The Impact of Foreign Variables on Domestic Money Demand: Evidence from the United Kingdom

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Abstract

This paper contributes to the existing money demand literature by developing and estimating a shopping-time model in an open economy framework. Based on this microfoundations-of-money model, United Kingdom quarterly data for the period 1973:2-1997:2 are analyzed in the empirical study. After accounting for nonstationarity in the time series processes, I find three long-run relationships among the relevant variables. Estimation of the error-correction representation implied by the model shows that the foreign exchange rates and the imports consumption, in addition to the domestic variables, have significant effects on British demand for real money. (*JEL* E41, F41)

Introduction

Successful use of a monetary aggregate as an intermediate target of monetary policies requires a stable relation between this aggregate and its determinants. Unfortunately, as widely documented, instability has been found in the traditional money demand function for many countries since the mid-1970's. Consequently, policy has been left without much guidance from a nominal quantity variable that is closely linked to its long-run goal. This void makes it difficult for monetary authorities to determine if their short-run decisions are consistent with their long-run objectives. Frequent judgmental adjustments of targets are required and, in some cases, the targeting of monetary aggregates has been abandoned altogether, such as in the United Kingdom in 1986.

Many studies have been devoted to searching for a new stable money demand function. These studies provided some modifications to the money demand function, such as more reasonable measures of monetary aggregates, opportunity costs, and scale variables. However, these studies have often been restricted to a closed economy framework [e.g., Goldfeld (1973, 1976) and Judd and Scadding (1982)]. In a floating exchange rate regime and in view of the increasing integration of world financial markets, one would intuitively expect foreign monetary developments to influence domestic money demand through their effects on foreign interest rates and/or exchange rates.

The relationship between money demand and the exchange rate was originally raised by Mundell (1963) when he discussed the effectiveness of monetary and fiscal policies. Hamburger (1977), on the other hand, analyzed different measures of foreign interest rates to see whether they should also be considered as opportunity costs of holding domestic money. Money demand specifications that take account of foreign factors are suggested by the bulk of research on currency substitution.

Nevertheless, a criticism of many open-economy money demand studies is that they simply try different measures of variables in their empirical analyses. Typically, they do not provide an explicit theoretical model to support their empirical models. For example, studies such as Brittain (1981), Bordo and Choudhri (1982), Cuddington (1983), Joines (1985), and Leventakis (1993) use levels of interest rates in their money demand regressions, while Arango and Nadiri (1981) and Ahking (1984) use logarithms of interest rates. Bahmani-

Oskooee (1991) even eliminates the foreign interest rate from his regressions. As to the exchange rate, Arango and Nadiri (1981) uses log nominal exchange rates, while Bahmani-Oskooee (1991) and Hueng (1998) use log real exchange rates. Brittain (1981), Bordo and Choudhri (1982), Cuddington (1983), and Ahking (1984) use the uncovered interest rate differential instead of exchange rates in their regressions.

Furthermore, Goldfeld and Sichel (1990) suggest that the disaggregation of a scale variable may be needed to appropriately reflect the nature of international transactions in an open-economy setting. Among the studies mentioned above, however, only Leventakis (1993) atheoretically includes a measure of foreign income in his empirical model.

This paper constructs a shopping-time model in an open economy framework to motivate the specification of the demand for money. This microfoundations-of-money model provides a theoretical justification for using which variables, and in what forms, in the empirical money demand function. In particular, the model includes the real exchange rate and foreign interest rates and distinguishes explicitly between consumption of imports and consumption of domestically produced goods. In addition, the model implies several long-run relations among relevant variables that can be utilized in the short-run dynamics of the money demand function.

United Kingdom quarterly data from 1973:2 to 1997:2 are analyzed in the empirical study. This paper gives special attention to nonstationarity in the macroeconomic time series data using econometric techniques designed to accommodate integrated and cointegrated variables. The results show that first, the long-run relations implied by the model are supported by the UK data. Second, in addition to the domestic variables, changes in the foreign exchange rates and imports consumption affect the stock of real cash balances held by the British people.

The remainder of this paper is organized as follows. The next section constructs the theoretical model. The third section uses UK data to estimate the model. The fourth section concludes the paper.

Theoretical Model

Modeling aggregate money demand in terms of microeconomic principles has become popular in practice. This method of modeling allows us to explicitly specify the role of money in the economy. The money-in-the-utility-function model has been widely used to account for the real liquidity services provided by money. However, some have argued it is the service that provides utility to agents rather than money itself. Therefore, many economists have suggested explicitly modeling the liquidity services provided by money through the agent's budget constraint.

