

Exchange Rate Determination from Monetary Fundamentals:  
an Aggregation Theoretic Approach

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**Abstract**

We incorporate aggregation and index number theory into monetary models of exchange rate determination in a manner that is internally consistent with money market equilibrium. Divisia monetary aggregates and user-cost concepts are used for money supply and opportunity-cost variables in the monetary models. We estimate a flexible price monetary model, a sticky price monetary model, and the Hooper and Morton (1982) model for the US dollar/UK pound exchange rate. We compare forecast results using mean square error, direction of change, and Diebold-Mariano statistics. We find that models with Divisia indexes are better than the random walk assumption in explaining the exchange rate fluctuations. Our results are consistent with the relevant theory and the “Barnett critique.”

**JEL Classifications:** C43, F31, F37

**Keywords:** Exchange rate, forecasts, vector error correction, aggregation theory, index number theory, Divisia index number.

**1. Introduction**

Following Meese and Rogoff’s (1983) (hereafter MR) finding that monetary models’ exchange-rate forecasting power are no greater than that of the random walk forecast, numerous studies have sought to find better estimation and forecasting methods. We investigate an

alternative approach to improvement: incorporation of index number and aggregation theory into the model in a manner assuring that the assumptions implicit in the data construction are internally consistent with the assumptions used in deriving the models within which the data are used.

Some of the prior attempts sought to increase the forecasting power by improving the estimation technique. Wolff (1987) used time varying coefficients, and Taylor and Peel (2000) estimated a nonlinear error correction model. Mark (1995) used a nonparametric bootstrapping method to investigate the structural models' forecasting power in the long horizon. Other prior attempts sought to expand the information sets. Groen (2000) and Mark and Sul (2001) tried to increase the structural models' forecasting power by pooling the data across countries. However, most of the results have not been clearly successful, and as a result the findings of MR still are widely accepted.<sup>1</sup>

These discouraging results suggest that the problem may not be solved by using better estimation or forecasting methods. Perhaps the focus needs to be directed at more fundamental problems. In this study, we switch the focus from econometrics to the fundamentals. In the monetary approach, money market equilibrium conditions, purchasing power parity (PPP), and uncovered interest parity (UIP) are basic to model structures. However, it is well known that those conditions often perform poorly empirically (e.g., Engel (1996,2000)). Hence, several models have sought to deal with the PPP and UIP problems. The sticky price monetary model relaxes the PPP assumption. Relaxing the UIP assumption, models with risk premia appeared,

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<sup>1</sup> Mark (1995) and Chinn and Meese (1995) have shown that fundamentals have forecasting power in the long horizon. But other critical studies, such as Kilian (1999) and Berkowitz and Giorwitz (2001), find that Mark's results are dependent upon assumptions on the data generating processes.

such as Frankel (1984). In contrast, little attention has been given to the money market equilibrium condition or the evidence of unstable money demand.

The objective of this paper is to investigate whether the exchange-rate forecasting power of monetary models can be improved by focusing on the monetary equilibrium condition. In particular, money demand may be more stable and thus the monetary equilibrium condition may perform better, if we use monetary aggregates derived from aggregation theory, instead of the commonly used atheoretical simple-sum aggregates.

Barnett (1980) derived the formula for the user cost of monetary services and the resulting theory of monetary aggregation, and produced the Divisia monetary aggregates that track the monetary quantity aggregator functions of aggregation theory. Many subsequent publications have found that using those aggregation-theoretic monetary aggregates resolves many of the “puzzles” in the literature. For a collection of much of the most important research from that literature, see Barnett and Serletis (2000), Barnett and Binner (2004), and Barnett, Fisher, and Serletis (1992). Unstable structure induced by use of simple sum monetary aggregates within models that are internally inconsistent with simple sum aggregation has been called the “Barnett critique” by Chrystal and MacDonald (1994).

