Currency preferences and the Australian dollar

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Abstract

We investigate the theory and empirics of currency substitution and currency complementarity. Analytical tractability is facilitated by focussing on a small currency. Data spanning 1985 to the turn of the century contain evidence of the Australian dollar's substitution for the mark and complementarity with the yen, consistent with our theory that international variables will in general affect the demand for domestic money. Our theory also predicts third-currency effects, and the data reveal several of these. For example, rises in the US Federal Funds rate were associated with depreciations of the Australian dollar against the yen, controlling for the spread between interest rates in Australia and Japan.

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1. Introduction

This paper is a theoretical and empirical study of international influences on the Australian dollar during the period 1985 to 2001. Its theoretical basis is atemporally non-separable preferences. These imply international variables in the money demand function and third-currency effects in exchange-rate determination. We build on the currency substitution literature and introduce the possibility of currency complementarity.

The paper is organized as follows. Section 2 relates our research to previous work, including an update of a landmark comparison of income velocities of circulation (Brittain 1981). Section 3 provides an informal analysis of currency substitution and currency complementarity, followed by a formal model based on the cash-in-advance paradigm. Section 4 investigates some associated empirics. It re-examines the demand for the Australian dollar, and also investigates third-currency effects on the external value of the dollar. Section 5 summarizes and concludes. A theoretical appendix draws out implications of our model for pricing currencies and discount bills, and an empirical appendix confirms the stability of money demand estimates in the main text.

2. Antecedents

Theory typically postulates that the demand for a nation's money is wholly determined by two domestic macroeconomic variables. Thus the textbook condition for equilibrium in the market for the Australian dollar is

$$\frac{M}{P} = L(Y, R) \qquad (1)$$

where M is the outstanding stock of Australian money, P is the general level of prices of Australian-produced goods and services, Y is the general level of real economic activity and R is some measure of short-term interest rates in Australia. If prices are assumed sticky, we describe Eq. (1) as the "LM curve". If not, the term "portfolio balance schedule" is often used instead. We assume $\partial L/\partial Y > 0$ and $\partial L/\partial R < 0$; Y is the "scale variable", and R is the "opportunity cost" variable in the money demand function.

Tobin (1969) added bond and stock returns to the menu of opportunity-cost variables, with bills, bonds and stocks all assumed to be "gross substitutes" for money. This has no deep theoretical rationale. On the other hand, the unaugmented money demand function on the right-hand side of Eq. (1) is readily given a theoretical justification; candidate microfoundations for money demand have included money directly in the utility function (Lucas 2000), and money indirectly in the utility function via a cash-in-advance constraint (Lucas 1984, Lucas and Stokey 1987). Whether the resulting money demand is direct or derived matters little in applications. These include estimating money demand functions (Mark and Sul 2002) and explaining the behavior of exchange rates (Obstfeld and Rogoff 1996).

The standard model of the money market [i.e., Eq. (1)] is restrictive compared to treatments of some other markets. A case in point is alcoholic beverages (Clements and Selvenathan 1991, Clements *et al* 1996). Holding constant the total consumption of alcohol in Australia, there is evidence of substitution across beer and wine in the sense that the two relevant cross-price elasticities are negative, consistent with the fact that a fall in beer consumption per head has gone hand in hand with a rise in wine consumption per head. On the other hand, there is evidence of complementarity between beer and spirits in the sense that if we hold constant the marginal utility of income then a rise in the relative price of spirits has been associated with a fall in the consumption of beer, a finding that has been rationalized by the "formal dinner model" of an evening meal that kicks off with beer and finishes with spirits. Wine is neither a substitute nor a complement for the other two beverages, in the sense that if we again hold constant the marginal utility of income then a change in the relative price of wine does not induce a significant change in the consumption of either beer or spirits.

A challenge for monetary economics is to match this level of analytical sophistication.

2.1. Currency substitution

Theoretical and empirical research on money demand has given consideration to the possibility of *currency substitution* (related to the concept of "dollarization"). The pioneering contribution was Boyer (1970), and an influential survey is Giovannini and Turtelbloom (1994).

For developed-world currencies the evidence from money demand regressions has been mixed. Among the pound, the mark and the US dollar, for example, only German M0 and M1 can be regarded as having shown anything like persuasive evidence of substituting for some other currency (Brittain 1981, Cuddington 1982, Traa 1985). In the case of Canada, for example, scant evidence has been found, despite the plausibility of the hypothesis that US dollars are a substitute for Canadian ones (Bordo and Choudri 1982, Traa 1985).

Since the 1990s, research on currency substitution has continued apace, but has largely been confined either to pure theory or to the empirics of transition economies; see, e.g. Trejos and Wright (2000) and Liviatan (1993) respectively. Moreover, the possibility of currency complementarity seems never to have been considered in any setting. The present paper formulates and tests a model that allows for non-separable currency preferences in the case of developed-world currencies, including the possibility of complementarity, and with special reference to the Australian dollar.

2.2. Velocity comparisons

Brittain's (1981) evidence of substitution between the deutschmark and the US dollar included a graphical comparison of income velocities of money in Germany and the United States. Rising velocity of US M1 contrasted with falling velocity of German M1, suggesting that there had been a substitution of deutschmarks for US dollars. While never represented as more than a prelude to formal regression tests, Brittain's graphical exercise shed light, and proved to be influential.

This subsection updates Brittain's V1 comparisons to the period spanned by our regressions, namely 1985 to 2001, and broadens the scope of the exercise by bringing in Japan and Australia. Additionally, we calculate pairwise correlation coefficients, across the four countries just mentioned. The coefficients include logged and differenced V0, as well as logged and differenced V1. For details see Figs. 1 and 2.

Fig. 1 compares the logs of V1 in Germany, Japan and the United States over the period 1985 to the turn of the century (v denotes logs).

[Fig. 1 here]

Beginning with Germany, Brittain's finding that German and US V1 are negatively correlated is confirmed by Fig. 1. However, the extent of negative correlation between logged and differenced V1 in the two countries is only –0.05. The relevant correlation coefficient for logged and differenced V0, namely –0.01, is even smaller in absolute value, although it too has a negative sign.

For the Germany-Japan pairing we get a mixed message; the correlation is negative for V1 but positive for V0. Accordingly, Fig. 1 sheds little light on whether there has been either substitution or complementarity between the mark and the yen. By contrast, there are two positive coefficients for the Japan-US pairing, consistent with complementarity between the yen and the US dollar.

In this study, formal multivariate tests for substitution and complementarity are confined to pairs involving the Australian dollar. At this point we give an informal indication; see Fig. 2.

[Fig. 2 here]

Fig. 2 suggests that the deutschmark substituted for the Australian dollar; the relevant correlation coefficients are –0.03 and –0.08. By contrast, Fig. 2 suggests also that the yen complemented the Australian dollar; the relevant coefficients are 0.04 and 0.23. Both pairs of results are broadly consistent with Section 4's regression results (which warrant more weight than Figs. 1 and 2). On the other hand, the US dollar is suggested as having been a complement with the Australian dollar, whereas the regressions in Section 4 lead to the conclusion that the US dollar has neither substituted nor complemented its Australian counterpart.

3. Theory

Eq. (1) is supplanted here by the general formulation

$$\frac{M_1}{P_1} = L_1\left(\boldsymbol{Y}, \boldsymbol{R}\right) \tag{2}$$

where $\boldsymbol{Y} \equiv \left(Y_1, ..., Y_n\right)$ is a vector of n constant-price GDPs, and $\boldsymbol{R} \equiv \left(R_1, ..., R_n\right)$ is a vector of n short-term nominal interest rates. In other words, there are n scale variables and n opportunity-cost variables.

As in standard theory we predict $\partial L_1 / \partial Y_1 > 0$ and $\partial L_1 / \partial R_1 < 0$. We have

$$\partial L_1 / \partial R_2 \gtrless 0 \tag{3}$$

according to whether currency 2 is a substitute for or complement with currency 1. The intuition for the case of *substitutes* is as follows. Imagine that the representative agent is a "citizen of the world" – a cosmopolitan individual without any particular national habitat. Suppose further that currency 2 is a substitute for currency 1 in the Edgeworth sense, that is, the two currencies satisfy similar wants or needs. If R_2 rises then standard theory tells us that $\partial L_2 / \partial R_2 < 0$, so there will be a fall in the equilibrium real stock of currency 2. Having relinquished some of the liquidity services provided by currency 2, the representative agent will substitute towards one or more other currencies generating similar services.

