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Financial innovation and Divisia monetary indices in Taiwan: a neural network approach

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In this paper a weighted index measure of money using the 'Divisia' formulation is constructed for the Taiwan economy and its inflation forecasting potential is compared with that of its traditional simple sum counterpart. This research extends an earlier study by Gazely and Binner by examining the theory that rapid financial innovation, particularly during the financial liberalization of the 1980s, has been responsible for the poor performance of conventional simple sum monetary aggregates. The Divisia index is adjusted in two ways to allow for the major financial innovations that Taiwan has experienced since the 1970s. The technique of neural networks is used to allow a completely flexible mapping of the variables and a greater variety of functional form than is currently achievable using conventional econometric techniques. Results suggest that superior tracking of inflation is possible for networks that employ a Divisia M2 measure of money that has been adjusted to incorporate a learning mechanism to allow individuals to gradually alter their perceptions of the increased productivity of money. Divisia measures of money appear to offer advantages over their simple sum counterparts as macroeconomic indicators.

Keywords: financial innovation, neural networks, Divisia money

1. INTRODUCTION

By the end of the 1970s, the demand for money appeared to be a stable function of a few key macroeconomic variables, changes in the supply of money appeared to have significant short-run effects on output and inflation appeared to be closely related to the trend rate of money growth. (See, for example, Belongia, 1996 for more details). Many economists believe that the link between monetary growth and inflation has weakened over the last two decades, however, due in part to rapid innovations in the financial sector (Crowder, 1998). It was becoming apparent throughout the developed economies in the mid-1980s that increased competition within the banking sector and the computerization of the financial world was beginning to have substantial effects on the relative user-costs ('prices') of bank liabilities and the ever-increasing array of substitutes for them. It is now well established that the substantial financial innovations of the 1980s introduced instability into estimated demand

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functions for broad money and it was largely for this reason that the case for monetary targeting was discredited (Friedman, 1996).

Recent empirical work (Belongia and Chrystal, 1991; Drake and Chrystal, 1994, 1997), puts forward the view that the breakdown in the demand for money functions during the 1980s outlined above is mainly attributable to the use of conventional official simple sum aggregates that assume that the component assets are perfect substitutes and hence should appear in the index with equal weights. It is now widely acknowledged that the simple sum procedure traditionally used by central banks to aggregate monetary assets is inappropriate in the absence of perfect substitutability between the component assets (Drake *et al.*, 2000). Barnett (1980) has demonstrated that the monetary index formulation devised by Divisia (1925) is the correct index to encapsulate a monetary aggregate and its concomitant price index. A Divisia index of money measures the flow of monetary services from a stock of money holdings. The underlying assumption is that individuals hold money for the services it provides. Money should therefore be included in the rational individual's utility function. One discrete time approximation of the Divisia index that is often used in empirical work is the Törnquist Theil (TT) approximation (see Törnquist, 1936 and Theil, 1967). The TT-index belongs to a class of superlative indices that can exactly track any unknown linearly homogenous aggregator function (Diewert, 1976, 1978). The Divisia index has its roots firmly based in microeconomic aggregation theory and statistical index number theory. Barnett *et al.* (1992) provide a survey of the relevant literature, whilst Drake and Mullineux (1997) review the construction of Divisia indices and associated problems. A new empirically weighted monetary aggregate has been developed for the UK by Drake and Mills (1999) and extensions of Divisia to incorporate the risk of assets have been derived by Barnett and Liu (2000) for the USA and Drake *et al.* (1999) for the UK.

Our hypothesis developed over a series of studies and summarized in Gazely and Binner (2000) is that measures of money constructed using the Divisia index number formulation are superior indicators of monetary conditions when compared to their simple sum counterparts. This hypothesis is reinforced by a growing body of evidence from empirical studies around the world which demonstrate that weighted index number measures may be able to overcome the drawbacks of the simple sum, provided the underlying economic weak separability and linear homogeneity assumptions are satisfied. Ultimately, such evidence could reinstate monetary targeting as an acceptable method of macroeconomic control, including price regulation.

