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How well does the Mundell–Fleming model fit Australian data since the collapse of Bretton Woods?

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Australian time series for the nominal interest rate, real output, the nominal exchange rate, prices and nominal money since 1973 are characterized by a vector autoregressive process driven by five exogenous disturbances. Those disturbances are identified so that they can be interpreted as the five main sources of fluctuations found in the Mundell–Fleming model of a small open economy under flexible exchange rates, namely: world interest rate, aggregate supply, IS, money supply and money demand shocks. The dynamic responses of the estimated model to the structural shocks are analysed and shown to match most of the predictions of the Mundell–Fleming model.

I. INTRODUCTION

The year 1973 marks the collapse of the Bretton Woods system of fixed exchange rates and the beginning of the world-wide movement to flexible exchange rates. Since the transition to flexible exchange rates, many countries have experienced wide fluctuations both on the real and nominal side. In addition to a substantial increase in the volatility of exchange rates, large fluctuations in output growth and the inflation rate have been of particular concern in terms of the stability of the economy. More than two decades of experience with the current flexible exchange rate system indicates that contrary to the expectations by the advocates of the system, the international transmission of growth, inflation and unemployment has not been eliminated. As Baillie and McMahon (1989) observe, macroeconomic interdependence has rather increased remarkably, and domestic economies appear to be more vulnerable to external shocks, which in turn, results in a greater volatility in many macroeconomic variables.

The purpose of this paper is to identify the sources of the recurrent fluctuations in the Australian economy since the collapse of Bretton Woods. In particular, the main focus of the paper is to assess the empirical validity of the Mundell–Fleming model in explaining such observed economic fluctuations. The Mundell–Fleming model is an open economy version of the IS-LM with inclusion of capital flows as an important component of the model. The model is designed for the analysis of macroeconomic policy in a small open economy that is a price taker in export and import markets.[1] There is not much doubt that Australia is a small economy. Australia is also an open economy. During the past ten years, for example, Australia's exports and imports of goods and services were averaged to 37.3% of GDP. The Mundell–Fleming model also requires capital mobility so that the role of capital flows is activated. In Australia, controls were placed on the inflow and outflow of capital until the 1970s. By the end of 1978, however, most controls on the capital inflow had been lifted. Controls on the outflow of capital had also been removed or relaxed during the early 1980s (see Tease, 1990 for a discussion). Since then, both inflows and outflows of capital have substantially increased and averaged to 6.5 and 2.5%, respectively, relative to GDP. In view of this relatively high degree of capital mobility and the size and openness of the economy, the Australian economy provides a good opportunity to compare the predictions of the Mundell–Fleming model with empirical data.

[1] This assumption is important because without it changes in the volume of exports and imports affect tradable prices and the overall effects of a shocks on domestic economy cannot be determined.

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The strategy used in this paper is to characterize the joint behaviour of the nominal interest rate, real output, the nominal exchange rate, prices and nominal money by way of a vector autoregressive (VAR) model. The interpretation given to the structural shocks in the VAR model is based on a version of the Mundell–Fleming model for a small open economy under flexible exchange rates. Based on this theoretical model, the five structural shocks in the VAR model are identified as: a world interest rate shock; an aggregate supply shock; a real spending shock (IS shock); a money supply shock; and a money demand shock.

Econometric identification of the underlying structural shocks is achieved by imposing long-run and contemporaneous restrictions in the VAR model. The world interest rate shock is identified on the assumption that for a small open economy, the domestic interest rate cannot deviate from the exogenously determined world interest rate in the long run, which can be regarded as a reflection of the uncovered interest rate parity relation. The aggregate supply shock is identified by assuming that aggregate demand innovations do not have a long-run effect on real output, a type of restriction proposed by Blanchard and Quah (1989). We further decompose aggregate demand innovations into those that originate from IS, money demand and money supply shocks, respectively, using contemporaneous identifying restrictions suggested by Gali (1992). By examining the responses to the structural shocks, we can evaluate how well the predictions of Mundell–Fleming model accord with the Australian evidence.