We investigate performance of monetary exchange-rate determination models, when Divisia monetary aggregates are used instead of the commonly used simple sum monetary aggregates. The use of simple sum monetary aggregates within those models violates fundamental nesting conditions needed for internal consistency of the models with the data. We compare the forecasts of (1) monetary models with simple-sum monetary aggregates, (2) the same monetary models with Divisia monetary aggregates, and (3) the random walk model.

## 2. The Role of Money Supply and Demand in Exchange Rate Models

Since the outset of the floating exchange-rate system in the early 1970s, the monetary approach (or the asset approach in a wider concept) has emerged as the dominant exchange rate determination model. The MR (1983) research, as well as most of the succeeding empirical studies of exchange rate determination, used monetary models in estimating and forecasting exchange rates.

In monetary models, the bilateral exchange rate, defined to be the relative price of two currencies, is influenced by the supply and demand for money in the two countries. Hence, one of the main building blocks of the model is the monetary equilibrium in each country:

$$m_t - p_t = a_1 y_t - a_2 i_t, \quad (1)$$

$$m_t^* - p_t^* = a_1^* y_t^* - a_2^* i_t^*, \quad (2)$$

where  $m_t, p_t, y_t$  are the logarithms of the money supply, price level, and output respectively, and asterisk denotes foreign variable. The level of the opportunity cost (user cost) of holding money is  $i_t$ .

If the parameters are equal across countries, so that  $a_1 = a_1^*, a_2 = a_2^*$ , then the “flexible price monetary model” for the log exchange rate,  $S_t$ , can be shown to be the following :

$$S_t = (m_t - m_t^*) - a_1 (y_t - y_t^*) + a_2 (i_t - i_t^*), \quad (3)$$

where  $S_t = p_t - p_t^*$  under purchasing power parity.

This classical flexible price monetary model provides the basic structure of the monetary approach. Although the assumptions underlying this model are generally strong, other models have relaxed the underlying assumptions and modified the structures of the

flexible price model. The major assumptions that have been relaxed are price flexibility and capital mobility.

Allowing for short-run price flexibility, Dornbusch's (1976) version of the sticky price monetary model has played an important role in explaining the short-run exchange-rate overshoot. Alternatively the portfolio-balance approach relaxes the perfect capital mobility assumption and treats domestic and foreign bonds as imperfect substitutes. In that approach, the supply and demand for bonds play an important role in exchange-rate determination.

In all versions of the monetary approach, the money supply and the variables that determine money demand, such as output and monetary user costs, affect the exchange rate movements, as seen from equations (1), (2), and (3). As a result, we introduce the aggregation-theoretic correct monetary aggregates and their opportunity costs. Nevertheless, the simple-sum monetary aggregates and short-run interest rates are commonly used as the money supply and the opportunity cost variables in these studies, despite their known inconsistency with aggregation and index number theory. Simple sum monetary aggregates, by giving an equal and constant weight to each component monetary asset, can severely distort the information about the monetary service flows supplied in the economy, and the commonly used narrow aggregates, such as M1 and M2, cannot represent the total monetary services supplied in the economy, since those aggregates impute zero weight to the omitted components that appear only in broader aggregates.

The short-run interest rate that is used as a measure of the opportunity cost of holding money is also theoretically invalid. When a very narrow aggregate containing only currency and non-interest-bearing demand deposits is used, a suitably determined short run interest rate can

measure the opportunity cost adequately; but broader aggregates include checkable NOW accounts yielding interest and other monetary assets yielding even higher rates of return. As a result, consuming the services of such assets does not require foregoing the complete short-term rate of return on nonmonetary alternative assets. Hence a short term rate of return overstates the opportunity cost, and thereby the user cost, of holding broad monetary assets that include interest-yielding monetary assets.

A large literature has shown that using the simple sum monetary aggregates and a short-run interest rate in monetary equilibrium can destabilize otherwise stable money demand. For an overview of much of that literature, see Barnett and Binner (2004). We believe that the poor performance of the monetary exchange-rate determination models may have the same source.