We offer an exploratory study of the relevance of the Divisia monetary aggregate for Taiwan over the period 1970 to date. We explore the potential of a new generation of Divisia monetary aggregates, adjusted to take account of the recent developments in the financial sector, using the artificial intelligence technique of neural networks and described here in Section 3. Our preference for using neural networks to examine the money–inflation link in the current work is in keeping with Dorsey's strong contention that the standard econometric methods for modelling financial innovation, such as introducing dummy variables to capture shifts in data, are ad hoc methods 'leading nowhere'

(Dorsey, 2000, p. 30). He goes on to claim that, during periods of high financial innovation, 'dozens (or hundreds) of studies using cointegration to investigate whether money growth and inflation move together in the long run have not provided evidence – on either side – that is useful to framing an answer' (Dorsey, 2000, p. 31). The results of our simple inflation forecasting experiment using neural networks to evaluate the link between money growth and inflation are presented in Section 4 whilst Section 5 concludes and offers suggestions for future research.

2. FINANCIAL INNOVATION AND THE DIVISIA MONETARY AGGREGATE IN TAIWAN

The banking system in Taiwan was heavily regulated by the Central Bank and the Ministry of Finance until July 1989, which saw the introduction of the revised Banking Law. At the beginning of the 1980s, drastic economic, social and political changed took place creating a long-term macroeconomic imbalance. Rising oil prices caused consumer prices to rise by 16.3% in 1981, followed by a period of near zero inflation in the mid-1980s, although from the 1990s onwards inflation has fluctuated around 5%. The control of inflation has not been the mainstay of recent economic policy in Taiwan, in contrast to the experience of the western world. Rather, policy has focused more on achieving balanced economic and social development.

The revolution in the financial sectors of Taiwan over the last two decades has yielded new types of financial assets and liabilities and new markets have been created, as outlined above. These changes have manifested themselves throughout the global economy in the emergence of competition and merger activity between the traditional commercial banks and previously distinct financial institutions. In the UK, for example, the banks introduced interest payments on formerly non-interest bearing cheque accounts together with a wide range of new mortgage products. In response the building societies began to offer cheque accounts, thereby bringing the banks and building societies into direct competition, stimulating product innovation.

We explore the econometric performance of a new generation of Divisia indices that have been reformulated to take account of recent financial innovations in Taiwan, extending the work of Ford (1997). Two innovation adjusted Divisia series are therefore analysed, the data having kindly been provided to us by Ford. Both Divisia series have been modified to allow for a learning process by individuals as they adapt to changes in the productivity of monetary assets and adjust their holdings.

- One adjusted series, namely Innovation1 Divisia, assumes that individuals, who had been adjusting well to cosmetic changes in interest rates, were slow to react to the increased productivity of money, initially under-estimating the effect of financial innovation. In keeping with Ford (1997, p. 21) we adopt the approach proposed in Baba *et al.* (1985, 1990), which imposes a learning adjustment process on the user cost of interest-bearing sight deposits in the construction of monetary indices. Specifically, the learning function used is an ogive-shaped weight function, w_t, representing the agents' learning about the assets and is applied to the interest rates. Thus,

$$w_t = (1 + \exp[\alpha\text{-}\beta(t\text{-}t^* + 1)])^{-1} \quad \text{for } t \geq t^* \text{ and zero otherwise} \qquad (1)$$

Here, t^* denotes the time at which the innovation occurred, α represents the existing level of knowledge about the innovation and β measures the speed to respond to it.

- The second series, namely Innovation2 Divisia, assumes a period of gradual and continuous learning throughout the whole period as individuals adjust to the increased productivity of money. The approach adopted in Ford (1997, p. 4) is used, whereby an approximate estimate of the degree of productivity improvements is obtained by using an index number of bank branches of all kinds (although medium-sized business banks are excluded).

In the case of Taiwan, financial innovation accelerated around the end of 1989 and as stated by Ford (1997, p. 3) for the construction of a Divisia aggregate, the changes are assumed to occur gradually and continuously throughout the years and were assimilated by individuals as they occurred, Innovation2; or alternatively, a period of learning occurs before individuals adapt to the change of regime, Innovation1.

3. NEURAL NETWORK METHODOLOGY AND DATA

We use artificial neural network technology, rather than standard econometric methods, to examine Taiwan's recent experience of inflation. This is an unusual tool in this context, although the application of neural networks in the field of economics is growing in popularity, as indicated by the diverse range of applications surveyed in Li *et al.* (1998). In view of Dorsey's (2000, pp. 30–31) contention that standard econometric methods have provided no concrete evidence one way or the other to explain the link between money growth and inflation, we feel neural networks offer more promise in the context of econometric modelling than standard linear models. As stated in our previous study, Gazely and Binner (2000, p. 1610), neural networks are not constrained by the requirement to specify regression parameters, assumptions about data distribution are less stringent and approximation of highly non-linear functions to any degree of accuracy is possible.