The remainder of this paper is organized as follows. Section II discusses an econometric procedure to identify the underlying structural shocks in the Mundell–Fleming model. In Section III, the empirical results are given and compared with the model predictions. Summary and concluding remarks are presented in Section IV of the paper. Since the Mundell–Fleming model is well known in the literature, we do not show a detailed exposition of the model in the text. In an Appendix, however, a simple version of the model is presented in order to provide a framework for interpreting the long-run responses of the variables to the structural shocks. The long-run solution to this model is also used in Section II for the identification of the structural shocks in the estimated VAR model.

II. IDENTIFICATION OF THE SHOCKS IN THE MUNDELL–FLEMING MODEL

Assume that the series in the (5×1) vector $\{X_t\}$ are the nominal interest rate, real output, the nominal effective exchange rate, prices and nominal money, respectively, denoted by $\{X_t\} = \{r_t\ y_t\ e_t\ p_t\ m_t\}'$. Also assume that there are five independent structural shocks governing the economy: world interest rate shocks (v_t^{fr}), aggregate supply shocks (v_t^{as}), IS shocks (v_t^{is}), money supply shocks (v_t^{ms}), and money demand shocks (v_t^{md}), and that these shocks are ordered as $v_t = \{v_t^{\mathrm{fr}}\ v_t^{\mathrm{as}}\ v_t^{\mathrm{is}}\ v_t^{\mathrm{ms}}\ v_t^{\mathrm{md}}\}'$. By employing the Wold decomposition, the reduced-form vector moving average (VMA) representation for $\{\Delta X_t\}$ can be expressed as:

$$\Delta X_t = \delta + C(L)\varepsilon_t \tag{1}$$

where $\Delta \equiv (1 - L)$ and L is the lag-operator, δ is a constant vector, and

$$C(L) = \sum_{i=0}^{\infty} C_i L^i$$

with $C_0 = I$. The five-dimensional disturbance vector $\{\varepsilon_t\}$ is iid with mean zero and covariance matrix Ω. As $\{\varepsilon_t\}$ is the reduced-form disturbance with no particular economic interpretation, it is assumed to be a linear transformation of a structural disturbance vector $\{v_t\}$ such as:

$$S^{-1}v_t = \varepsilon_t \tag{2}$$

where S^{-1} is a (5×5) matrix measuring the contemporaneous effects of the structural shocks on the series. The corresponding structural VMA representation is:

$$\Delta X_t = \delta + C(L)S^{-1}v_t = \delta + \Xi(L)v_t \tag{3}$$

where

$$\Xi(L) = \sum_{i=0}^{\infty} \Xi_i L^i$$

and $\Xi_i = C_i S^{-1}$ for $i = 1, 2, \ldots, \infty$ with $\Xi_0 = S^{-1}$. The vector of structural disturbances $\{v_t\}$ is distributed as an iid Gaussian process with zero mean and identity covariance matrix, i.e. $v_t \sim N(0, 1)$. From Equation 3, the relationship between the long-run effects on the series of the reduced-form and structural-form shocks can be expressed as

$$C(1)\,S^{-1} = \Xi(1) \tag{4}$$

where $C(1) = \sum C_i$ and $\Xi(1) = \sum \Xi_i$.

The 25 parameters in S^{-1} (or S) from Equations 2 and 4 must be uniquely determined in order to identify the underlying structural shocks in the model. Following standard practice, we assume orthogonality between the structural shocks which provides 15 $[5(5+1)/2]$ restrictions on S from $S\Omega S' = I$ in Equation 2. An additional 10 restrictions are required for exact identification of S. Now rewrite Equations 2 and 4 using $S^{-1} = \Omega S'$ from the orthogonality conditions as:

$$\Omega S' v_t = \varepsilon_t \tag{2'}$$

$$C(1)\Omega S' = \Xi(1) \tag{4'}$$

We appeal to the long-run solution of the Mundell–Fleming model in order to distinguish the world interest rate shock and the aggregate supply shock from aggregate demand shocks (see Appendix). To identify the world interest rate shock, we assume that it is the only shock which has a long-run effect on the domestic nominal interest rate as a reflection of the uncovered interest parity condition. None of the other shocks in the model are assumed to have long-run effects on the domestic interest rate. These four long-run restrictions on the interest rate can be imposed by assuming that elements (1,2), (1,3), (1,4) and (1,5) of $C(1)\Omega S'$ in Equation 4′ are equal to zero, which provides four restrictions on S. To identify the aggregate supply shock, we assume that IS, money supply and money demand shocks, which are components of the aggregate demand shock, do not have long-run effects on real output. Many empirical studies have used these long-run properties as identifying restrictions, for example, Blanchard and Quah (1989), Gali (1992), Moreno (1992), Clarida and Gali (1994), and Kim (1994) *inter alia*. These long-run identifying restrictions can be imposed by setting elements (2,3), (2,4) and (2,5) of $C(1)\Omega S'$ in Equation 4′ to zero, giving another three restrictions on S.

In order to distinguish IS shocks from the two monetary disturbances, we follow Gali (1992) and assume that neither money supply nor money demand shocks have a contemporaneous effect on real output. Given that quarterly data are used in the empirical analysis, these identifying restrictions are meant to capture the effect of time lags: we assume that aggregate demand for goods and services is not directly affected by monetary shocks in the current quarter, but only subsequently through resulting changes in the interest rate or the exchange rate. That is, aggregate demand takes some time to respond to those shocks. (See Gali for cited references supporting this assumption.) These contemporaneous restrictions are imposed by setting elements (2,4) and (2,5) of $\Omega S'$ in Equation 2′ to zero, which gives a further two restrictions on S.

Upon identifying the first three structural shocks, one final identifying restriction is required in order to disentangle the two types of monetary shocks: demand and supply. Following Blanchard and Watson (1986) and also Gali, the identifying assumption we use is to exclude contemporaneous prices from the structural equation for nominal money. This restriction may be rationalized on the grounds that the monetary authority may not observe the current quarter price level when formulating monetary policy or that they may not react to the current quarter price level as there may be considerable noise in the short-run movements of that variable. Given the ordering of the variables in $\{X_t\}$, this final restriction is imposed on S directly by setting element (5,4) of S (not $\Omega S'$ in Equation 2′) to zero.

Once these 10 identifying restrictions are imposed on S together with the 15 restrictions from the orthogonality conditions, the 25 parameters in S can be uniquely obtained by solving the 25 equations simultaneously in Equations 2′ and 4′ and from $S\Omega S' = I$. Once S is estimated, the dynamic effects of the structural shocks are calculated from inverting S to obtain S^{-1} and, hence, $\Xi(L) = C(L)S^{-1}$ from Equation 3. The forecast-error variances at various horizons due to the structural shocks are also computed and compared to the total forecast-error variance in order to determine the relative importance of the shocks over time.

III. EMPIRICAL RESULTS

The analysis outlined above is applied to quarterly Australian data for the sample period 1973:2 to 1995:4. Definitions of the data series are as follows. The interest rate (r) is the yield on 13-week Treasury notes expressed as a per cent per annum. The measure of real output (y) is the value of expenditure-based GDP seasonally adjusted, in constant 1989/90 prices. The nominal exchange rate (e) is a nominal trade-weighted index (May/1970 = 100) and is measured as units of domestic currency per unit of foreign currency. The price variable (p) is the Consumer Price Index (1989/90 = 100) and was seasonally adjusted using the X-11 procedure. Money (m) is measured as currency plus current deposits with banks, which are seasonally adjusted. All variables except the interest rate are expressed in logarithms.[2]

Prior to estimating a VAR model, Phillips–Perron and Augmented Dickey–Fuller tests were used to determine the order of integration of the series. Both tests indicated that each series in levels is characterized as an $I(1)$ process. We then applied the Johansen (1988) procedure to test for evidence of cointegration among the series. Both the trace and maximum eigenvalue tests indicated no cointegrating relationships among the series at the 5% significance level.[3] Based on those results, the reduced-form VAR model in the first differences of the series is estimated with three lags and a constant.[4] Then, the estimated VAR models are expanded

[2] All data were taken from the DX database of Econdata Pty Ltd: their identification numbers are FIRMMTNIY13 (r), NPDQ.AK90GDP#E (y), FXRTWI (e), RSRQ.UI90C90110001 (p), DMACSA and DMACDTSA (m), respectively. The series for the interest rate and the nominal exchange rate were provided monthly and averaged to quarterly values.