One way to indirectly include money in the utility function is to use the cash-in-advance constraint in the model. However, the cash-in-advance model has been criticized for placing a strict upper limit on purchases during the period. To avoid this unrealistic restriction, McCallum and Goodfriend (1988) suggested the use of a more general model, the shopping-time model, which was originally introduced by Saving (1971). In this model, extra purchases are possible, but they are more expensive in terms of time. Therefore, money enters the utility function indirectly by way of a shopping-time function.

This paper extends the closed-economy shopping-time model proposed by McCallum (1989) and McCallum and Goodfriend (1988) to an open economy framework. Specifically, consider a small open economy which takes foreign variables as given. The representative agent maximizes the expected present value of utility over an infinite horizon:

$$U(c_t, c_t^*, L_t) + \sum_{j=1}^{\infty} \beta^j \mathrm{E}_t [U(c_{t+j}, c_{t+j}^*, L_{t+j})], \tag{1}$$

where c_t and c_t^* are home-country real consumption of domestic and foreign goods, respectively, L_t is leisure, $\beta \in (0,1)$ is the constant discount rate, and E_t denotes the expectation conditional on information at time t. The utility function $U(\cdot)$ is assumed to be twice continuously differentiable, strictly concave, and to satisfy the Inada conditions.

The agent receives real income in the amount y_t and divides her wealth among four assets, which include domestic money, foreign money, and domestic and foreign bonds which pay a nominal interest rate of r_t and

r_t^*, respectively. Let M_t, M_t^*, B_t, and B_t^* be the nominal domestic money, foreign money, domestic bonds, and foreign bonds held at the end of period t. Therefore, the agent begins period t with assets in the amount $M_{t-1} + e_t M_t^* + B_{t-1} + e_t B_t^*$, where e_t is the nominal exchange rate defined as units of domestic currency per unit of foreign currency.[1] The agent's budget constraint can be written as:

$$m_t + b_t + q_t m_t^* + q_t b_t^* = \frac{P_{t-1}}{P_t} m_{t-1} + \frac{P_{t-1}}{P_t}(1 + r_{t-1}) b_{t-1} + q_t \frac{P_{t-1}^*}{P_t^*} m_{t-1}^* + q_t \frac{P_{t-1}^*}{P_t^*}(1 + r_{t-1}^*) b_{t-1}^* + y_t - c_t - q_t c_t^*, \qquad (2)$$

where m_t and m^*_t are real holdings of domestic and foreign money; b_t and b_t^* are real holdings of domestic and foreign bonds; and P_t and P_t^* are domestic and foreign price levels. The real exchange rate is $q_t = e_t P_t^* / P_t$.

To acquire consumption goods, the agent must spend time shopping, S_t. The amount of time left over for leisure is L_t. That is, $L_t = T - S_t$, where T is the total amount of time available per period. The smaller the amount of time spent in shopping, the greater the amount of time left over for leisure. For simplicity, labor is assumed to be supplied inelastically and omitted from the time constraint.

The amount of time spent in shopping depends positively on the volume of consumption. For a given volume of consumption, holding money facilitates transactions and reduces the amount of time in shopping. Following Stockman (1980), Lucas (1982), and Guidotti (1993), it is assumed that domestic and foreign goods have to be purchased with domestic and foreign currencies, respectively. Therefore, the time spent in purchasing domestic (foreign) goods only depends on the consumption of domestic (foreign) goods and holdings of domestic (foreign) money. That is,

$$S_t = S(c_t, c_t^* \, m_t, m_t^*) = S^D(c_t, m_t) + S^F(c_t^*, m_t^*), \qquad (3)$$

where the first derivatives $S_c \$ 0$, $S_{c*} \$ 0$, $S_m \# 0$, and $S_{m*} \# 0$; and the second derivatives $S_{ii} \$ 0$ and $S_{ij} \# 0$ for $i, j = c, c*, m, m*, i..j$. S^D is the time spent in purchasing domestic goods and S^F in purchasing foreign goods.

One may argue that the average consumer simply uses domestic currency to buy foreign goods and spends no extra time acquiring foreign goods. However, the economy as a whole does use foreign currencies and spends time acquiring foreign currencies to buy imported goods. The importers are those who hold foreign currency accounts and spend time acquiring foreign goods. Therefore, we may consider that the importers are representatives for consumers in buying foreign goods in the first stage, whereas in the second stage the consumers use domestic currency to buy foreign goods from the importers.