### **3. Aggregation and Index Number Theory**

Rigorous microeconomic and aggregation-theoretic foundations were introduced into monetary economics, when Barnett (1980,1981) produced the theoretical linkage between monetary theory and aggregation theory. Recognizing that monetary assets are durable goods, he developed and applied the theory needed to construct monetary aggregates based on microeconomic aggregation theory. Since a durable good does not depreciate fully during one time period, a monetary aggregate that reflects the “monetary service flow” during a holding period is not equal to the monetary stock. In fact it more recently has been shown that the capital stock of money is the discounted present value of the aggregation-theoretic monetary service flow.

It follows that the price of the monetary service flow is the opportunity cost (user cost)

of holding monetary assets per unit time. The real user-cost price has been proven by Barnett (1980) to be the present value of the interest foregone by holding the assets, when a higher rate of return is available on a pure investment asset providing no monetary services. The resulting formula for monetary asset  $i$  during current period  $t$  is:

$$\pi_{it} = \frac{R_t - \gamma_{it}}{1 + R_t}, \quad (4)$$

where  $\gamma_{it}$  is the own rate of return on asset  $i$ , and  $R_t$  is the yield available in the economy on a pure investment asset (“benchmark” asset) providing no services other than its own investment rate of return.

With the monetary service flow and its user-cost price well defined, the aggregation-theoretic monetary-service-flow aggregate can be tracked and thereby accurately measured using statistical index number theory. A class of particularly highly regarded statistical index numbers is the class of “superlative index numbers” defined by Diewert (1976) to track aggregator functions up to third order remainder terms. Two well known superlative indexes are the Fisher ideal index and the Divisia index. In this study, we use the Divisia index.<sup>2</sup>

Let  $m_{it}$  be nominal balances of monetary asset  $i$  in period  $t$ , let

$s_{it} = \pi_{it} m_{it} / \sum \pi_{jt} m_{jt}$ , and let  $s_{it}^* = (1/2)(s_{it} + s_{it-1})$ .<sup>3</sup> Then the nominal Divisia quantity index  $M_t$  is defined by:

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<sup>2</sup> The choice between the Fisher ideal index and the Divisia index is of little significance, since the two indexes differ by less than the roundoff error in the component data. See Barnett (1980, 1981).

<sup>3</sup> The extension to risk aversion under intertemporal nonseparability of preferences recently has been produced by Barnett and Wu (2005). When rates of return on monetary assets are subject to exchange-rate risk, that extension could be important. However, no empirical applications of Barnett and Wu’s difficult formula have yet appeared. When the econometric problems associated with use of that risk-adjusted index number have been resolved, we anticipate that our already promising results can be further improved.

$$\ln M_t - \ln M_{t-1} = \sum_{i=1}^n s_{it}^* (\ln m_{it} - \ln m_{it-1}). \quad (5)$$

The growth rate of the Divisia index is a weighted average of the growth rates of the component monetary assets. The weight of each component is the user-cost-evaluated value share of that component. In continuous time differential equation form, the Divisia index is exact for any aggregator function and second order in this finite change (Törnqvist) form. The corresponding real Divisia user-cost price index,  $\Pi_t$ , is<sup>4</sup>

$$\ln \Pi_t - \ln \Pi_{t-1} = \sum_{i=1}^n s_{it}^* (\ln \pi_{it} - \ln \pi_{it-1}). \quad (6)$$

If there is a change in the interest rate on a component monetary asset, the asset holders will respond by substituting towards the assets with relatively lower user costs. A simple sum aggregate, by treating component assets as perfect substitutes, does not correctly capture any of those substitution effects among the component assets. A Divisia index treats component assets as imperfect substitutes, internalizes substitution effects, and measures the income effects, thereby capturing the exact change in the monetary service flows.