To evaluate the degree to which limited data on money provides information for explaining inflation, a simple model of the relationship between money and inflation was employed and one basic network design was chosen (see equation 2). This procedure allows comparisons of the information content of Divisia and simple sum indices to be evaluated on an equal footing and corresponds with the work undertaken by Dorsey (2000) for the USA in the first known application of neural networks to Divisia money.

$$\Pi_t = f(M_{t-1}, M_{t-2}, M_{t-3}, M_{t-4}, \Pi_{t-1} + \varepsilon_t) \qquad (2)$$

where Π_t represents inflation, M_t is the measure of money (simple sum and the three Divisia measures are interchanged alternately) lagged over time periods one to four and ε_t is a classical stochastic error term.

The model specification takes inflation in the current period to be a function of money measures in the four preceding periods. An autoregressive term representing inflation for the preceding period is included, along with an additional variable to represent time (here taking the values 1 to 96), to allow for the possibility that external factors, not catered for by the autoregressive variable, might affect the inflation rate. This model had been found to be superior in our earlier studies to even more simple models, although of course we recognize that a more sophisticated model may prove to yield superior results. In a similar spirit, a neural architecture of five hidden units in a standard back-propagation network, and a policy of deliberate extended training was used (Masters, 1993) rather than risk the unreliability of premature stopping techniques since this policy had proved successful in earlier studies. See Gazely and Binner (2000) for more details of the neural network methodology employed.

Inflation was constructed for each quarter as year-on-year growth rates of prices. Quarterly data over the sample period 1970Q1 to 1995Q3 was used as illustrated in Fig. 1. Our preferred price series, the Consumer Price Index (CPI), was obtained from DataStream. Monetary data consisted of three Divisia series provided by Ford (1997), one conventional Divisia, Innovation1 and Innovation2, together with a simple sum series, constructed from component assets obtained from the Aremos-Financial Services database in Taiwan. In contrast to the previous studies using data for the UK, USA and Italy, the macroeconomic series for Taiwan were highly erratic owing to the swings in policy over the last two

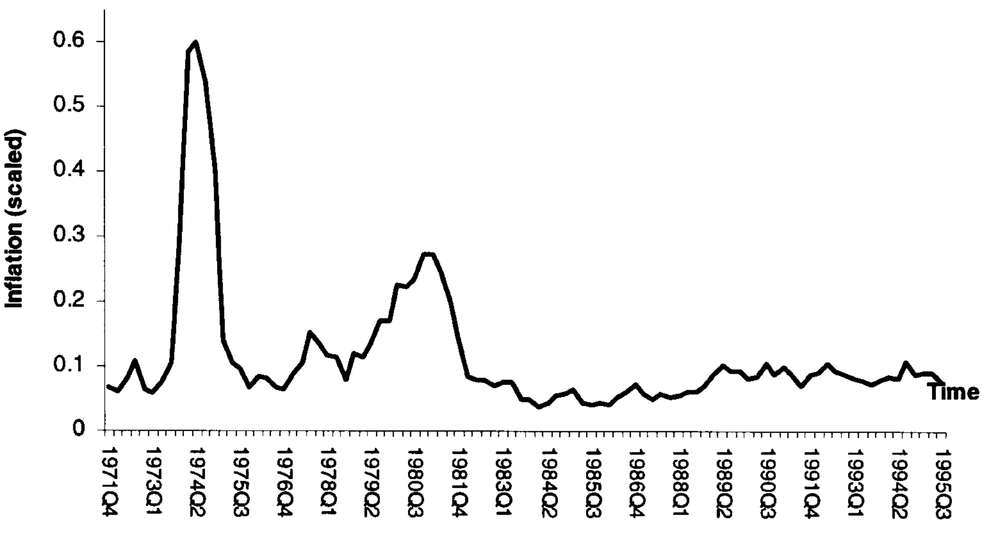

Fig. 1. Taiwan: inflation 1971–1995.