Given the objective function (1), subject to the constraints (2) and (3), the first-order conditions necessary for optimality of the agent's choices imply:

$$\frac{U_L S_m}{U_L S_c - U_c} = 1 - \frac{1}{1 + r_t}, \qquad (4)$$

$$\frac{U_L S_{m*}}{U_L S_{c*} - U_{c*}} = 1 - \frac{1}{1 + r_t^*}, \qquad (5)$$

$$\frac{U_c - U_L S_c}{U_{c*} - U_L S_{c*}} = \frac{1}{q_t}. \qquad (6)$$

Equations (4) and (5) state that the marginal rate of substitution between real cash balances and consumption equals the opportunity cost of holding money. Equation (6) says that the marginal rate of substitution between domestic and foreign goods equals their relative price.

Since both the utility function and the shopping-time function are assumed to be twice continuously differentiable and the optimal solutions exist, according to the implicit function theorem, equations (4)-(6) imply a relation that is similar to those normally described in the literature as "money demand functions."

McCallum and Goodfriend (1987) refer to this type of expression as a portfolio-balance relationship. Specifically, the domestic money demand function in an open economy takes the form: $m_t = f(c_t, c_t^*, r_t, r_t^*, q_t)$.

To express the money demand function explicitly, assume that the utility function takes a Cobb-Douglas form and the utilities from consuming domestically-produced goods and imports are the same:

$$U(c_t, c_t^*, L_t) = c_t^{\frac{\alpha}{2}} c_t^{*\frac{\alpha}{2}} L_t^{1-\alpha}, \tag{7}$$

where 0<"<1. In addition, assume that shopping time is constrained by a technical relationship that reflects the transaction-facilitating properties of money. This technical relationship is assumed to be characterized by a Baumol-Tobin type technology in which cash withdrawals involve time instead of monetary transaction costs as in Baumol (1952). Specifically, assume that $S_t^D = c_t/m_t$ and $S_t^F = A_t c_t^*/m_t^*$,where A_t>0 is a transactions technology parameter and is allowed to change over time. The shopping-time function can then be expressed as:

$$S_t = \frac{c_t}{m_t} + A_t \frac{c_t^*}{m_t^*}. \tag{8}$$

Since the flow of consumption to be financed occurs continuously, cash withdrawals are spread evenly throughout the time period. Therefore, c_t/m_t and c_t^*/m_t^* can be interpreted as frequencies of withdrawals in domestic and foreign currencies, respectively. The cost of using domestic currency in units of time is set to one and A_t reflects how much more time it takes proportionally to obtain foreign currency instead of domestic currency. The variation in A_t is assumed to be temporary.

Substituting (7) and (8) into (4)-(6) yields:

$$m_t = \frac{q_t c_t^* - c_t}{i_t - \sqrt{A_t i_t i_t^* q_t \frac{c_t^*}{c_t}}}, \tag{9}$$

where $i_t = \frac{r_t}{1 + r_t}$, and $i_t^* = \frac{r_t^*}{1 + r_t^*}$.[2] Equation (9) is neither linear nor loglinear in relevant variables. To express it as a linear equation like those in many money demand studies, rewrite (9) as:

$$\begin{aligned} \ln m_t - \ln c_t + \ln i_t = {} & -(\ln c_t - \ln c_t^* - \ln q_t) + \ln[1 - \exp(\ln c_t - \ln c_t^* - \ln q_t)] \\ & - \ln\{1 - \exp[\tfrac{1}{2}\ln A_t - \tfrac{1}{2}(\ln c_t - \ln c_t^* - \ln q_t - \ln i_t^* + \ln i_t)]\}. \end{aligned} \tag{10}$$

Let $d_{1t} = \ln c_t - \ln c_t^* - \ln q_t$, $d_{2t} = 1/2 \ln A - 1/2(\ln c_t - \ln c_t^* - \ln q_t - \ln i_t^* + \ln i_t)$, with $÷_1$ and $÷_2$ representing the steady state values of d_{1t} and d_{2t}, respectively. Taking the first-order Taylor series expansion of (10) around $÷_1$ and $÷_2$ yields:[3]

$$\ln m_t - \ln c_t + \ln i_t = \theta_0 + \theta_1(\ln c_t - \ln c_t^* - \ln q_t) + \theta_2(\ln i_t^* - \ln i_t) + \theta_2 \ln A_t, \tag{11}$$

where the coefficients 2's are functions of $÷_1$ and $÷_2$. Equation (11) states that the domestic consumption velocity adjusted for the domestic interest rate $(\ln m_t - \ln c_t + \ln i_t)$ is a function of the ratio of consumers' expenditure on domestically-produced goods to that on imported goods in terms of domestic currency $(\ln c_t - \ln c_t^* - \ln q_t)$ and the ratio of the return on foreign bonds to that on domestic bonds $(\ln i_t^* - \ln i_t)$.