#### 4. Exchange Rate Forecasting with Divisia Money and User Cost Prices

##### 4.1. Model Specification

In accordance with the asset approach model of Hooper and Morton (1982) (hereafter HMM), the basic equation for estimation and forecasting of log exchange rates,  $S_t$ , is the following:

$$S_t = a_0 + a_1(m_t - m_t^*) + a_2(y_t - y_t^*) + a_3(i_t - i_t^*) + a_4(\dot{p}_t - \dot{p}_t^*) + a_5ca_t + a_6ca_t^* + u_t \quad (7)$$

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<sup>4</sup> Alternatively an implicit price dual to the monetary service index is defined by Fisher's weak factor reversal test. But the difference between that exact dual and the Divisia user-cost price index is negligible in most applications.

where  $\dot{p}_t$  is the expected inflation rate and  $ca_t$  is the current account deficit at time  $t$ .<sup>5</sup> As in the special case equation (3), asterisks denote foreign variables.

Two well known special cases are nested within equation (7). If we assume that  $a_5 = a_6 = 0$ , then equation (3) reduces to the sticky price monetary model (SPM) of Dornbush (1976). If  $a_4 = a_5 = a_6 = 0$ , the equation (7) reduces further to the flexible price monetary model (FPM) of Frenkel (1976) and Bilson (1978), as in equation (3) above. We use these three models, FPM, SPM and HMM, for estimation and forecasting, but with improvement through inclusion of aggregation theoretic variables for measurement of monetary flows and opportunity costs.<sup>6</sup>

#### 4.2. Data Specification and Transformation

We use quarterly data from the United Kingdom and the United States for the period 1977:1 to 2002:3, since the Bank of England and the Federal Reserve Bank of St. Louis both provide Divisia monetary aggregate data for that time period. The exchange rate, income, interest rate, price, and current account variables are drawn from the IMF's International Financial Statistics. In particular, we use the seasonally-adjusted nominal exchange rate(US\$/£), real GDP, three-month bond-equivalent Treasury bill rate (TB3MB), consumer

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<sup>5</sup> For the current account terms, Hooper and Morton (1982) used the cumulative current account deficit, under the assumption that long-term exchange rate changes are correlated with unanticipated shocks to the current account balances. Meese and Rogoff (1983) used cumulative deviations from trend balances as proxies for the unanticipated shocks. But cumulative deviation from trend balance is not invariant to the specification of the trend balance process. We use the current account balance itself, to avoid dependence upon a nonunique trend process specification.

<sup>6</sup> Chrystal and MacDonald (1995) recognized the usefulness of including aggregation theory in exchange rate modeling and showed that the flexible monetary model, with Divisia money, performs well during a particular period of financial deregulation. We examine whether three monetary models of exchange rate determination, with full use of Divisia monetary-quantity and user-cost aggregation and rolling regression, can, in general, be expected to perform better than the random walk model. Rather than seeking to resolve a particular period's puzzle, we investigate general solution to the problem of monetary exchange rate modeling.

price index (CPI), and current account deficit for each country as  $S_t$ ,  $y_t$ ,  $i_t$ ,  $p_t$ , and  $ca_t$  respectively. The monetary aggregates, M1, M3 (for the US), and M4 (for the UK), and the component quantity and interest rate data are acquired from the databases of the Federal Reserve Bank of St. Louis and the Bank of England.

Details regarding the Federal Reserve data are available from Anderson, Jones, and Nesmith (1997a,b,c). For the UK monetary services indexes, the Bank of England (hereafter BOE) publishes in its Quarterly Bulletin the Divisia indices for M4, based upon Fisher, Hudson and Pradhan (1993). However, we reconstructed the UK monetary-services index in a manner consistent with the procedures and transformations used with the Federal Reserve. In particular, with the UK data we followed the BOE's classification of component monetary assets and their interest rates. However, the BOE's computation of the user cost of monetary asset is slightly different from that of the US counterpart. We used equation (4) in calculating the user cost of the UK monetary components for consistency with the St. Louis Federal Reserve Bank's procedure.

### **4.3. Estimation and Forecasting**

We estimate each of the three models twice. First, we use the simple-sum monetary indexes to measure the pair  $(m_t, m_t^*)$  and the conventional short term interest rates to measure the pair of opportunity costs  $(i_t, i_t^*)$ , despite the fact that some of the monetary components themselves yield interest. We repeat the estimation with the Divisia money-services index used to measure  $(m_t, m_t^*)$  and the Divisia user-cost price index used to measure the opportunity costs  $(i_t, i_t^*)$ . We compare the forecasting power of the resulting six monetary models with that of a random walk forecast without drift.