[3] The results for unit root and Johansen cointegrating tests are available from the authors upon request.

[4] The lag length of $p = 3$ was chosen on the basis of the Sims likelihood ratio test. For the test of the null hypothesis that $p = 2$ against $p = 3$, the test statistic is 46.75 with a marginal significance level of 0.00, so that the null is rejected. However, the likelihood ratio test statistics for $p = 3$ versus, respectively, $p = 4$, $p = 5$ and $p = 6$ have marginal significance levels of 0.24, 0.21, and 0.17, so that the null hypothesis of $p = 3$ was not rejected. In addition, this is the lag length for which the Breusch–Godfrey Lagrange multiplier test indicates absence of serial correlation in each equation of the estimated reduced-form VAR model. Based on regression of residuals on initial regressors and four lagged residuals, the test statistics are 2.98 (r), 3.94 (y), 5.01 (e), 3.82 (p) and 4.65 (m), which are distributed as χ^2 with four degrees of freedom.

to models in the levels of the series. For structural analysis, the estimated VAR models are inverted numerically to obtain estimates of the reduced-form shocks $C(L)$. Having obtained $C(L)$, the structural analysis of Section II can proceed.

Figures 1 to 3 show the dynamic responses of the levels of the series to a one-standard-deviation shock in each structural disturbance. Also depicted are one standard error confidence bands generated by 300 bootstrap replications of the structural model. From the first column of Fig. 1, a positive world interest rate shock leads to a rise in the domestic interest rate, and a depreciation of the nominal exchange rate. This shock also raises the domestic price level at all horizons. In response to the positive world interest shock, real output and nominal money initially increase but both fall rapidly as this shock results in an increase in the domestic interest rate. Smith and Murphy (1994) reach essentially the same conclusion that an increase in the world interest rate reduces the level of output and nominal money in Australia.

The dynamic effects of a positive aggregate supply shock are depicted in the second column of Fig. 1. This shock leads to an increase in domestic real output, and a fall in the price level. The nominal interest rate falls initially but, in the long run, returns to its level prior to the shock as a consequence of the identifying restrictions. Nominal money increases mainly to accommodate the increase in real output. The long-run effects of aggregate supply shocks on the nominal exchange rate are, *a priori*, indeterminate in the Mundell–Fleming model. (See Appendix and also Clarida and Gali, 1994.) Figure 1 shows that a favourable aggregate supply shock causes the nominal exchange rate to appreciate. This is in accordance with the findings of other countries, for example, Karras (1993) and Kim (1994) for the US, and Sims (1992) for the US, France and Germany.

The dynamic effects of a positive IS shock are shown in the first column of Fig. 2. In response to the IS shock, prices increase significantly, and this is consistent with the model prediction as in the Appendix. Recall from Equation A9 that when the exchange rate is not part of the money demand function (i.e. $\phi_5 = 0$) as in the conventional Mundell–Fleming model, IS shocks have no long-run effect on the price level (also see Mark, 1990). Real output and the domestic interest rate increase over short horizons but eventually return to their levels prior to the shock as a consequence of the identifying restrictions. The nominal exchange rate appreciates permanently in response to the IS shock. This is consistent with Fisher (1996) who investigates movements in Australian nominal and real exchange rates. Karras (1993) and Kim (1994) also reach the conclusion that a positive IS shock results in a permanent appreciation of the nominal exchange rate for the US.