Given Covered Interest Parity we can use the forward discount on currency 1, $D \equiv R_1 - R_2$, as the “international” opportunity–cost variable in Eq. (2), instead of R_2. If D falls while R_1 remains constant then there must be an equal rise in R_2. The demand for currency 1 is again predicted to rise. To the extent that Uncovered Interest Parity holds, the fall in D represents an expectation of appreciation of currency 1 against currency 2, so this prediction may have some intuitive appeal. What is essential is that we include more than one opportunity-cost variable in Eq. (2), thereby controlling for the money/discount bill margin *and* the domestic money/foreign money margin.

Intuition for the case of *complements* follows readily. Suppose that currency 2 complements currency 1 in the Edgeworth sense, in other words, the two monies are used in conjunction with each other. Once a rise in R_2 has shrunk the real stock of currency 2, the representative agent no longer has the same need for currency 1, and the demand for it will fall.

The interplay between foreign scale variables and domestic real balances is less straightforward. On the one hand, one might expect Y_2 to affect the demand for currency 1 in a way similar to the influence of Y_1. A counter-argument is that a rise in

Y_2, having induced a rise in M_2/P_2, might lead to less need for currency 1. This counter-argument has less force in the case of complements. Overall, we settle for

$$\partial L_1/\partial Y_2 \gtrless 0 \tag{4}$$

with a presumption that the sign is more likely to be positive in the case of complements.

One would expect the effects of multiple changes in scale or opportunity-cost variables to be constrained by suitable multivariate analogues of the standard conditions $\partial L/\partial Y > 0$ and $\partial L/\partial R < 0$. For example, a one percent rise in all national GDPs would be expected to raise the demand for currency 1, notwithstanding the ambiguity suggested by Eq. (4). Likewise, a one percentage point rise in all national interest rates would be expected to reduce the demand for currency 1, even in the case of substitution between currencies 1 and 2.

3.1. Model

The remainder of this section provides microfoundations for the money demand function (2), and the criteria (3) and (4). We use a multicountry generalization of the cash-in-advance model due to Lucas (1984) and Lucas and Stokey (1987). There are *n* "cash goods" that can be paid for only by means of currency *i*, and also *n* "credit goods" that are paid for by means of one-period trade credits denominated in currency *i* $(i = 1,...,n)$. One could think of the agent's wallet as containing *n* distinct currencies, and also *n* credit cards, one per currency.

Consider a representative agent with utility function described by

$$E\left[\sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^{t} U\left(\boldsymbol{C}_t\right)\right] \qquad 0<\frac{1}{1+\rho}<1 \tag{5}$$

where, at each date $t = 0, 1, 2, \ldots,$ the consumption vector written out in full is

$$\boldsymbol{C} \equiv \left(C_1, C_2, \ldots, C_{2i-1}, C_{2i}, \ldots, C_{2n-1}, C_{2n}\right) \tag{6}$$

and E denotes the expectations operator. On the menu are odd-numbered cash goods $C_1, C_3, \ldots, C_{2i-1}, \ldots, C_{2n-1}$, and even-numbered credit goods $C_2, C_4, \ldots, C_{2i}, \ldots, C_{2n}$. Both C_{2i-1} and C_{2i} $(i = 1, \ldots, n)$ carry a price tag reading P_i units of currency i per unit of C_{2i-1} or C_{2i}; currency i is the unit of account for both cash good $2i-1$ and credit good $2i$ $(i = 1, \ldots, n)$. The quantity of currency i is denoted by M_i $(i = 1, \ldots, n)$. All consumption takes place at the end of the period. For simplicity we confine analysis to the case of full current information. That is, at the beginning of each period the state of the economy is known, but there is there is no new information until the beginning of the next period.

The period utility function $U(\cdot)$ is assumed to be concave and twice differentiable in its $2n$ arguments. In order to guarantee that each money demand function has a negative sign with respect to its own-currency interest rate (see below) it is also assumed that $U_{2i-1,2i}$ is less than either $-U_{2i-1,2i-1}$ or $-U_{2i,2i}$. In other words, we impose an upper bound on the extent of any Edgeworth complementarity that might obtain between cash goods and credit goods denominated in the same currency.

Currency substitution and complementarity can be defined in terms of sign restrictions arising from a quasi-indirect utility function. This requires some explanation. The equilibrium quantity of real balances i is given by M_i / P_i and the endowment of commodity i to the representative agent is given by Y_i $(i = 1, \ldots, n)$. In a full-current-information environment, cash-in-advance constraints bind, that is,

$$M_i = P_i C_{2i-1} \qquad (i = 1, \ldots, n). \tag{7}$$

Goods-market equilibrium requires

$$C_{2i-1} + C_{2i} = Y_i \qquad (i = 1,\ldots,n). \tag{8}$$

Hence the quasi-indirect period-utility function is given by

$$U\left(\frac{M_1}{P_1}, Y_1 - \frac{M_1}{P_1}, \ldots, \frac{M_i}{P_i}, Y_i - \frac{M_i}{P_i}, \ldots, \frac{M_n}{P_n}, Y_n - \frac{M_n}{P_n}\right). \tag{9}$$

Now real-balances 1 and 2 are Edgeworth substitutes ("serve similar wants and needs") if and only if

$$\frac{\partial^2 U}{\partial\left(\frac{M_1}{P_1}\right)\partial\left(\frac{M_2}{P_2}\right)}\left(\frac{M_1}{P_1}, Y_1 - \frac{M_1}{P_1}, \frac{M_2}{P_2}, Y_2 - \frac{M_2}{P_2}, \ldots\right) < 0. \tag{10}$$

In terms of the *direct* utility function this means

$$U_{13} - U_{14} - U_{23} + U_{24} \quad < 0. \tag{11}$$

This Edgeworth criterion will be shown to correspond closely to an analogue of the familiar "gross substitutes" criterion derived from an "ordinary" demand function[1]. Reversal of the inequality defines currency complementarity.

As in Lucas (1984) and Lucas and Stokey (1987), the timing assumptions here are that all transactions are conducted at the beginning of the period, including portfolio reallocations, whereas production and consumption take place at the end of the period. At the beginning of each period the agent's *sources* of funds W_t can be written as

$$W_t \equiv \sum_{i=1}^{n} S_{it}^{-1}\left[H_{it} + M_{i,t-1} + B_{it} + (1+R_{it})^{-1} P_{it} Y_{it} + (S_{it} - F_{i,t-1}) X_{it}\right] \tag{12}$$

where S_{it} is spot units of currency *i* per unit of currency *n* $(S_n \equiv 1)$, H_{it} is the helicopter-style drop of currency *i*, B_{it} is receipts from currency-*i* trade credits purchased in period $t-1$ (assumed to be of the discount-bill variety, and negative in the case of trade debts), $(1+R_{it})^{-1}$ is the period-*t* currency-*i* price of a discount bill denominated in currency *i*, $F_{i,t-1}$ is the one-period-ahead forward price, determined in period $t-1$, of currency i per unit of currency n $(F_n \equiv 1)$, and X_{it} is the number of forward contracts to sell F_i units of currency i in exchange for one unit of currency n. $(X_{nt} \equiv 0)$.

Forward contracts are derivative securities that can be replicated by suitable combinations of long and short positions in discount bills. Hence they are redundant in the portfolio of the representative agent. However, in order to confirm that Covered Interest Parity holds in our model (see Appendix 1), forward contracts are included here.

Uses of funds are shown by the budget constraint of the representative agent:

$$W_t = \sum_{i=1}^{n} S_{it}^{-1} \left\{ M_{it} + (1+R_{it})^{-1} \left[B'_{i,t+1} + P_{it} \left(C_{2i-1,t} + C_{2i,t} \right) \right] \right\}. \tag{13}$$

That is, available resources are allocated between money balances, discount bills, and goods.

In addition to the aggregate resource constraint (8), we have the money supply identity

$$M_{i,t-1} + H_{it} = M_{it}. \tag{14}$$

Also, one person's trade credit is another's trade debt, so that

$$B_{it} = 0 \tag{15}$$

in the aggregate.