We use the “rolling regression” procedure with fixed sample size in the model estimation and forecasting. In rolling regression, two-step procedures are repeated sequentially. In the first step, the model is estimated over a selected data sample and forecasted over the out-of-sample data period. In the second step, the sample period is rolled one observation forward. This two-step procedure is repeated until all the out-of-sample observations are consumed. We first estimate the model for the 41 observations from 1977:1 through 1987:1, with the out-of-sample forecast conducted over the period of 62 observations from 1987:2 through 2002:3, corresponding to the post Louvre Accord period.

There are two common problems in the exchange rate models: the explanatory variables in the model are all endogenous and are nonstationary. As result, we use vector error correction (VEC) in estimation, and we simultaneously solve the full model in forecasting. Estimating the relationships among multiple variables using vector error correction is accomplished in two steps. In the first step, cointegrating relationships are tested and estimated. An error correction term is constructed from the estimated cointegrating relations. The vector error-correction specification is a vector autoregression (VAR) in the first differences, including the error correction terms. In the second step the resulting specification is estimated over each sample period.

In some prior studies, the cointegrating vectors were estimated over the full data span. However, we estimate the cointegrating vector in each rolling period. As a result, the number of cointegrating relationships and the estimates of those relationships can vary across the sample periods.<sup>7</sup>

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<sup>7</sup> Mark (1995) and Chinn and Meese (1995) impose the cointegrating vector *a priori*. MacDonald and

#### 4.4. Forecast Comparisons

To evaluate the accuracy of a structural model's exchange rate forecasts, we use the ratio of the structural model's mean squared error (MSE) to that of a random walk without drift. If an MSE value is smaller than one, then the structural model has better forecasting power than the random walk forecast. For each of the six models, we compute the MSE ratios for 1 through 8 periods forward. Forecasting the direction of the change of the exchange rate is important, regardless of the magnitude of the change. As a result, we compute the direction of change (DOC) statistic, following Diebold and Mariano (1995) and Cheung, Chinn and Pascual (2002). The DOC statistic is the ratio of the number of correctly predicted directions of change to the total number of predictions. If the DOC statistic is significantly larger than 0.5, then the structural model has better direction-of-change forecasting power than a no-change assumption forecast. If the exchange rate were a random walk, the expected value of the DOC statistic would be 0.5. A test statistic value significantly smaller than 0.5 implies that the model forecasts changes in the wrong direction and thereby produces misleading information about exchange rate movements.

We also use the Diebold-Mariano (DM) statistics to compare the accuracy and direction of forecasts of the structural model with those of the random walk. The DM statistic tests the null hypothesis that there are no differences in the accuracies and/or directions of the two forecasts.<sup>8</sup>

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Taylor (1993) estimated it over the entire sample.

<sup>8</sup> There are problems in using DM statistics for evaluating out-of sample forecasts, when parameters are estimated. Nevertheless, we use the DM statistic as a source of further information, despite the limitations of the DM tests. There are two DM statistics: one for accuracy and one for direction of change. See Diebold-Mariano (1995) for detailed explanation of each. For the accuracy test, we use a rectangular lag window.

## 5. The Empirical Results

### 5.1. The MSE and DM Comparisons

The MSE ratios and the DM test statistics of the models using non-aggregation-theoretic traditional data are summarized in Table 1. Each cell in the table has two entries. The first is the MSE ratio and the second, in parenthesis, is the DM test statistic. There are 24 MSE ratios produced from the three models with 8 forecasts per model. Of the 24 cases, only 7 produce MSEs that are smaller than 1.0. Among those 7 ratios, only 4 are smaller than 0.9. With the flexible monetary model and the sticky price monetary model, the ratios are less than 1.0 until the 3<sup>rd</sup> period. However after that period, the ratios become larger than 1.0. The HM model does not produce any improvement in forecasting accuracy.