Since the transactions technology A_t cannot be identified in the data, it is considered as a residual in equation (11). Assume that the logarithm of A_t follows a stationary AR(1) process:

$$\ln A_t = \xi_0 + \xi_1 \ln A_{t-1} + \epsilon_t, \tag{12}$$

where $0<\xi_1<1$ introduces some persistence on the technology parameter and the ϵ_t's are iid. The mean of $\ln A_t$ is $\xi_0/(1-\xi_1)$. We allow the possibility that A_t may be less than one, which reflects the fact that the importers may be more efficient in transferring currencies than is the average consumer.

Equations (11) and (12) imply that the short-run dynamics of the model can be characterized by the following:

$$\begin{aligned} &\ln m_t - \ln c_t + \ln i_t = \theta_0' + \theta_1(\ln c_t - \ln c_t^* - \ln q_t) + \theta_2(\ln i_t^* - \ln i_t) + u_t \\ &u_t = \xi_1 u_{t-1} + e_t, \end{aligned} \tag{13}$$

where the effects of $\ln A_t$ are included in the error term u_t and the mean of $\ln A_t$ is absorbed in θ_0'.

An important implication of this linear money demand model is that, to use the Taylor series expansion, $d_{1t} = \ln c_t - \ln c_t^* - \ln q_t$ and $d_{2t} = 1/2 \ln A_t - 1/2(\ln c_t - \ln c_t^* - \ln q_t - \ln i_t^* + \ln i_t)$ must be stationary for χ_1 and χ_2 to exist. That is, this model implies that $(\ln c_t - \ln c_t^* - \ln q_t)$, $(\ln i_t^* - \ln i_t)$, and, therefore, $(\ln m_t - \ln c_t + \ln i_t)$ are all stationary. In other words, consumption velocity adjusted for domestic interest rates, the ratio of consumption shares in units of domestic currency, and the interest rates differential are stationary over time.

Equation (13) can be expressed in an error-correction format:

$$\begin{aligned} \Delta \ln m_t = {} & \beta_{10} + \beta_{11}\Delta \ln c_t + \beta_{12}\Delta \ln c_t^* + \beta_{13}\Delta \ln q_t + \beta_{14}\Delta \ln i_t + \beta_{15}\Delta \ln i_t^* \\ & + b_{11}(\ln m_{t-1} - \ln c_{t-1} + \ln i_{t-1}) + b_{12}(\ln c_{t-1} - \ln c_{t-1}^* - \ln q_{t-1}) + b_{13}(\ln i_{t-1}^* - \ln i_{t-1}) + e_{1t}, \end{aligned} \tag{14}$$

where $\beta_{10} = (1-\xi_1)\theta_0'$, $\beta_{11} = \theta_1+1$, $\beta_{12} = -\theta_1$, $\beta_{13} = -\theta_1$, $\beta_{14} = -\theta_2-1$, $\beta_{15} = \theta_2$, $b_{11} = -1+\xi_1$, $b_{12} = (1-\xi_1)\theta_1$, and $b_{13} = (1-\xi_1)\theta_2$. Each term in the error-correction representation (14) is I(0). The coefficients b_{1i} (i=1,2,3) can be interpreted as the effects of the short-run deviations from the money demand equilibrium. The coefficients β_{1i} (i=1,2, . . . ,5) are the short-run effects of the explanatory variables on money demand, given that money demand is in equilibrium.

Another interesting implication of the model is that the sum of those two consumption elasticities is equal to one. This is more general than the common argument in the traditional money demand studies that the income elasticity of money demand is unity, which is usually not supported by many empirical studies.

Empirical Analysis

United Kingdom quarterly data from 1973:2 to 1997:2 are analyzed in the empirical study. The United Kingdom has been analyzed in many open-economy money demand studies [e.g., Arango and Nadiri (1981), Brittain (1981), Cuddington (1983), Joines (1985), Adam (1991), Choudhry (1992), Leventakis (1993), and Hoffman, Rasche and Tieslau (1995)] because it has the characteristics of a small open economy which takes foreign variables as given, as assumed in our model. In addition, analysis of the U.K. data allows us to compare our results to those in the previous studies.