Aggregate forward positions in currencies have an analogous zero-sum feature:

$$X_{it} = 0 \qquad (i = 1,...,n). \tag{16}$$

To recapitulate, the forcing variables in this model consist of a beginning-of-period helicopter drop of n currencies $\boldsymbol{H}_t$, together with an end-of-period endowment of n outputs $\boldsymbol{Y}_t$, in quantities known to agents at the beginning of the period.

3.2. Solution

The problem of the representative agent is readily solved by dynamic programming. For convenience we drop time subscripts and denote one-period-ahead values by primes. The relevant recursion is:

$$J\left(W,\boldsymbol{P},\boldsymbol{R},\boldsymbol{S}\right)\equiv\max_{(\boldsymbol{C},\boldsymbol{M},\boldsymbol{B}',\boldsymbol{X}',\mu,\lambda)}\Big\{U\left(\boldsymbol{C}\right)+\sum_{i=1}^{n}\mu_i S_i^{-1}\left(M_i-P_iC_{2i-1}\right)$$

$$+\lambda\left\{W-\sum_{i=1}^{n}S_i^{-1}\left[M_i+\left(1+R_i\right)^{-1}\left[B_i'+P_i\left(C_{2i-1}+C_{2i}\right)\right]\right]\right\}$$

$$+(1+\rho)^{-1}E\left[J\left(W',\boldsymbol{P}',\boldsymbol{R}',\boldsymbol{S}'\right)\right]\Big\}\quad,\tag{17}$$

where vectors are indicated by bold letters, μ_i is the multiplier to the cash-in-advance constraint on purchases of cash good $2i-1$ $\left(i=1,...,n\right)$, measured in terms of currency *n*, and λ is the multiplier to the budget constraint, with the interpretation of the marginal utility of wealth measured in terms of currency *n*.

First-order conditions with respect to C_{2i-1},C_{2i},M_i,B_i' and X_i' are

$$U_{2i-1}-\mu_i S_i^{-1}P_i-\lambda S_i^{-1}\left(1+R_i\right)^{-1}P_i=0\tag{18}$$

$$U_{2i}-\lambda S_i^{-1}\left(1+R_i\right)^{-1}P_i=0\tag{19}$$

$$\left(\mu_i-\lambda\right)^{-1}S_i^{-1}+(1+\rho)^{-1}E\left(\lambda'/S_i'\right)=0\tag{20}$$

$$-\lambda\left(1+R_i\right)^{-1}S_i^{-1}+(1+\rho)^{-1}E\left(\lambda'/S_i'\right)=0\tag{21}$$

$$(1+\rho)^{-1}E\left[\lambda'\left(S_i'-F_i\right)/S_i'\right]=0\,.\tag{22}$$

For an analysis of these conditions see Appendix 1.

3.3. Money demands

As a preliminary to analysing money demands, note that (18), (19) and (20) give the following standard result for cash-in-advance models with credit goods:

$$\frac{U_{2i-1}(C)}{U_{2i}(C)} = 1 + R_i \qquad (i = 1,...,n) \quad . \tag{23}$$

In Eq. (23), replace the vector $C \equiv (C_1, C_2, ..., C_{2n-1}, C_{2n})$ by its equilibrium counterpart $\left(\frac{M_1}{P_1}, Y_1 - \frac{M_1}{P_1}, ..., \frac{M_n}{P_n}, Y_n - \frac{M_n}{P_n}\right)$. This generates n money demand functions $L_i(\boldsymbol{Y}, \boldsymbol{R})$ ($i = 1,...,n$).

The functions $L_i(\boldsymbol{Y}, \boldsymbol{R})$ are in general complicated mappings from the quasi-indirect utility function $U(M_1/P_1, ..., Y_n - M_n/P_n)$ and interest rates $(R_1, ..., R_n)$. We ease analysis while maintaining relevance to the Australian case by going to the special case of a "small" value of currency 1, parallelling the familiar "small country" assumption of international trade theory. Specifically, terms of order $\frac{M_1/P_1}{M_2/P_2}$ are assumed to be second-order. For example, one could think of currency 2 as the, deutschmark, yen, or US dollar, while currency 1 corresponds to the Australian dollar. We also set $n = 2$.

The total differential of the equilibrium counterpart of Eq. (23), with currency 1 assumed "small", and in the case $n = 2$, can be written as

$$\begin{bmatrix} [U_{11} - U_{12} - (1+R_1)(U_{21} - U_{22})](M_1/P_1) & [U_{13} - U_{14} - (1+R_1)(U_{23} - U_{24})](M_2/P_2) \\ 0 & U_{33} - U_{34} - (1+R_2)(U_{43} - U_{44}) \end{bmatrix} \begin{bmatrix} d\ell n(M_1/P_1) \\ d\ell n(M_2/P_2) \end{bmatrix}$$

$$= \begin{bmatrix} U_2 & 0 \\ 0 & U_4/(M_2/P_2) \end{bmatrix} \begin{bmatrix} dR_1 \\ dR_2 \end{bmatrix} + \begin{bmatrix} [-U_{12} + (1+R_1)U_{22}]Y_1 & [-U_{14} + (1+R_1)U_{24}]Y_2 \\ 0 & [-U_{34} + (1+R_2)U_{44}]V_2 \end{bmatrix} \begin{bmatrix} d\ell nY_1 \\ d\ell nY_2 \end{bmatrix}. \tag{24}$$

This has the compact representation

$$\Gamma \boldsymbol{d\ell n}\left(\boldsymbol{M/P}\right) = \Omega \boldsymbol{dR} + \Theta \boldsymbol{d\ell nY} \tag{25}$$

where the definitions of new symbols are clear from (24). The determinant of Γ, or $|\Gamma|$, is given by

$$\left(M_1/P_1\right)\left[U_{11} - U_{12} - \left(1+R_1\right)\left(U_{21} - U_{22}\right)\right]\left[U_{33} - U_{34} - \left(1+R_2\right)\left(U_{43} - U_{44}\right)\right] > 0. \tag{26}$$

Straightforward manipulation of Eq. (25) gives the sign of $\partial \ell n L_1 / \partial R_1$:

$$\frac{\partial \ell n\left(M_1/P_1\right)}{\partial R_1} = \frac{U_2/\left(M_1/P_1\right)}{U_{11} - U_{12} - \left(1+R_1\right)\left(U_{21} - U_{22}\right)} < 0. \tag{27}$$

Similarly, with respect to the "foreign" interest rate we get

$$\frac{\partial \ell n\left(M_1/P_1\right)}{\partial R_2} = \frac{-U_4\left[U_{13} - U_{14} + \left(1+R_1\right)\left(U_{23} - U_{24}\right)\right]}{|\Gamma|} \lesseqgtr 0. \tag{28}$$

If the term $R_1\left(U_{23} - U_{24}\right)$ is second-order, currency substitution in the Edgeworth sense is necessary and sufficient to deliver a positive sign for the right-hand term.[2] Currency complementarity is associated with a negative sign.[3]

Turning to the effects of changes in the scale variables, for domestic output Y_1 we have

$$\frac{\partial \ell n\left(M_1/P_1\right)}{\partial \ell n Y_1} = \frac{\left[-U_{12} + \left(1+R_1\right)\right]V_1}{U_{11} - U_{12} - \left(1+R_1\right)\left(U_{21} - U_{22}\right)} > 0. \tag{29}$$

By contrast, the effect of the foreign scale variable on domestic money demand is ambiguous: [4]

$$\frac{\partial \ell n\left(M_1/P_1\right)}{\partial \ell n Y_2}=\frac{\left[-U_{14}+\left(1+R_1\right)U_{22}\right]V_2}{U_{11}-U_{12}-\left(1+R_1\right)\left(U_{21}-U_{22}\right)}$$

$$+\frac{\left[-U_{13}+U_{14}-\left(1+R_1\right)\left(U_{23}-U_{24}\right)\right]\left[-U_{34}+\left(1+R_2\right)U_{44}\right]Y_2}{\left|\Gamma\right|}$$

$$\gtrless \quad 0 \quad . \tag{30}$$

Recalling our assumption that the final term in square brackets is negative, there are three factors making for the "perverse" case $\partial \ell n\left(M_1/P_1\right)/\partial \ell n Y_2 < 0$. These are substitution between domestic cash goods and foreign credit goods $\left(U_{14}<0\right)$, complementarity between domestic and foreign credit goods $\left(U_{24}>0\right)$, and substitution between domestic and foreign monies $\left(U_{13}-U_{14}-\left(1+R_1\right)\left(U_{23}-U_{24}\right)<0\right)$. By way of explanation of the first two factors, an increase in foreign output will raise the equilibrium quantity of foreign credit goods, as well as foreign cash goods, so if the foreign credit good substitutes for the domestic cash good $\left(U_{14}<0\right)$ and complements the domestic credit good $\left(U_{24}>0\right)$ then the total available quantity Y_1 of domestic goods will be reallocated towards domestic credit goods, and away from domestic cash goods. On both counts the equilibrium quantity of domestic real balances will fall.