The second column of Fig. 2 shows the impulse responses corresponding to a positive money supply shock. In response to this shock, the interest rate falls initially, consistent with the liquidity effect, and real output rises. Their long-run responses are zero by the identifying restrictions. A positive money supply shock leads to a rise in prices and a depreciation of the nominal exchange rate, and the long-run responses of these two series are almost of the same magnitude. On the other hand, the increase in nominal money is greater than the increase in the nominal exchange rate and prices in the long-run. Their result is not consistent with the implications of conventional Mundell–Fleming models (i.e. $\phi_5 = 0$ in Equation A2), where prices, the nominal exchange rate and money increase by the same unit in response to money supply shocks. However, the result is consistent with our specification that the nominal exchange rate enters the money demand function with a positive coefficient ($\phi_5 > 0$ in Equation A2). In that case, Equation A9 shows that nominal money increases by more than the exchange rate and prices in the long run in response to a positive money supply shock.

There is an interesting difference between the response of the nominal exchange rate to a money supply shock shown here and that in the model of Dornbusch (1976). In Dornbusch's overshooting model, a positive money shock typically generates a large instantaneous depreciation of the nominal exchange rate, followed by a subsequent appreciation so that the long-run depreciation is less than the initial depreciation. By contrast, Fig. 2 shows that the nominal exchange rate depreciates monotonically for around 5 quarters and then appreciates somewhat so that the long-run depreciation is less than what occurs in the short run. In other words, there is an overshooting response but it takes five quarters for this to become apparent. This finding is in accord with Beaudry and Devereux (1995), and Eichenbaum and Evans (1995) for the US nominal exchange rate.

Figure 3 summarizes the responses of the model to a positive money demand shock. The interest rate rises and real output falls in the short run, consistent with the conventional wisdom. Their long-run responses are zero by the identifying restrictions. A positive money demand shock also leads to a nominal appreciation of the exchange rate, a fall in prices of roughly the same order of magnitude in the long run, and an increase in nominal money. In particular, the short-run increases in nominal money are quite substantial in order to accommodate the increase in money demand. After two quarters, the response of nominal money is not statistically significant from zero, as is the response of the nominal exchange rate at all horizons.

An assessment of the relative importance of the five shocks at various horizons can be gained by examining the proportion of the variance of the forecast error which is accounted for by each of the shocks. The top panel of Table 1 reports the fraction of the forecast error variance in the domestic interest rate attributable to each structural shock at horizons up to 32 quarters. By construction, all of