Only data from the floating exchange rate period are used because there is no justification for pooling data from the fixed and floating exchange rate periods. Foreign factors become more important over the period of flexible exchange rates because the relative stability of the exchange markets under the fixed exchange rate system may reduce the effects of the foreign monetary variables.

Data on prices and foreign interest rates are taken from the *International Financial Statistics* (IFS) CD-ROM data base. Consumption data are from various issues of *Monthly Digest of Statistics* (MDS) of the Central Statistical Office, Great Britain. Data on money stock and domestic interest rates are from the Bank of England *Statistical Abstract*.

Since a representative-agent model is used to derive the money demand function, money and consumption are in per capita terms. That is, data on money and consumption are divided by population before estimation. I collected the midyear estimates of the population (in millions of people) from IFS and then used evenly weighted average values of two successive observations to estimate quarterly observations for population.

For the nominal money stock (M_t), official monetary aggregates constructed by simple-sum aggregation such as M1 and M2 have been criticized for assuming that all of the component assets are perfect substitutes [see Belongia and Chrystal (1991)]. Most of the short-term instruments included in these measures are actually poor substitutes for each other. Therefore, different methods of weighting different components of money by the degree of moneyness have been widely used. The most well-known index of monetary aggregate is the Divisia money. This index weighs the growth of each asset using a formula based upon its user cost, which is designed to reflect its liquidity in making transactions. This paper uses UK Divisia M4 because M4 is the major monetary index published by the Bank of England [Spencer (1994)].[4]

As for the domestic interest rate, the benchmark rates used to construct the Divisia M4 are used. The U.S. three-month treasury bill rates are used as the foreign nominal interest rates. The variable P_t is defined as the Consumer Price Index (CPI, 1990=1).

The nominal exchange rate (e_t) is defined as units of domestic currency per unit of foreign currency. The real exchange rate is defined as the price of imported consumption goods in units of domestic currency ($e_t p_t^*$) divided by domestic CPI. The import price index in IFS is used to approximate $e_t p_t^*$.

The variable c_t^* is defined as real imports of consumption goods. The nominal imported consumption in units of pounds includes three items from the UK imports table: (i) food, beverages and tobacco, (ii) fuels, and (iii) finished manufactures.[5] To get c_t^*, we divide this variable by the price of imported consumption goods in units of domestic currency, which is again approximated by the import price index from IFS. The nominal consumption of domestically-produced goods is defined as the difference between total consumer expenditures and the nominal imported consumption goods. Dividing this variable by CPI yields c_t.

Money balances and consumption series are all seasonally adjusted. Real money and domestically-produced consumption goods are evaluated in real pounds at 1990 prices, while the real imported consumption is in real "foreign currency" at 1990 prices.

Before estimating the model, I identify the order of integration for each variable by using the augmented Dickey-Fuller (ADF) D test. Different regressions apply to different time series. Real money balances and real consumption would be expected to exhibit a persistent upward trend due to technological improvements. However, we do not know whether this trend is better modeled as arising from the positive drift term of a random walk or from a stationary process with a deterministic time trend. Therefore, a time trend is included in the regressions.

On the other hand, there is no economic theory which suggests that the interest rates and the exchange rate should exhibit a deterministic time trend. Therefore, a natural null hypothesis is that the true model is a random walk without trend and the alternative hypothesis would be a stationary process including a constant term.

An issue that arises with the implementation of the ADF tests is the choice of the order of autoregression. Ng and Perron (1995) show that a data-dependent rule that takes sample information into account is superior to a deterministic rule. To show that the criteria for choosing lag length do not affect our inferences, this paper uses three data-dependent rules suggested by Ng and Perron (1995): the Akaike Information Criterion (AIC), Schwartz's criterion, and a sequence of 5% t tests for the significance of coefficients on additional lags. The lag lengths are assumed to have an upper bound 4 and a lower bound 0. After the lag lengths are selected, to ensure that the resulting residuals are white noise, the Ljung-Box Q-test is used to test the serial correlation in the residuals.

It is argued that the standard unit root tests, which test the null hypothesis of nonstationarity, have low power against stationary alternatives. That is, stationarity is not often found in these tests. Therefore, to complement the ADF test, we also conduct the generalized KPSS-test proposed by Hobijn, Franses, and Ooms (1998), which tests the null hypothesis of stationarity against the alternatives of nonstationarity. This test combines the socalled KPSS test [Kwiatkowski, Phillips, Schmidt, and Shin (1992)] and the automatic data dependent bandwidth selection procedure introduced by Newey and West (1994). For money and consumption, the null hypothesis of the test is trend stationarity. For exchange rate and interest rates, it is level stationarity.