4. Empirics

This section presents our empirical findings concerning currency preferences and the Australian dollar.

4.1. Money demand estimates

A perennial issue in money demand regressions is the choice of monetary aggregate. Since Section 3 recognises the transactions motive for holding money, and assumes that money does not bear interest, we opt for M0 (monetary base) and M1 (narrow money) measures. Section 3 highlights "cash in advance" theory, suggesting a beginning-of-period dating for money stocks rather than end-of-period or period-average dating.[5] Similarly, the interest rates (opportunity costs) are dated on a beginning-of-period basis. The theory suggests using GDP deflators rather than CPIs for transforming nominal money balances into real ones.

Our data are quarterly, and span 1985 to 2001. This choice of start date mitigates measurement difficulties arising from the financial innovations and deregulations that were a feature of the first half of the 1980s in Australia (Milbourne, 1990). It implies that our sample falls entirely within the post-1983 era of floating exchange rates. The transition in 1999:4 from deutschmarks to euros is handled by dummy variables. All the variables employed in our analysis are seasonally adjusted whenever a seasonal is present.

The money demand regressions reported below are estimated by the Johansen technique, which turned out to yield estimates with better diagnostic properties than dynamic OLS. In all cases the estimated functional form is

$$mk \ = \ \alpha + p + \boldsymbol{\beta y} + \boldsymbol{\gamma R} + \ \varepsilon \tag{31}$$

where $mk \ \ (k = 0,1)$ is the log of either Australia's monetary base $(k = 0)$ or volume of M1 $(k = 1)$, α is the intercept term, p is the log of Australia's GDP deflator, $\boldsymbol{\beta} \equiv (\beta_{AUD}, \beta_{DEM}, \beta_{JPY}, \beta_{USD})$ is a row vector of coefficients showing elasticities with respect to scale variables, $\boldsymbol{y}$ is a column vector of logged GDPs and $\boldsymbol{\gamma} \equiv (\gamma_{AUD}, \gamma_{DEM}, \gamma_{JPY}, \gamma_{USD})$ is a row vector of coefficients showing semi-elasticities with respect to opportunity-cost variables. For example, β_{AUD} is the elasticity with respect to Australia's GDP, and γ_{AUD} is the semi-elasticity with respect to Australia's 90-day Bank-Accepted Bill rate. The error term is ε. Results are set out in Table 1.

[Table 1 here]

The linear homogeneity restriction imposed on prices was only barely rejected at a 5% significant level for the M0 estimate (the result of the applied LR test is Chi^2(1) = 3.9229 [0.0476]) and was not rejected by the applied LR-test for the M1 estimate (Chi^2(1) = 1.1572 [0.2820]) [5].Therefore, we can reasonably state in the latter case that the non-existence of money illusion assumption is satisfied. Although the evidence with respect to price homogeneity is not strong for the M0 estimate, we restrict the price level in line with our theoretical model.

Beginning with the domestic opportunity costs of holding M0 and M1 we confirm the significantly negative signs predicted by standard theory. The absolute size of the M0 semi-elasticity is small, consistent with the low volatility of V0 over the sample period.

Turning to the offshore semi-elasticities, there is a positive coefficient for the German opportunity-cost variable in the M1 case. Specifically, a rise of 1 percentage point in the German call money rate is associated with a 2.7 percent rise in the demand for Australia's M1. Hence, we find that there was substitution between the deutschmark and the Australian dollar (at least in the case of M1), consistent with Cheah and Kingston (1987).

By contrast, there is a negative coefficient for the Japanese opportunity cost variable, for both M0 and M1. Although the coefficient is significant only in the latter case, it is sizeable; a rise of 1 percentage point in the Japanese call money rate is associated with a 4.7% fall in the demand for Australia's M1. We conclude that the

Japanese yen and Australian dollar have been complements. This is consistent with the observation that commodity-importing Japan has an economy that is exceptionally complementary with that of commodity-exporting Australia (without ruling out the possibility of a capital-account explanation).

Judging by the insignificant coefficient on the US Federal Funds rate in the case of both M0 and M1, there was neither substitution nor complementarity between the US dollar and its Australian counterpart. This is contrary to the intuition that the two currencies are substitutes, given the similarities between the structures of the two economies. One possible explanation is multicollinearity involving either the US and Australian scale variables or the US and Australian opportunity-cost variables. Another explanation runs as follows: As one of the very few first-world commodity exporters, the Australian economy tends to be complementary with the developed-world economy that accounts for the bulk of Australia's international trade and payments, yet it is scarcely an exaggeration to say that the United States *is* the developed-world economy. During the 1990s, for example, the United States was the destination of over half the world's international portfolio investment. In this way the Australian dollar may have been pushed away from its natural relationship of being a substitute for its US counterpart.

Concerning scale variables, domestic GDP has a strongly significant influence on the demand for the Australian dollar, as one would expect. German GDP has a significantly positive effect on the demand for Australia's monetary base, whereas Japanese GDP has a significantly negative effect. Section 3 was ambiguous about the influence of foreign scale variables on domestic money demand. Moreover, synchronization of the international business cycle could well be creating multicollinearity problems. The negative sign for the coefficient on the Japanese scale variable is not only at odds (to some extent) with the Section 3 theory, but with results later in this section on third-currency effects. In all these ways there are limits to what can be inferred about the estimates of particular scale coefficients.

4.2. Restrictions

Section 3 noted the plausible restriction that an increase of 1 percent point in interest rates everywhere will reduce the demand for domestic money, even if domestic money is a substitute for one or more foreign currencies. Likewise, a rise of 1 per cent in outputs everywhere should raise the demand for domestic money even if a foreign scale variable enters the relevant regression with a negative coefficient.

A preliminary exercise is simply to calculate the "global" scale and opportunity-cost coefficients, implied by Table 1, that correspond to the mental experiments just described. In the case of M0 the relevant global coefficient for scale variables is given by 1.13 + 0.52 - 0.63 = 1.02. Likewise, the global coefficient for opportunity-cost coefficients comes in at -.001. In the case of M1 the global scale and opportunity-cost variables are 1.37 and -.047. Overall, then, each of the global coefficients has the expected sign. Moreover, each is of a magnitude that is no less reasonable than its domestic counterpart.

Again drawing on Table 1, Table 2 tests formally some international restrictions on the demand for the Australian dollar.

[Table 2 here]

Beginning with the first row of Table 2, consider the hypothesis that in the case of M1 the coefficient on the 90-day BAB rate is equal to the negative of the coefficient on the German call money rate. Although the Australian coefficient is more precisely estimated, we cannot reject this hypothesis.

The second row reports a test of the hypothesis that in the case of M0 the coefficient on the BAB rate is equal to the negative of the coefficient on the Japanese call money rate. Although the Japanese coefficient is very imprecisely estimated, we again cannot reject the hypothesis that the absolute values of the coefficients are equal. Moreover, we cannot be confident of a negative slope for Australia's M0 demand function with respect to interest rates worldwide, consistent with the very low volatility of Australia’s V0 over our sample period.

Turning to the third row, consider the hypothesis that in the case of M1 the coefficient on the Australian scale variable is equal to the negative of its German counterpart. This is rejected at the 10% level. The fourth row shows tests of the hypothesis that that the opportunity-cost semi-elasticities sum to zero. This cannot be rejected in the case of M0, but can in the case of M1.