The results of the three traditional structural models are generally unfavorable. These unfavorable results are reinforced by the DM test statistics. All of the DM values are between  $-1.64$  and  $1.64$ , thereby implying that the null hypothesis of no difference in accuracy, relative to the random walk forecast, cannot be rejected at the 10% significance level. We find that the structural models' forecasts are no better than the random walk model's forecasts of the exchange rate. These findings are consistent with previously published results that are unfavorable to the monetary models with traditional non-aggregation-theoretic monetary data.

Table 2 displays the MSE ratios and the DM test results with the Divisia monetary models. In contrast to the above results with traditional data, the Divisia monetary models produce strikingly favorable MSE ratios. Out of the 24 results, the values of 21 MSEs are smaller than 1.0. Of those 21 favorable values, 17 are smaller than 0.9. The results with the sticky price monetary model are particularly strong. All the values are within the range of

0.6035 to 0.7884, indicating that we can reduce the MSE from 20% to 40% by using Divisia monetary models, rather than the random walk forecast. The DM test statistics again produce favorable results. With the sticky price model, the absolute values of the DM statistics are greater than 1.64 from the 1<sup>st</sup> period through the 4<sup>th</sup> period. The flexible price model displays better forecasting results than the random walk forecasts from 2 to 4 periods forward.

These results imply that the monetary models' exchange-rate forecasting accuracy can be improved substantially by using aggregation-theoretic monetary aggregates. These results are consistent with previous research demonstrating that aggregation-theoretic monetary aggregates and use-cost prices can stabilize monetary equilibrium conditions, which are central to the monetary exchange-rate forecasting models.

## **5.2. The DOC Results**

The traditional monetary models' DOC forecasting results are reported in Table 3. As with the MSEs, the results are not favorable to those models. For up to 2-period forecasts, the DOC values are greater than 0.5. Thus the traditional monetary models' results on direction-of-change forecasts are favorable in those cases. But beyond 2 periods, the DOC values drop below 0.5. At the 10% significance level, the DM statistics indicate that the sticky price model and the HM model-forecasts outperform the random-walk one-step-ahead forecasts. Far less favorable results are provided for other forecast periods, such as the 4 to 6 period ahead forecasts, since the flexible price model then produces erroneous information about the direction of the change. In general, the traditional models with non-aggregation-theoretic data display very little power regarding the direction of the exchange rate movements.

Again, when Divisia monetary models are used, the results are favorable, as shown in

table 4. All the DOC values are larger than 0.5, ranging from 0.5254 to 0.7419. The DM test results also are favorable. The 1<sup>st</sup> period forecasts of all three models are significantly better than those from the random walk forecast. The 2<sup>nd</sup> period forecasts of the FPM and the HMM also are significantly improve, with 8 out of 24 being significant at the 10% level.

The Divisia monetary models, unlike the same models with non-aggregation-theoretic monetary data, produce favorable forecasting performance.

## **6. Conclusion**

This paper incorporates monetary aggregation and index number theory into exchange rate determination theory. We investigate whether exchange rate forecasting power can be improved by specifying the monetary equilibrium condition more accurately. With Divisia monetary aggregates and their user costs, we find that the monetary fundamentals explain exchange rate movements more accurately than the random walk forecast.

In this study, data-availability limits us to modeling and forecasting the US dollar/UK pound exchange-rate movements. At present only the Federal Reserve of St. Louis and the Bank of England publish Divisia monetary aggregates data. Although our results with that exchange rate are strong, reversal of MR's results cannot be considered conclusive without data on more exchange rates. It is expected that Divisia data for many European countries will be available soon from the European Central Bank, in accordance with the procedures for multilateral aggregation developed by Barnett (2005). When the new European data is available, a complete analysis with several bilateral exchange rates will be possible.