Following suggestion by Dickey and Pantula (1987), the unit root tests are first conducted with two roots, and if two roots are rejected, then single unit root is tested. The results of the unit root tests are shown in Tables 1 and 2. Table 1 shows the test statistics of the first difference of each series and Table 2 shows those of the level of each series. In Table 1, all the statistics show that the variables should not be modeled as I(2).

[Tables 1 and 2 about here]

In Table 2, the results are mixed. All but one statistics from the ADF test accept the null of unit root at the 5% significance level. On the other hand, the generalized KPSS-test rejects the null of stationarity for money and exchange rate, but cannot reject the null for consumption and interest rates at the 5% level. However, the null is rejected at the 10% level for interest rates, and the statistics for consumption are marginally significant around 10% level. Therefore, we proceed with all the variables being modeled as I(1).

When dealing with a model where all the variables contain unit roots, one should be concerned about the possibility of a spurious regression. However, recall that $(\ln m_t - \ln c_t + \ln i_t)$, $(\ln c_t - \ln c_t^* - \ln q_t)$, and $(\ln i_t^* - \ln i_t)$ are stationary as implied by the model in the second section. If they are, each term in the error-correction representation (14) is I(0) and the problems caused by a spurious regression disappear. Therefore, the next step is to use our data to test whether these three terms are stationary.

The same unit root tests can be applied.[6] Note that $(\ln m_t - \ln c_t + \ln i_t)$ is the consumption velocity adjusted for interest rates, $(\ln c_t - \ln c_t^* - \ln q_t)$ is the log consumption differential in units of domestic currency, and $(\ln i_t^* - \ln i_t)$ is the log interest rates differential. Therefore, these variables should not exhibit a deterministic time trend. The results are shown in Table 3. Both the ADF and the KPSS tests show that these three terms are better modeled as stationary series. Therefore, the long-run relationships implied by the model are supported by the UK data.

[Table 3 about here]

The next step is to estimate the short-run dynamics of the money demand function with the long-run relationships imposed. The OLS estimation of the error-correction representation (14) shows:

$$
\begin{aligned}
)\ln m_t = \; & \underset{(0.100)}{-0.180} + \underset{(0.075)}{0.506}\,)\ln c_t + \underset{(0.039)}{0.249}\,)\ln c_t^* + \underset{(0.053)}{0.278}\,)\ln q_t + \underset{(0.014)}{0.023}\,)\ln i_t - \underset{(0.016)}{0.012}\,)\ln i_t^* \\
& \underset{(0.006)}{-0.007} (\ln m_{t-1} - \ln c_{t-1} + \ln i_{t-1}) + \underset{(0.013)}{0.022} (\ln c_{t-1} - \ln c_{t-1}^* - \ln q_{t-1}) + \underset{(0.006)}{0.009} (\ln i_{t-1}^* - \ln i_{t-1})
\end{aligned}
$$

$R^2 = 0.492$.

The numbers in parentheses are standard errors. The results show that, first of all, the elasticity of money demand is positive with respect to consumption of domestic goods, as expected, and the estimated coefficient is significantly different from zero at the traditional significance level.

Secondly, the estimated coefficient on imports consumption is positive and significantly different from zero. Note that consumption of domestically-produced goods and consumption of imports are perfect substitutes in terms of direct contribution to the utility function. On the indirect effects, a rise in imports consumption increases the shopping time and therefore brings disutility to the agent. The agent can either increase the holdings of foreign currencies to reduce the shopping time for imports or increase the holdings of domestic money to reduce the shopping time for domestic goods. Therefore, the positive imports-consumption elasticity indicates the second effect.

Thirdly, the shopping-time model predicts that the sum of the two consumption elasticities should be equal to one. The estimated value is 0.755. However, the P-value for this null hypothesis test is only 0.02. On the other hand, the shopping-time model also implies that imports-consumption elasticity and exchange-rate elasticity of money demand have the same sign and are equal in magnitude. This null hypothesis is easily accepted (P-value=0.39). These two estimated values are also significantly different from zero at the traditional level.

As to the interest rate elasticities, the estimated domestic interest rate elasticity has the wrong sign, but it is not significant. Similar results were found in Brittain (1981) and Cuddington (1983), who used a partial adjustment model for M3. On the other hand, the estimated coefficient on foreign interest rates is also insignificant. The insignificant effect of the foreign interest rate on domestic money demand is consistent with the findings in Brittain (1981) and Joines (1985). Brittain (1981) suspected that the failure of the portfolio hypothesis may be due to the existence of British exchange controls.