The last row reports a test of the hypothesis that the scale elasticities sum to zero. This can be rejected for both M0 and M1, engendering confidence that a 1 percent increase in GDP worldwide will raise the demand for the Australian dollar.

4.3. Implications for exchange rates

Non-separable currency preferences have implications for exchange rates. Notably, there can be third-currency effects. Yet the pre-existing literature employs bilateral models of exchange rates, with the sole exception of Hodrick and Vassalou (2002). They build a multilateral factor model based on short-term and long-term interest rates. Bilateral modelling was indeed found to be inadequate for the major currencies. For example, UK interest rates affected DEM/USD and DEM/JPY exchange rates. Drawing upon the Euler equations derived in Section 3, the remainder of this section tests for third-currency effects on the AUD over the period 1986 to 1998.

The estimated equation is derived in Appendix 1. For convenience it is reproduced here (recall that Δ is the backward-difference operator):

$$e'_{ij} = \alpha + \boldsymbol{\beta}\Delta\ell nY' + \boldsymbol{\gamma}\Delta R' + \delta r'_n + \varepsilon \qquad (32)$$

The dependent variable $e'_{ij} \equiv \Delta\ell n(S'_i / S'_j) - (R_i - R_j)$ is the excess return, measured in units of currency i, to a one-period zero-investment strategy whereby the agent borrows one unit of currency *i*, immediately exchanges the proceeds into currency *j*, and then lends in that currency. In other words, e'_{ij} represents ex post deviations from Uncovered Interest Parity. On the right-hand side of Eq. (32) there is an intercept term α, predicted to be zero, row vectors $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ of slope coefficients, with signs that depend in a complicated way on the structure of preferences, a scalar slope coefficient δ, which reflects Appendix 1's choice of currency *n* as a numeraire currency, and an independent variable r'_n denoting the current period's ex post real interest rate on discount bills denominated in the numeraire currency. Results are shown in Table 3, wherein i stands for the AUD and *n* stand for the USD.

[Table 3 here].

Beginning with the first row of Table 3, a prediction in Appendix 1 is that to the extent there is nontrivial variation in the ex post real interest rate on discount bills denominated in the analyst's choice of numeraire currency (in our case the USD), the variable in question will carry a negative sign. For all three hypothetical speculative positions, however, the estimates of δ are insignificant.

Rows three to nine bear on the question of on third-currency effects.[7] Rises in the US Federal Funds rate were associated with depreciations of the AUD against the yen, controlling for the AUD/JPY interest-rate spread. By contrast, rises in third-currency output growth rates tended to be associated with appreciations of the Australian dollar, controlling for the relevant interest-rate spreads. Rises in US GDP growth were associated with appreciations of the Australian dollar against the deutschmark, controlling for the spread between Australian and German interest rates. Likewise rises in Japanese GDP growth were associated with appreciations of the Australian dollar against both the deutschmark and the US dollar.

Two of the constant terms in the Table 3 regressions are significantly different from zero, contrary to a prediction derived in Appendix 1.

That the AUD has tended more often than not to strengthen when third-currency outputs grow more strongly may reflect a tendency for major foreign currencies to complement the Australian dollar more strongly than they complement one another, consistent with the observation that there is an unusual degree of complementarity between Australian goods and services and those of its trading partners.

5. Summary and conclusion

Atemporally non-separable currency preferences can be classified under the broad headings of currency substitution and currency complementarity. Substitution and complementarity can each be defined either in utility terms or in terms of the cross-elasticity of money demand with respect to a foreign interest rate. Specifically, substitute currencies serve similar wants and needs in trade and payments, and are evidenced by negatively correlated velocities, or (more reliably) by positive cross-interest elasticities in a money demand regression. By contrast, complementary currencies are used in conjunction with each other and are evidenced by positively correlated velocities, or negative cross-interest elasticities.

Velocity correlations for the period 1985 to the turn of the century corroborated Brittain's (1981) finding that the deutschmark and US dollar were substitutes. They also suggested the novel generalization that the yen is a prime candidate for complementarity with other currencies.

Money demand regressions provide a more rigorous basis for inferences about substitution and complementarity. Over the period 1985 to the turn of the century, a 1 percentage point rise in the German call money rate raised the demand for Australia's M1 in real terms by 2.7 per cent, the same as the absolute value of the semi-elasticity for the Australian 90 day Bank Bill Rate, although less well determined. On the other hand, there was no significant effect of the German rate on the demand for M0, even though coefficients on the Australian Bank Bill rate had the standard negative signs for M0 and M1 alike. On balance, then, there is evidence for substitution between the deutschmark and the Australian dollar.

There was a significantly negative coefficient on the Japanese call money rate in an M1 regression, suggesting complementarity between the yen and the Australian dollar. As noted above, this type of result is new.

In the case of the US dollar there was negligible evidence from money demand regressions for either substitution or complementarity with the Australian dollar. This result echoed previous findings for the US dollar vis-à-vis its Canadian counterpart.

Turning to the question of third-currency effects, multilateral models of excess returns to hypothetical uncovered short positions in the Australian dollar over the period 1986 to 1998 came up with the following instances. Rises in the US Federal Funds rate were associated with depreciations of the Australian dollar against the yen, controlling for the spread between interest rates in Australia and Japan. Rises in US GDP growth were associated with appreciations of the Australian dollar against the deutschmark, and rises in Japanese GDP growth were associated with appreciations against both the deutschmark and the US dollar, again controlling for the relevant spreads between Australian and offshore interest rates.

In short, there is considerable evidence for offshore influences on the demand for the Australian dollar, and for third-currency effects on its external value. By concentrating on interactions involving a small currency, however, this paper has scarcely scratched the surface of what atemporally non-separable preferences might imply for interactions between the major currencies. One topic for future research is the money-demand analogue of the much-tested "symmetry restriction"[8] from standard demand analysis. Another topic is potential gains to moving beyond a bilateral setting when investigating "forward discount puzzles"[9], that being a shorthand term for a variety of anomalies documented primarily for the major exchange rates.

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Appendix 1: Asset pricing

The first-order conditions (18) to (22) have a number of implications for asset prices. The purpose of this appendix is to draw out these, for completeness, and to justify the selection of explanatory variables in Section 4's empirical investigation of third-currency effects.

Specialised to the case $i = n$, Eq. (21) gives the standard Fisher-type result that the price of a discount bill denominated in a particular currency is equal to the expectation of the stochastic discount factor:

$$\frac{1}{1+R_n} = E\left(\frac{\lambda'}{(1+\rho)\lambda}\right) \quad . \tag{A.1}$$

Note that simple renumbering of the currencies gives the same result for $i \neq n$, once λ has been suitably redefined for the relevant $i \neq n$.

Eq. (21) gives a corresponding result for uncovered positions in foreign discount bills (sometimes described as speculating in foreign "currency"). Specifically, the currency-*i* price of a discount bill denominated in currency *i* is equal to the expectation of the product of the stochastic discount factor and the proportionate appreciation of currency *i* against currency *n*:

$$\frac{1}{1+R_i} = E\left(\frac{\lambda' S_i}{(1+\rho)\lambda S_i'}\right) . \tag{A.2}$$

From Eqs. (23), (A.1) and (A.2) we obtain the familiar result that the interest factor for currency *i* relative to currency *n* will be as predicted by Uncovered Interest Parity, plus a risk premium:

$$\frac{1+R_n}{1+R_i} = E\left(\frac{S_i}{S_i'}\right) + \left(1+R_n\right) Cov\left(\frac{\lambda'}{\lambda(1+\rho)}, \frac{S_i}{S_i'}\right) . \tag{A.3}$$

Another familiar result, from Eqs. (22) and (A.2), is that Covered Interest Parity holds:

$$\frac{1+R_i}{1+R_n}=\frac{F_i}{S_i}. \tag{A.4}$$

A distinctive feature of asset pricing here is the rich menu of potential determinants of the marginal utility of wealth (λ). To see this, note that the first-order conditions (18), (19) and (20) together imply

$$\lambda=\frac{S_i U_{2i-1}}{P_i}. \tag{A.5}$$

Since U_{2i-1} is a function, in equilibrium, of the entire vectors $\boldsymbol{M}/\boldsymbol{P}$ and $\boldsymbol{Y}$, it is potentially possible for (say) monetary policy in Zaire to affect asset prices in Australia. This observation can be translated into a testable proposition about the role of third-currency effects in deviations from Uncovered Interest Parity. Specifically, we explain such deviations by a multiple linear regression that includes changes in third-currency interest rates and output growth rates among the explanatory variables. We need three steps.