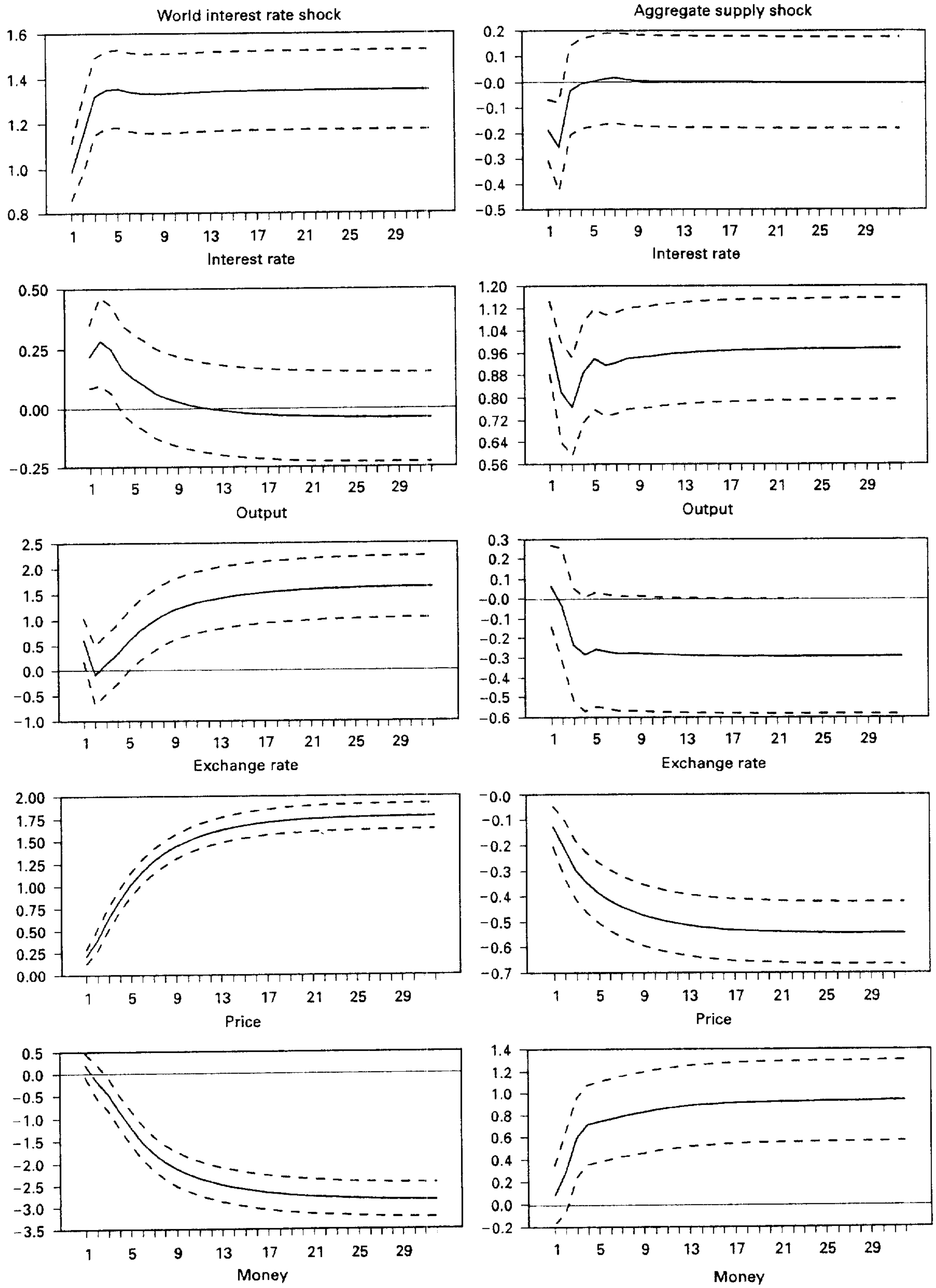

Fig. 1. *Responses of the series in levels (%)*

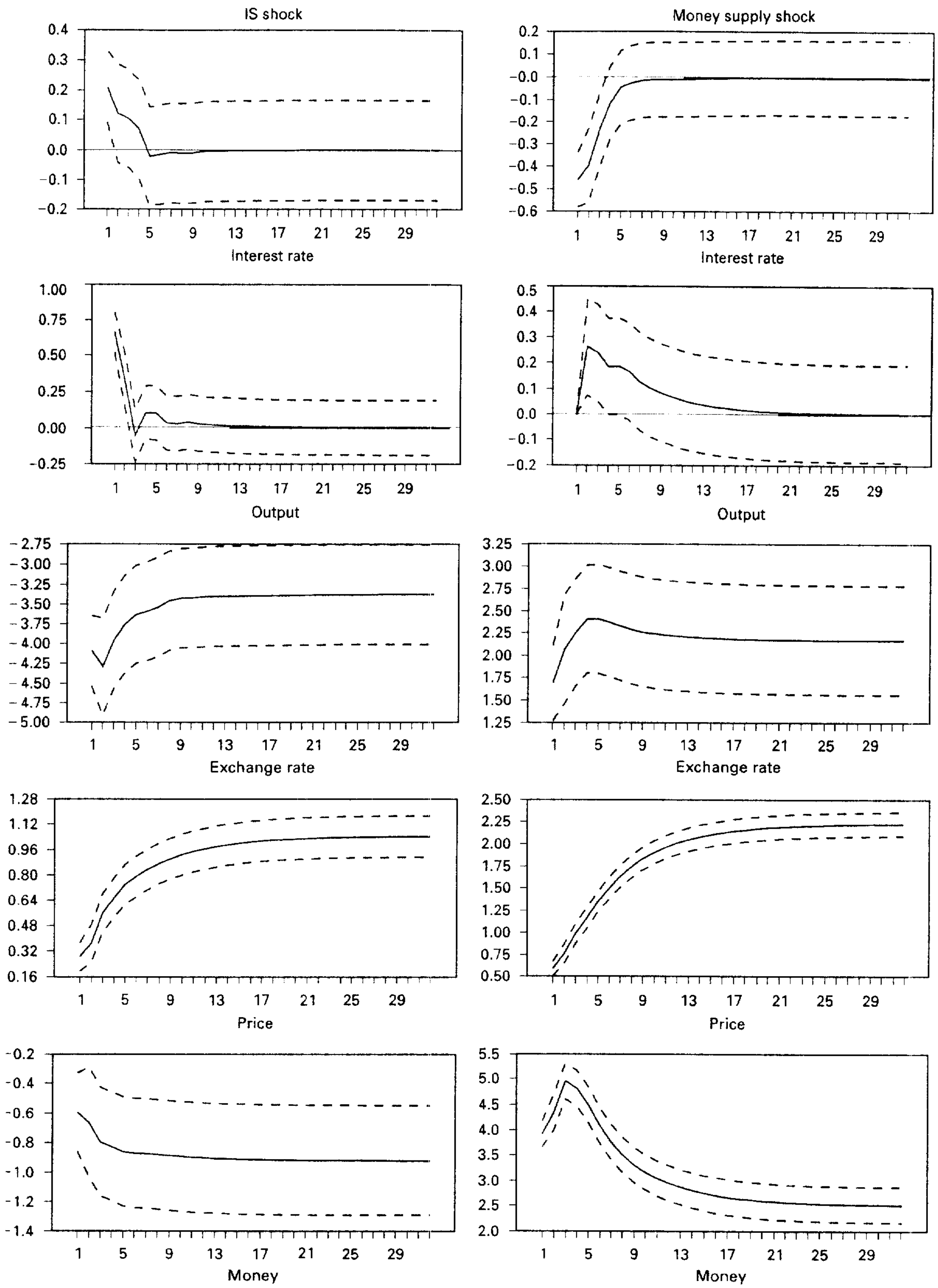

Fig. 2. *Responses of the series in levels (%)*

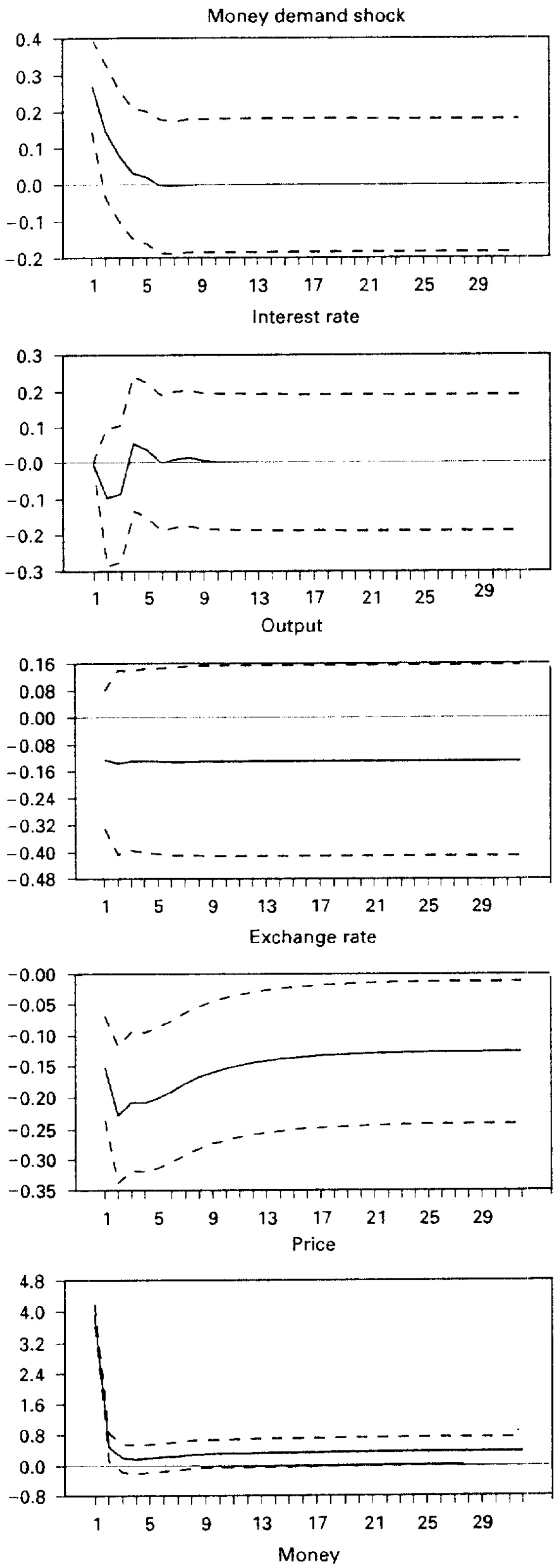

Fig. 3. *Responses of the series in levels (%)*

the forecast error variance in the domestic interest rate is explained entirely by the world interest rate shock in the long run. This world interest rate shock also explains most of the short-run forecast error variance in the domestic interest rate: the shock accounts for around 73 and 89% of the forecast error variance at horizons of one and four quarters, respectively. At the one quarter horizon, the money supply shock accounts for 16% of the forecast error variance in the nominal interest rate, but this effect diminishes rapidly and eventually becomes zero as a consequence of the identifying restrictions.

The second panel shows the relative contribution of each structural shock in explaining the forecast error variance of real output. The aggregate supply shock explains by far most of the variability in real output over all horizons. This shock accounts for around 68% of the forecast error variance of real output at short horizons and 96% at long horizons. At the one