Finally, the signs of the estimated coefficients on the error-correction terms show the adjustments from the deviations are on the right direction. Specifically, first, the negative estimated value of b_{11} indicates that if the agent's domestic money holding for purchasing domestic goods was higher than equilibrium level, she should reduce the holding. Second, if the ratio of domestic consumption to imports consumption was higher than the long-run level, the agent should increase the domestic money holding for purchasing domestic goods, which would save time in transactions. Finally, the positive sign on the third error-correction term indicates that if the agent observed that foreign interest rate was relatively high, she should reduce the foreign money holding to take advantage of the higher returns on other foreign assets. Since domestic goods and imports are perfect substitutes, the agent should diversify out of imports consumption and increase the domestic money holding to prepare for domestic goods consumption. The sizes of the adjustments from the deviations, however, are very small and statistically insignificant.

Conclusion

Traditional studies on money demand have only concentrated on the domestic interest rate and real income. Some previous attempts to take account of foreign monetary developments in the money demand function have tried different measures of variables in their empirical analysis with little theoretical justification. Conversely, this paper develops an open-economy shopping-time model to provide a theoretical justification for the choice of variables included in the empirical money demand function. In particular, the real exchange rate and foreign interest rates are included in the money demand function. Consumption is distinguished explicitly between imports and domestically-produced goods. In addition, the model provides several cointegrating relationships among relevant variables that can be utilized in the error-correction representation of the money demand function.

United Kingdom national quarterly time series data for the period 1973:2-1997:2 are used to estimate the model. After accounting for nonstationarity in the time series processes, I find that in addition to the domestic variables, the foreign exchange rates and imports consumption have significant effects on domestic money demand.

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Notes

1. As noted in McCallum (1989), it might be that the real money held at the start of period *t*, rather than at the end, is the relevant magnitude. In actuality, however, the real balances held at each instant of time during the period are relevant. Therefore, for simplicity, the current specification is used.

2. For the real money balance in (9) to be positive, the inequality $(q_t c_t^* - c_t)(i_t - \sqrt{A_t i_t i_t^* q_t c_t^* / c_t}) > 0$ has to hold. This implies $(1 - c_t/q_t c_t^*)(1 - S_t^F/S_t^D) > 0$. Therefore, either $S_t^D/S_t^F < 1 < c_t/q_t c_t^*$ or $S_t^D/S_t^F > 1 > c_t/q_t c_t^*$ has to hold. That is, if the expenditure on domestically-produced goods is larger (smaller) than that on imports, the agent must spend less (more) time in shopping for domestically-produced goods than in shopping for imports. Since and yield the same utility to the agent, these restrictions seem reasonable enough.

3. Specifically, $\ln[1 - \exp(d_t)] \approx \ln[1 - \exp(\bar{d})] - \frac{\exp(\bar{d})}{1 - \exp(\bar{d})}(d_t - \bar{d})$.

4. Data on Divisia M4 and the benchmark interest rates used to construct the index from 1973:2 to 1976:4 are taken from the Ole Miss International Divisia Database. Data after 1976:4 are from the Bank of England *Statistical Abstract*.

5. The title of the table is "United Kingdom imports, by commodity". The other two items which are not included in my measure of imported consumption goods are "Basic material" and "Unfinished manufactures."

6. An alternative way to test the cointegration vectors is to constructed an unrestricted VAR model including all those six variables and use Johansen's Full-Information Maximum Likelihood test to find the cointegration vectors. The two test statistics (Trace and Maximum Value) from the Johansen test give ambiguous results and do not show exactly those three cointegration vectors impled by the theoretical model. However, given the short data period and the large number of regressors in the VAR model, I choose not to rely on this test. Instead, I impose the long-run relationships implied by the theoretical model and use a simpler, but equally reliable, univariate test on the restricted long-run cointegration vectors, then proceed to the analysis of money demand function. I do this just as others have imposed a unitary price elasticity in money demand, or a unitary income elasticity in the currency substitution literature, without testing it.