Step one is to approximate the product of the currency n discount factor and the stochastic discount factor by a sum of changes in interest and growth rates:

$$\left(\frac{1+R_n}{1+\rho}\right)\frac{\lambda'}{\lambda} = \left(\frac{1+R_n}{1+\rho}\right)\frac{U'_{2n-1}}{U_{2n-1}}\frac{P_n}{P'_n} \qquad \text{[from Eq. (A.5) with } i=n\text{]} \tag{A.6}$$

$$\equiv \left(\frac{1+r'_n}{1+\rho}\right)\frac{U'_{2n-1}}{U_{2n-1}} \qquad \text{[where } r'_n \equiv \frac{(1+R_n)}{P'_n}P_n\text{]} \tag{A.7}$$

$$\approx 1+ r'_n - \rho + \sum_{i=1}^{n}\left(\frac{\bar{C}'_{2i-1}}{\bar{U}_{2n-1}}\bar{U}_{2i-1,2n-1}\Delta\ell n C'_{2i-1} + \frac{\bar{C}_{2i}}{\bar{U}_{2n}}U_{2i,2n-1}\Delta\ell n C'_{2i}\right) \tag{A.8}$$

[overbars denote sample means; assume $\overline{r}_n \approx \rho$]

$$\approx 1 + r_n' - \rho + \sum_{i=1}^{n} \left[\frac{\overline{C}_{2i-1}'}{\overline{U}_{2n-1}} \overline{U}_{2i,2n-1} \Delta \ell n C_{2i-1}' + \frac{\overline{C}_{2i}'}{\overline{U}_{2n-1}'} \overline{U}_{2i,2n-1} \left(\frac{\overline{Y}_i \Delta \ell n Y_i'}{\overline{Y}_i - \overline{C}_{2i-1}} - \frac{\overline{C}_{2i-1}' \Delta \ell n C_{2i-1}'}{\overline{Y}_i - \overline{C}_{2i-1}} \right) \right]$$

[recall that $C_{2i} = Y_i - C_{2i-1}$] (A.9)

$$= 1 + r_n' - \rho + \sum_{i=1}^{n} \left[\frac{\overline{C}_{2i-1}}{\overline{U}_{2n-1}} \left(\overline{U}_{2i-1,2n-1} - \overline{U}_{2i,2n-1} \right) \Delta \ell n C_{2i-1}' + \frac{\overline{U}_{2i,2n-1}}{\overline{U}_{2n-1}} \overline{Y}_i \Delta \ell n Y_i' \right]$$

[upon collecting terms] (A.10)

$$\approx 1 + r_n' - \rho + \sum_{i=1}^{n} \left[\frac{\overline{C}_{2i-1}}{\overline{U}_{2n-1}} \left(\overline{U}_{2i-1,2n-1} - \overline{U}_{2i,2n-1} \right) \left(\sum_{j=1}^{n} \gamma_{ij} \Delta R_j' + \sum_{j=1}^{n} \eta_{ij} \Delta \ell n Y_j' \right) + \frac{\overline{U}_{2i,2n-1}}{U_{2n-1}} \overline{Y}_i \Delta \ell n Y_i' \right]$$

[recall that $C_{2i-1} = L_i$ and note the definitions $\gamma_{ij} \equiv \partial \ell n L_i / \partial R_j$ and $\eta_{ij} \equiv \partial \ell n L_i / \partial \ell n Y_j$] .(A.11)

Step two is a simple log-linearization:

$$\frac{S_i}{S_i'} - \frac{S_j}{S_j'} \approx -\Delta \ell n S_{ij}' \qquad \text{where } S_{ij} \equiv S_i / S_j \quad . \qquad \text{(A.12)}$$

The final step uses the two foregoing linearizations to express deviations from Uncovered Interest Parity, e_{ij}', in a readily testable form:

$$e_{ij}' \equiv \Delta \ell n S_{ij}' - \left(R_i - R_j \right) \qquad \text{(A.13}$$

$$\approx \left(1 + \rho\right)^{-1} \left(1 + R_n\right) Cov \left(\frac{\lambda'}{\lambda}, \frac{S_i}{S_i'} - \frac{S_j}{S_j'} \right) \qquad \text{[from (A.5)]} \qquad \text{(A.14)}$$

$$\approx -Cov \left(\left(\frac{1 + R_n}{1 + \rho} \right) \frac{\lambda'}{\lambda}, e_{ij}' \right) \qquad \text{[properties of covariances]} \qquad \text{(A.15)}$$

$$\approx \alpha + \boldsymbol{\beta} \Delta \ell n\, Y' + \boldsymbol{\gamma} \Delta R' + \delta r_n' + \varepsilon \tag{A.16}$$

where the intercept α is predicted to be zero, the row vectors $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are slope coefficients with signs that depend on the structure of preferences, δ is a negative slope coefficient that reflects our choice of currency n as the numeraire, and ε is the error term. In contrast to its counterpart in Eq. (31), the error term here reflects the arrival of new information rather than measurement error.

Appendix 2: Stability of the money demand estimates

This appendix tests for stability of the estimates in Table 1. We first examine the estimated coefficients' stability by means of their recursive profile and subsequently the stability of the overall estimated relation using a one-step-forecast test and Chow's one- and N-step-forecast and breakpoint tests. We apply these to the estimated vectors after normalisation and imposed linear homogeneity restriction on prices. The results are reported in Fig. A1.

[Fig. A1 here]

[Fig. A2 here]

In the case of M0 the coefficients are fairly stable over time. More precisely, the elasticity of the domestic scale variable slightly declines whereas the elasticity of the foreign scale variable in the case of Japan rises at the end of the estimated period. On the other hand, the semi-elasticity of the M0 money with respect to the Japanese interest rate apparently declines over time. The tests on the stability of the overall estimated relation tend not to reveal significant episodes of instability. The two exceptions are the result of a one-step forecast and Chow's one-step test that both indicate moderate instability event in the fourth quarter of the year 2000. This instability event could well be the result of the Goods and Services Tax that was introduced in July 2000. We can also observe an effect of the Asian currency crisis during the year 1997. However, this event does not reach conventional significant levels. In the case of M1 there is a similar pattern. For example, we see a moderate increase in the elasticity with respect to the international scale variable, German GDP in this case.

Footnotes

[1] By using an additive multi-period utility function we circumvent a standard objection to the Edgeworth criterion in one-period settings, that is, its fragility in the face of arbitrary monotonic-increasing transformations of the utility function. Put another way, the discounted sum of one-period felicities here is ordinal, but its constituent one-period felicities are not.

The term "ordinary" is placed within quotation marks because outputs appear as arguments of this paper's money demand functions only as a consequence of the agent's transactions demand (7) in conjunction with the aggregate resource constraint (8), not the budget constraint (13). The agent's desire for cash goods is the only reason that she holds money. In standard one-period demand analysis, by contrast, the variable Y also represents sources of funds available to the agent. In both standard analysis and Tobin's (1969) analysis, two items can be (gross) substitutes for each other wholly as a consequence of the agent's budget constraint. That is not the case here.

2. The limiting case of perfect substitution between currencies can be defined as $U_1 = U_3$ along with $U_2 = U_4$. That is, the marginal utility of cash good 1 is equal to the marginal utility of cash good 2, and the marginal utility of the credit good denominated in currency 1 is equal to the marginal utility of the credit good denominated in currency 2. It is easy to show that in this case nominal interest rates are equalized internationally and absolute purchasing power holds. The exchange rate will follow a random walk, regardless of the system's forcing processes (Boyer and Kingston 1987).

3. A reader of Tobin (1969) might interpret a negative sign as the hallmark of substitution rather than complementarity. However, that would not only fail to square with Edgeworth concepts of substitution and complementarity, but sees negatively-

correlated income velocities as an indication of complementarity rather than substitution, contrary to commonsense.

4. In the limiting case of perfect substitution between currencies the sensitivity of the demand for currency 1 with respect to output 2 is zero.