Table 1: MSE comparison of the traditional monetary models

	1 period	2 period	3 period	4 period	5 period	6 period	7 period	8 period
FPM	0.7206	0.8134	0.9550	1.1243	1.3911	1.6602	1.4709	1.7023
	(-1.16)	(-0.88)	(-0.26)	(0.46)	(0.86)	(1.15)	(0.88)	(1.19)
SPM	0.7532	0.8305	0.9470	1.1006	1.3401	1.5028	1.3183	1.5819
	(-0.90)	(-0.81)	(-0.30)	(0.33)	(0.65)	0.76)	(0.47)	(0.72)
HMM	0.9214	1.0598	1.2386	1.2267	1.3003	1.3832	1.1461	1.2260
	(-0.28)	(0.23)	(1.02)	(0.91)	(0.91)	(1.16)	(0.49)	(0.69)

Note: FPM, SPM, HMM denote flexible price monetary model, sticky price monetary model, and Hooper and Morton model, respectively. The values in parenthesis are the Diebold-Mariano test statistics for forecast accuracy.

Table 2: MSE comparison of the Divisia monetary models

	1 period	2 period	3 period	4 period	5 period	6 period	7 period	8 period
FPM	0.6321	0.6075	0.5905	0.6743	0.8445	1.0346	0.9543	1.1552
	(-1.41)	(-2.36)	(-2.83)	(-1.71)	(-0.44)	(0.08)	(-0.10)	(0.27)
SPM	0.6035	0.6589	0.6641	0.6374	0.7011	0.7663	0.6806	0.7884
	(-1.64)	(-1.94)	(-2.98)	-2.28)	(-1.19)	(-0.96)	(-1.40)	(-0.94)
HMM	0.6786	0.8679	0.9160	0.9351	0.9761	1.0184	0.8179	0.8856
	(-1.58)	(-0.61)	(-0.46)	(-0.25)	(-0.07)	(0.05)	(-0.54)	(-0.40)

Note: FPM, SPM, HMM denote flexible price monetary model, sticky price monetary model, and Hooper and Morton model, respectively. The values in parenthesis are the Diebold-Mariano test statistics for forecast accuracy.

Table 3: The DOC comparison of the traditional monetary models

	1 period	2 period	3 period	4 period	5 period	6 period	7 period	8 period
FPM	0.5645	0.5246	0.4333	0.3559	0.3621	0.3684	0.4107	0.4364
	(1.02)	(0.38)	(-1.03)	(-2.21)	(-2.10)	(-1.99)	(-1.34)	(-0.94)
SPM	0.6613	0.5738	0.4333	0.3898	0.3966	0.4386	0.5	0.4727
	(2.54)	(1.15)	(-1.03)	(-1.69)	(-1.58)	(-0.93)	(0.00)	(-0.40)
HMM	0.6935	0.5902	0.4833	0.4407	0.3793	0.4035	0.4643	0.4909
	(3.05)	(1.41)	(-0.26)	(-0.91)	(-1.84)	(-1.46)	(-0.53)	(-0.13)

Note: FPM, SPM, HMM denote flexible price monetary model, sticky price monetary model, and Hooper and Morton model, respectively. The values in parenthesis are the Diebold-Mariano test statistics for direction of change.

Table 4: The DOC comparison of the Divisia monetary models

	1 period	2 period	3 period	4 period	5 period	6 period	7 period	8 period
FPM	0.7419	0.6557	0.5833	0.5593	0.5690	0.5789	0.5714	0.5636
	(3.81)	(2.43)	(1.29)	(0.91)	(1.05)	(1.19)	(1.07)	(0.94)
SPM	0.7097	0.5574	0.5500	0.5254	0.5690	0.5789	0.6786	0.6000
	(3.30)	(0.90)	(0.77)	(0.39)	(1.05)	(1.19)	(2.67)	(1.48)
HMM	0.6613	0.6066	0.5333	0.5254	0.5517	0.5965	0.6429	0.6182
	(2.54)	(1.66)	(0.52)	(0.39)	(0.79)	(1.46)	(2.14)	(1.75)

Note: FPM, SPM, HMM denote flexible price monetary model, sticky price monetary model, and Hooper and Morton model, respectively. The values in parenthesis are the Diebold-Mariano test statistics for direction of change.

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