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Table 1: Unit Root Test Statistics for the Log Differences of the Variables

Variable	AIC k	AIC ADF	Schwartz k	Schwartz ADF	Sequential-t k	Sequential-t ADF	Generalized KPSS-test Bandwidth	Generalized KPSS-test statistics
ªln m_t	4	-27.672	4	-27.672	3	-17.065	6	0.140
ªln c_t	4	-326.514	4	-326.514	4	-326.514	5	0.087
ªln c_t^*	0	-94.540	0	-94.540	4	-939.358	3	0.031
Critical Values:	1%:-27.615		5%:-20.837		10%:-17.616		1%:0.219 5%:0.148	10%:0.119
ªln q_t	4	-151.955	0	-78.020	4	-150.955	4	0.051
ªln i_t	0	-78.827	0	-78.827	0	-78.827	5	0.038
ªln i_t^*	2	-43.779	2	-43.779	2	-43.779	5	0.051
Critical Values:	1%:-19.606		5%:-13.692		10%:-10.872		1%:0.754 5%:0.460	10%:0.348

(ADF-D Test: AIC, Schwartz, Sequential-t)

Notes: The sample period is 1973:2-1997:2. Variable definitions are as follows: m_t is real money; c_t is real consumption of domestic goods; c_t^* is real imports consumption; q_t is real exchange rate; $i_t = r_t/(1+ r_t)$, where r_t is domestic nominal interest rate; and $i_t^* = r_t^*/(1+r_t^*)$, where r_t^* is foreign nominal interest rate. Real money and consumption are in per capita terms. In the augmented Dickey-Fuller (ADF) D-test, the upper half reports the lag lengths and the test statistics for the following null hypothesis: X_t = ù$_1$)X_{t-1} + . . . +ù$_k$)X_{t-k} + " + X_{t-1} + u_t. The alternative hypothesis is: X_t = ù$_1$)X_{t-1} + . . . +ù$_k$)X_{t-k} + " + DX_{t-1} + *t + u_t. The lower part reports those of the following null hypothesis: X_t = ù$_1$)X_{t-1} + . . . +ù$_k$)X_{t-k} + X_{t-1} + u_t. The alternative hypothesis is: X_t = ù$_1$)X_{t-1}+ . . . +ù$_k$)X_{t-k} + " + DX_{t-1} + u_t. The Ljung-Box Q-test on the residuals shows that the null of no autocorrelation is accepted against first-to-fourth autocorrelations at the traditional significance level for all regressions. The Q-test results are available from the author upon request. In the generalized KPSS-test, the model is: X_t = " + *t + $d(u_1 + . . . + u_t)$ + ,$_t$. The upper half reports the Newey-West bandwidth and the test statistics for the null of trend stationarity (d=0). The null hypothesis of the statistics in the lower half is level stationarity(d=*=0). The alternative hypothesis is unit root nonstationarity (d=1).

Table 2: Unit Root Test Statistics for the Log Levels of the Variables

Variable	ADF-D Test: AIC *k*	AIC ADF	Schwartz *k*	Schwartz ADF	Sequential-t *k*	Sequential-t ADF	Generalized KPSS-test: Bandwidth	Generalized KPSS-test: statistics
ln m_t	4	-10.725	1	-6.443	4	-10.725	6	0.196
ln c_t	4	-19.406	3	-14.146	2	-24.583	6	0.108
ln c_t^*	0	-14.295	0	-14.295	0	-14.295	6	0.094
Critical Values:	1%:-27.615		5%:-20.837		10%:-17.616		1%:0.219 5%:0.148	10%:0.119
ln q_t	4	-5.071	1	-2.718	0	-1.640	6	1.036
ln i_t	1	-10.056	1	-10.056	1	-10.056	6	0.423
ln i_t^*	3	-11.489	3	-11.489	3	-11.489	6	0.436
Critical Values:	1%:-19.606		5%:-13.692		10%:-10.872		1%:0.754 5%:0.460	10%:0.348

Note: See Table 1.

Table 3: Unit Root Test Statistics for the Error-Correction Terms

Error-Correction Term	ADF-D Test: AIC k	AIC ADF	Schwartz k	Schwartz ADF	Sequential-t k	Sequential-t ADF	Generalized KPSS-test: Bandwidth	Statistics
$\ln m_t - \ln c_t + \ln i_t^*$	1	-14.162	1	-14.162	1	-14.162	6	0.144
$\ln c_t - \ln c_t^* - \ln q_t$	3	-29.799	3	-29.799	2	-43.085	5	0.111
$\ln i_t^* - \ln i_t$	2	-16.725	1	-21.177	1	-21.177	6	0.152
Critical Values:	1%:-19.606		5%:-13.692		10%:-10.872		1%:0.754 5%:0.460	10%:0.348

Note: See Table 1.