5. That money stocks are dated on a beginning-of period basis (as are interest rates) whereas outputs and prices are dated on a through-the period basis is perhaps unconventional in money demand regressions, but is consistent with our cash-in-advance theory and delivers (marginal) improvements in empirical performance.

6. The time profile of the LR-tests of price homogeneity is available from the authors upon request.

7. In a preliminary version of this paper we estimated a version of Eq. (32) that was less tightly linked to the Section 3 model. Notably, the dependent variable was the (log of the) exchange rate rather than deviations from Uncovered Interest Parity, and there was a more extensive menu of independent variables. Third-currency effects were found even though interest rates were absent from the dependent variables, engendering confidence that they are not just statistical artifacts.

8. See Clements *et al* (1996) for a survey. According to our Section 3 framework , and provided that terms involving products of interest rates are second-order, the currency analogue of the symmetry condition is

$$\left(\frac{P_j M_j}{S_j}\right)\frac{\partial \ell n L_j}{\partial R_i} = \left(\frac{P_i M_i}{S_i}\right)\frac{\partial \ell n L_i}{\partial R_j} .$$

Boyer and Kingston (1987) use this condition in a theoretical analysis of exchange rates in order to eliminate a free parameter.

9. See Engel (1996) for a survey of forward discount puzzles. The most famous of these is that currencies with “high” short-term interest rates have tended not to depreciate to the extent predicted by Uncovered Interest Parity.

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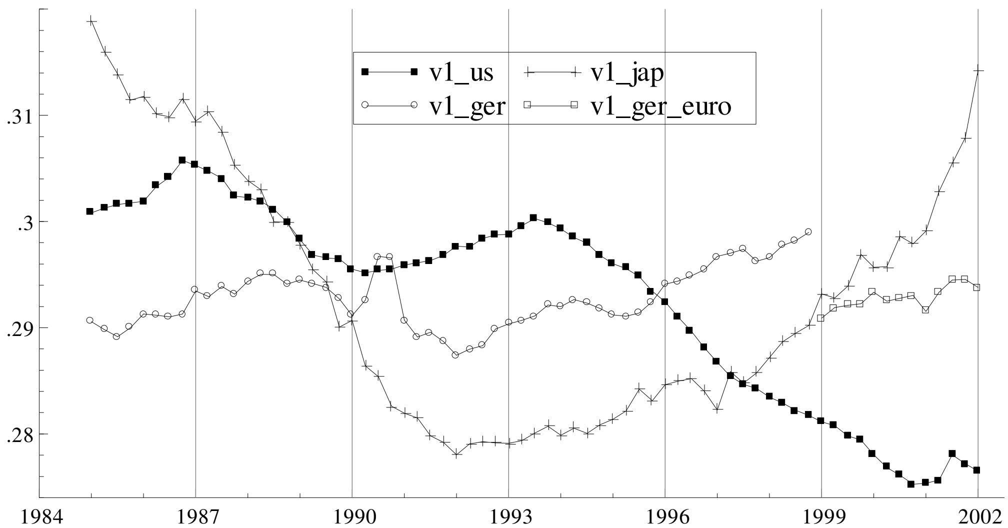
Figures

Fig. 1
Comparison of V1 velocity for the U.S., Japan and Germany

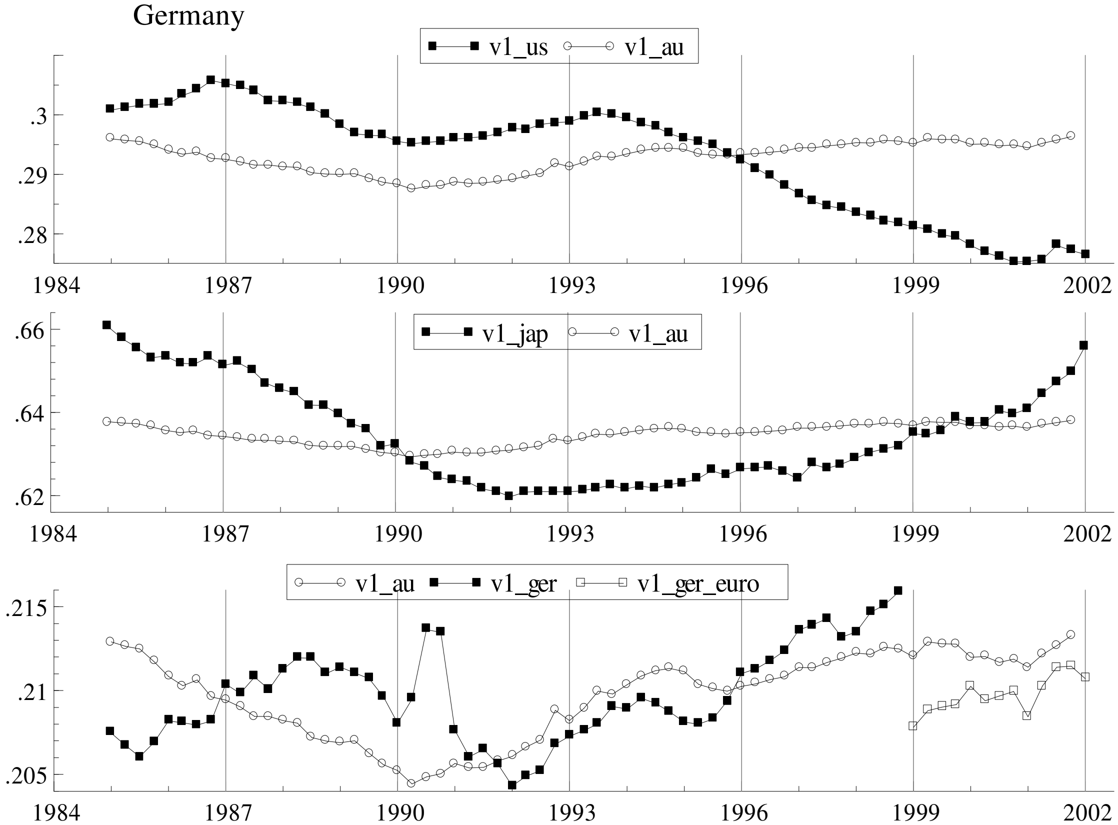


Source: Reserve Bank of Australia; International Financial Statistics (IMF).

Notes: Fig. 1 shows v1 for each country, that is, the log of quarterly GDP expressed as a fraction of the volume of M1. In 1999:1 Euro M1 is spliced to German M1. The covariance matrix of $\Delta v0$, and $\Delta v1$, that is, logged and differenced V0 and V1, is:

	Germany		Japan		United States	
	$\Delta v0$	$\Delta v1$	$\Delta v0$	$\Delta v1$	$\Delta v0$	$\Delta v1$
Germany	1		0		0	
Japan	-0.025	0.23	1		0	
United States	-0.10	-0.05	0.09	0.05	1	

Fig. 2
Pairwise comparison of V1 velocity for Australia to V1 for the U.S., Japan and Germany



Source: Reserve Bank of Australia; International Financial Statistics (IMF).