decades. Pre-processing of the data normally not considered necessary in the application of neural networks was found to be appropriate in this case to improve the fit. The Divisia series were subjected to a smoothing process by taking three quarter averages to reduce noise. Also, to avoid the swamping of mean percentage error by huge values during a period of very low inflation from 1983–1986, the entire series was translated upwards by 5% and results are presented on this basis. The transformed monetary series are presented here in Fig. 2. Of the total quarterly data points available, after loss of data points due to the smoothing process and the time lag implicit in the model of up to four quarters, 96 quarters remained, of which the first 89 were used for training and the last 7 for testing (forecasting). This proportion of training to testing is higher than that conventionally used for neural networks, but at this exploratory stage we are primarily interested in the ability of the network to model the data as a precursor to predictive ability, rather than focusing exclusively on predictive accuracy *per se*.

4. RESULTS AND DISCUSSION

The effect of incorporating financial innovations into the construction of the monetary aggregates in Taiwan is clearly evident in Fig. 2. The impact of recent

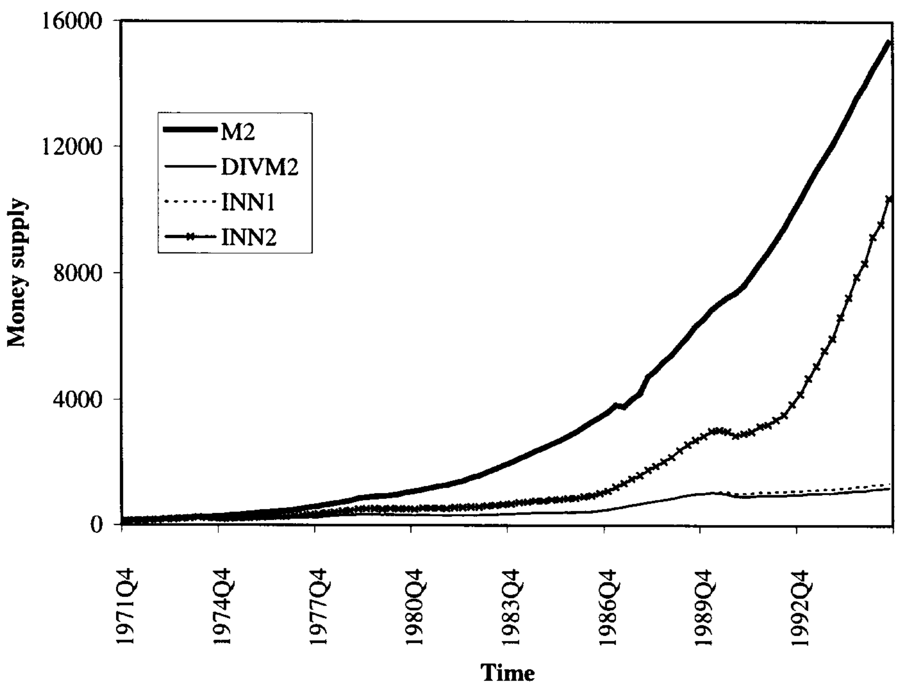

Fig. 2. Innovation adjusted monetary indices.

