. And it gives less free money demand parameters as compared to shopping time models, money-in-the-utility function models, and cash-good, credit-good models, in the sense that there are no unrestricted utility and "transactions cost function" parameters; Indeed it is the attempt to restrict such free utility parameters with some basis in outside data that has led researchers to impose a constant interest elasticity within the shopping time framework. Such parameters here are replaced by only the technology parameters of the credit production function that follows the intermediation literature of Clark (1984). By using a time series for a measure of the productivity of the credit services sector, the estimation implies an estimate of the degree of diminishing returns. This gives an estimated technology parameter that is constant, while the behavioural "parameter" of the interest elasticity is allowed to vary

endogenously.

8   Conclusion

The finding of a stable money demand compares to Mark and Sul (2003), who find a cointegrated Cagan money demand function for individual countries and in a panel. In contrast, is the constant interest elasticity assumption in the exogenous growth, general equilibrium, shopping time models of, for example, Goodfriend (1997), Lucas (2000), and Dittmar, Gavin, and Kydland (2005). The difference is important in that the inflation-growth profile has been shown to be replicated in general equilibrium only with a variable interest elasticity, which rises in magnitude with the interest rate and with productivity increases in credit supply. The rising interest elasticity, in response to the inflation tax rising, may be part of a broader phenomena of greater price sensitivity as tax rates increase, with the results of negative but diminishing growth effects. And such increasing price elasticities also means that tax revenues, inflation, labor or capital taxes, will go up at a decreasing rate as the taxes increase, making such increases less efficacious.

Greater inflation tax sensitivity adds support to the agenda of low inflation from the growth perspective, and may help explain the global move towards inflation targeting at low levels of inflation, while seeking high-growth economic policies. As Gillman and Kejak (2005b) illustrate, there can be bigger increases in growth as the inflation rate is knocked downwards; and as extended to other taxes, this suggests that a low inflation and low flat tax regime is useful in achieving high growth.

Appendix: Data Description

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 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 subsector 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.

References

[1] Barnett, W. A. (1980). Economic Monetary Aggregates: An Application of Index Number and Aggregation Theory. Journal of Econometrics, 14, 11-48.

[2] Barnett, W. A. (1997). Which Road Leads to Stable Money Demand? Economic Journal, 107, 1171-1185.

[3] Benk, S., Gillman M., and M. Kejak (2005). Credit Shocks in the Financial Deregulatory Era: Not the Usual Suspects. Review of Economic Dynamics, 8, 668-687.

[4] Benk, S., Gillman M., and M. Kejak (2006). Money Velocity in an Endogenous Growth Business Cycle with Credit Shocks. CDMA Conference, Paper Series 0604.

[5] Cagan, P. (1956). The Monetary Dynamics of Hyperinflation, in Studies in the Quantity Theory of Money, 25-120, M. Friedman (Ed.), The University of Chicago Press, Chicago.

[6] Clark, J. A. (1984). Estimation of Economies of Scale in Banking Using a Generalized Functional Form. Journal of Money, Credit, and Banking, 16, 53-68.

[7] Collins, S., and R. Anderson (1998). Modeling U.S. Households' Demands for Liquid Wealth in an Era of Financial Change. Journal of Money, Credit and Banking, 30, 83-101.

[8] Dittmar, R., Gavin W., and F. Kydland (2005). Inflation Persistence and Flexible Prices. International Economic Review, 46, 245-261.

[9] Dixon, H. (1997). Controversy: Microfoundations and the Demand for Money. Economic Journal, 107, 1169-1170.

[10] Dowd, K. (1990). The Value of Time and the Transactions Demand for Money. Journal of Money, Credit and Banking, 22, 51-64.

[11] Friedman, M. (1959). The Demand for Money: Some Theoretical and Empirical Results. Journal of Political Economy, 67, 327-351.

[12] Friedman, M., and A. Schwartz (1963). Money and Business Cycles. Review of Economics and Statistics, 45, 32-64.

[13] Friedman, M., and A. Schwartz (1982). Monetary Trends in the United States and the United Kingdom, The University of Chicago Press, Chicago.

[14] Gillman, M., Harris M., and L. Matyas (2004). Inflation and Growth: Explaining a Negative Effect. Empirical Economics, 29, 149-167. Reprinted in Studies in Empirical Economics, Panel Data: Theory and Applications (2004), B. H. Baltagi (Ed.), Physica-Verlag.

[15] Gillman, M., and M. Kejak (2004). The Demand for Bank Reserves and Other Monetary Aggregates. Economic Inquiry, 42, 518-533.

[16] Gillman, M., and M. Kejak (2005a). Contrasting Models of the Effect of Inflation on Growth. Journal of Economic Surveys, 19, 113-136.

[17] Gillman, M., and M. Kejak (2005b). Inflation and Balanced-Path Growth with Alternative Payment Mechanisms. Economic Journal, 115, 247-270.

[18] Gillman, M., and A. Nakov (2004). Causality of the Inflation-Growth Mirror in Accession Countries. Economics of Transition, 12, 653-682.

[19] Gillman, M., Siklos P., and J. L. Silver (1997). Money Velocity with Costly Credit. Journal of Economic Research, 2, 179-207.

[20] Goodfriend, M. (1997). A Framework for the Analysis of Moderate Inflations. Journal of Monetary Economics, 39, 45-65.

[21] Hancock, D. (1985). The Financial Firm: Production with Monetary and Nonmonetary Goods. Journal of Political Economy, 93, 859-880.

[22] Hoffman, D. L., Rasche R. H., and M. A. Tieslau (1995). The Stability of Long-Run Money Demand in Five Industrial Countries. Journal of Monetary Economics, 35, 317-341.

[23] Johansen, S. (1995). Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, Oxford University Press, Oxford.

[24] Johansen, S., and K. Juselius (1990). Maximum Likelihood Estimation and Inference on Cointegration-With Applications to the Demand for Money. Oxford Bulletin of Economics and Statistics, 52, 169-210.

[25] Karni, E. (1974). The Value of Time and Demand for Money. Journal of Money, Credit and Banking, 6, 45-64.

[26] Lowe, P. (1995). Labour-Productivity Growth and Relative Wages: 1978-1994. Reserve Bank of Australia, DP 9505, Sydney.

[27] Lucas, Jr., R. E. (1988). On the Mechanics of Economic Development. Journal of Monetary Economics, 22, 3-42.

[28] Lucas, Jr., R. E. (2000). Inflation and Welfare. Econometrica, 68, 247-275.

[29] Mark, N. C., and D. Sul (2003). Cointegration Vector Estimation by Panel DOLS and Long Run Money Demand. Oxford Bulletin of Economics and Statistics, 65, 655-680.

[30] Orden, D., and L. A. Fisher (1993). Financial Deregulation and the Dynamics of Money, Prices, and Output in New Zealand and Australia. Journal of Money, Credit and Banking, 25, 273-292.

[31] White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix and a Direct Test for Heteroskedasticity. Econometrica, 48, 817-838.