Notes: See the notes to Fig. 1. The pairwise correlations between Δv0 in Australia and in Germany, Japan and the United States, along with the corresponding correlations for Δv1, are:

	Germany		Japan		United States	
	Δv0	Δv1	Δv0	Δv1	Δv0	Δv1
Australia	-0.03	-0.08	0.04	0.23	0.10	0.08

Fig. A1
Stability of M0 money demand estimates

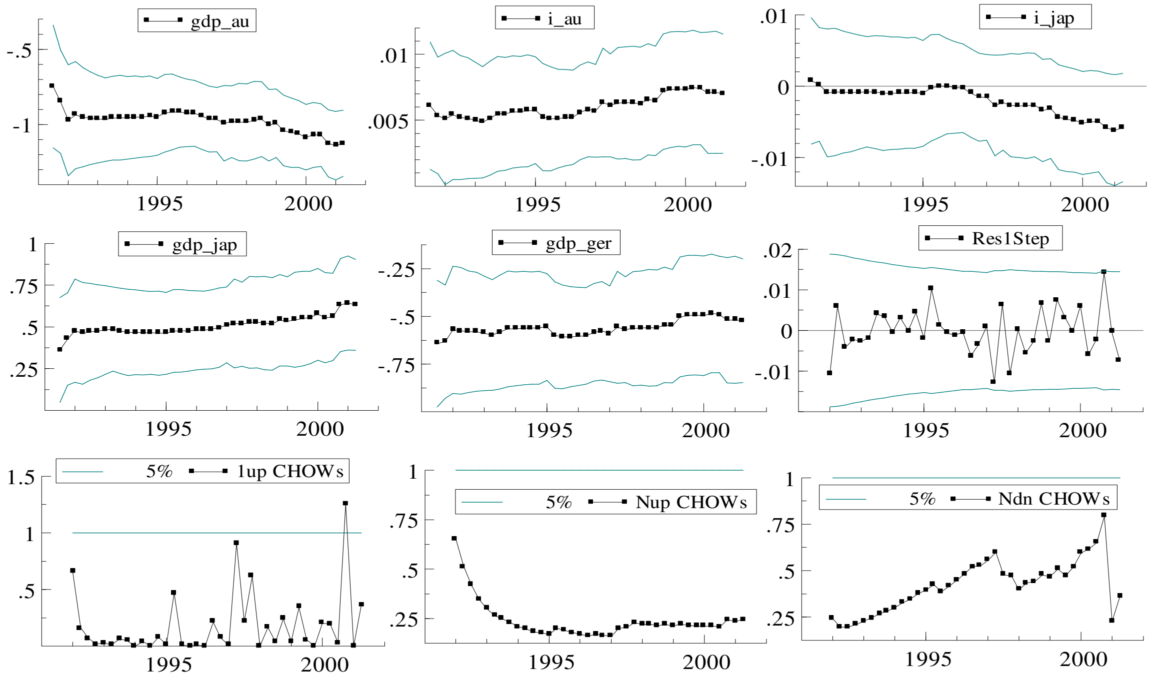
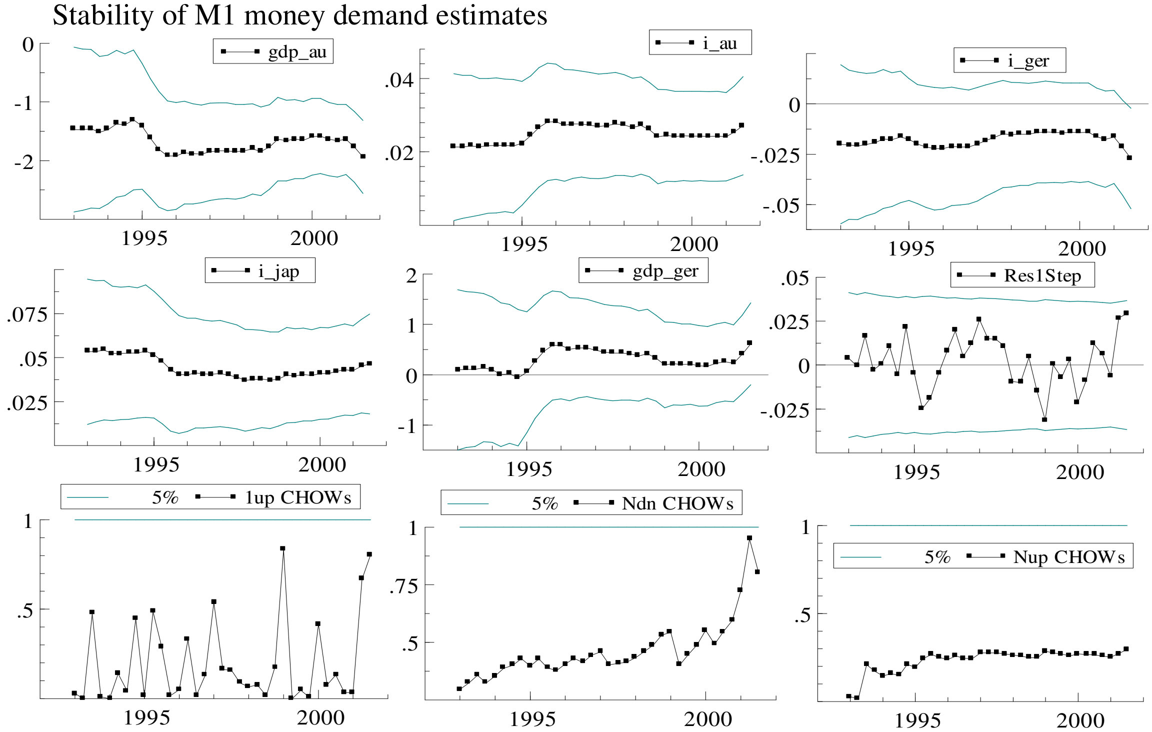


Fig. A2
Stability of M1 money demand estimates



Tables

Table 1
Demand for the Australian dollar

Independent variables (logs except for interest rates)	Dependent variable (logs) M0	M1
AUD *gdp deflator*	1	1
AUD *gdp*	1.13 (0.11)***	1.93 (0.33)***
DEM *gdp*	0.52 (0.169)***	-0.62 (0.436)
JPY *gdp*	-0.63 (0.14)***	…
USD *gdp*	…	…
AUD 90 day BAB rate	-0.007 (0.002)***	-0.027 (0.0072)***
DEM call money rate	…	0.027 (0.0134)**
JPY call money rate	0.006 (0.0039)	-0.047 (0.0152)***
USD Federal Funds rate	…	…

Sources: RBA, IMF
Notes: The estimation periods for M0 and M1 span 1985:1 to 2001:2 and 1985:1 to 2001:3 respectively. Standard errors are shown in parentheses; *, ** and *** indicate significance at 10%, 5% and 1% levels; **…** denotes insignificance of the particular variable. Money prices and output are in logs; interest rates are in levels. Linear homogeneity of money with respect to the price level is imposed; tests accepting this restriction are accepted only in the case of M0, with rejection at the 1% level in the case of M1. The reported estimates are via the Johansen technique, which accords with dynamic OLS estimates in all instances except for the elasticity of M1 with respect to German GDP. Constant terms are not shown.

Table 2
Restrictions

Hypothesis	Likelihood ratio test where applicable	
	M0	M1
$\gamma_{AUD} = -\gamma_{DEM}$	n.a.	1.1572 (0.5607)
$\gamma_{AUD} = -\gamma_{JPY}$	4.0553 (0.1316)	n.a.
$\beta_{AUD} = -\beta_{DEM}$	n.a.	5.1949 (0.0745)*
$\Sigma\gamma_i = 0$	4.0553 (0.1316)	16.336 (0.0001)***
$\Sigma\beta_i = 0$	18.182 (0.0000)***	5.1949 (0.0745)*

Notes: * indicates rejection of the null at the 10% significance level. Each result is for a Chi^2(2) statistic, corresponding to a restriction of a unit coefficient on *p* in addition to the relevant restriction shown on the left-hand side of the table.

Table 3
Third currency effects
Dependent variables: *excess returns to speculation against the AUD*

Independent variables	Excess returns: USD positions	Excess returns: JPY positions	Excess returns: DEM positions
r'_{USD}	-----	-----	-----
$\Delta R'_{AUD}$	-----	-----	0.047 (0.026)*
$\Delta R'_{DEM}$	-----	-----	-----
$\Delta R'_{USD}$	-----	-0.256 (0.115)**	-----
$\Delta R'_{JPY}$	-----	0.212 (0.120)**	-----
$\Delta \ell n Y'_{AUD}$	-----	-----	-----
$\Delta \ell n Y'_{DEM}$	-----	-----	5.93 (2.44)**
$\Delta \ell n Y'_{USD}$	32.18 (19.01)*	-----	13.52 (6.85)*
$\Delta \ell n Y'_{JPY}$	17.21 (9.55)*	16.61 (6.07)**	9.34 (3.45)**
Constant	-0.78 (0.19)***	4.29 (0.074)***	Unrestricted

Source: RBA, IMF

Notes: The data span 1986:1 to 2001:4 , except in the case of positions in DEM, in which case the data end in 1998:4. Standard errors are shown in parentheses; *, ** and *** - indicate significance at 10%, 5% and 1% level, respectively. ----- denotes insignificance of the particular variable. Estimation is by FIML. An AR(1) process of the dependent variable is considered in the estimated equation.