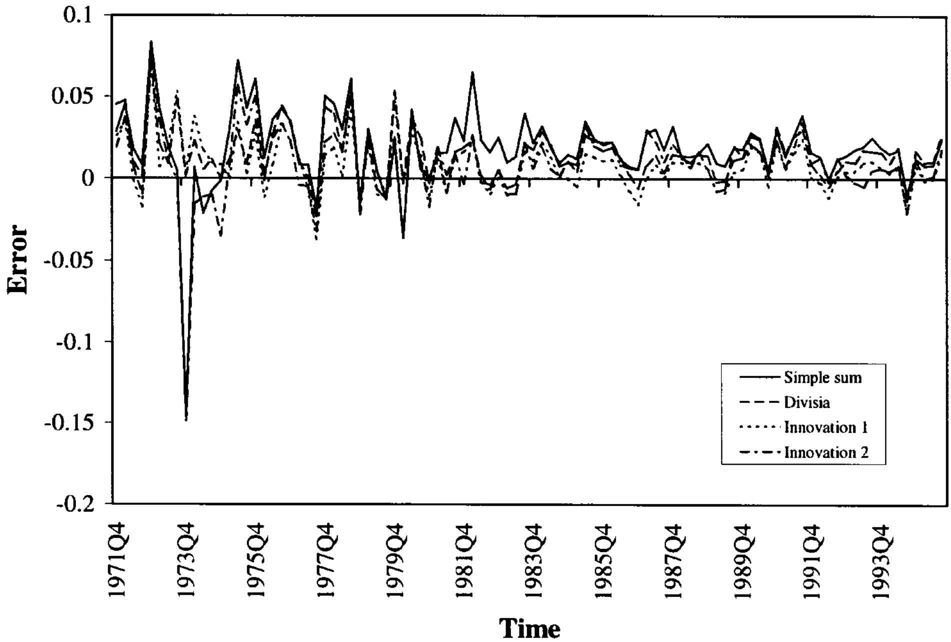

Fig. 3. Model output error over time.

financial liberalization during the period under study is considerable in the case of Innovation2, where the productivity improvements of money are adjusted by using an index number of bank branches. Note, however, that Innovation1 does not deviate from the standard Divisia M2 until 1989.

Figure 3 shows error (simply inflation for the quarter subtracted from the model output) for the four monetary series. It can be seen that for much of the period a simple sum measure overestimates inflation, while Innovation2 produces several noticeable under-estimates. The mean *absolute* difference for each series, together with the mean percent error and the root mean squared errors, are shown in Table 1.

Our results support our general hypothesis that Divisia measures are superior to simple sum in modelling inflation. Moreover, they also support the results of Ford (1997) in that Innovation1 is a superior form of Divisia than either conventional Divisia, or Innovation2. For all three measures of error and both within-sample and out-of-sample, Innovation1 shows smaller error. Looking at mean absolute difference for example, within-sample error is found to be 21% lower for Innovation1 Divisia compared to the next best alternative. Likewise, out-of-sample forecast errors are found to produce an 11% reduction in error compared with Innovation2 Divisia and a 42% reduction when compared with the traditional simple sum measures of money.

Table 1. Within-sample and out-of-sample forecast errors

	Simple sum	Divisia	Innovation1	Innovation2
In-sample				
RMS error	0.032106	0.022578	0.018764	0.026806
Mean absolute difference	0.0247	0.0175	0.0139	0.0182
Mean percentage error	30%	22%	16%	21%
Out-of-sample				
RMS error	0.014801	0.016043	0.010715	0.011575
Mean absolute difference	0.0138	0.0150	0.0080	0.0090
Mean percentage error	16%	17%	9%	10%

5. CONCLUDING REMARKS

This paper presents results that are not only relevant to macroeconomic policy, but which use a combination of advanced methods that have never been combined before, i.e. aggregation theoretic monetary aggregates, neural network forecasting and technological change in the production of monetary services. The neural network methodology allows greater flexibility of functional form than that currently obtainable by use of conventional econometric methodology and alleviates the problems associated with the *ad hoc* application of conventional econometric methods. Evidence presented here supports the view that Divisia indices appear to offer advantages over simple sum indices as macroeconomic indicators. It may be concluded that a money stock mismeasurement problem exists and that the technique of simply summing assets in the formation of monetary aggregates is inherently flawed. Further empirical work on Divisia money may serve to restore confidence in formerly well-established money–inflation links. Ultimately, it is hoped that money may be re-established as an effective macroeconomic policy tool in its own right.

We have stressed in this paper that particular advantages arise from the use of weighted monetary measures that have been adjusted to accommodate financial innovations, such as the introduction of new assets or the payment of interest on formerly non-interest bearing accounts. We have shown that the effects of financial innovation during the period considered in this study are considerable; hence the weights used to construct the Divisia monetary index should be modified to allow for the impact of the growth in monetary services provided. By allowing monetary aggregates to vary in response to changes in interest rates, reflecting changes in the yield curve, we have demonstrated that we can improve on their information content. Results suggest that the Divisia index, designed to accommodate a learning mechanism to allow individuals to gradually alter their perceptions of the increased productivity of money, enhances the explanatory power of the standard Divisia aggregate and dominates its simple sum and traditional Divisia index counterpart. Finally, it would be fruitful to compare the performance of the neural networks with more sophisticated parametric non-linear models, such as GARCH. This is ongoing research and will form the subject of a future paper.

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