quarter horizon, the IS shock explains around 29% of the forecast error variance in real output, but explains little of the short-run variability in real output thereafter. Monetary shocks explain virtually none of the forecast error variance of real output at all horizons. It appears that aggregate demand shocks do not have a significant role in influencing real output even in the short run.

The third panel shows the relative importance of each shock in explaining the nominal exchange rate. The IS shock is most important and accounts for between 64 and 83% of the forecast error variance in the nominal exchange rate at all horizons. On the other hand, the money supply shock accounts for, at most, 26% of the forecast-error variance in the nominal exchange rate at all horizons. This finding is consistent with the equilibrium theory of exchange rate determination (Stockman, 1987, 1988) that emphasizes the importance of real shocks as opposed to monetary shocks. Fisher (1996) also finds that real shocks are the major determinant of movements in the Australian nominal exchange rate as does Lastrapes (1992) for several major industrial economies. In Table 1, the aggregate supply shock explains none of the forecast error variance of the nominal exchange rate while IS shocks explain at least 64%. Unlike Fisher and Lastrapes, we identify real shocks as either aggregate supply or IS shocks and evaluate their relative importance for fluctuations in the exchange rate.

The fourth panel shows the relative contribution of each shock in explaining the level of prices. The money supply shock explains most of the short-run forecast error variance in prices. In particular, this shock accounts for 68% of the forecast error variance in prices at the one quarter horizon. The contribution of this shock to the forecast-error variance steadily decreases, accounting for 52% at a horizon of 32 quarters. On the other hand, the contribution of the world interest rate shock to the forecast error variance of prices becomes more important as the forecast horizon increases.

Table 1. *Decomposition of forecast-error variance*[a]

Series	Number of quarters	Structural shocks v^{fr}	v^{as}	v^{is}	v^{ms}	v^{md}
	1	72.8 (5)	2.6 (2)	3.3 (2)	15.6 (4)	5.7 (3)
	4	89.1 (9)	1.5 (4)	1.1 (4)	6.6 (7)	1.7 (5)
r	8	94.8 (14)	0.7 (5)	0.6 (5)	3.2 (10)	0.6 (7)
	12	96.5 (18)	0.5 (7)	0.4 (6)	2.1 (13)	0.5 (9)
	20	98.0 (18)	0.3 (7)	0.2 (6)	1.2 (13)	0.3 (10)
	32	98.7 (19)	0.2 (7)	0.1 (6)	0.8 (13)	0.2 (10)
	1	3.2 (3)	68.0 (8)	28.8 (8)	0.0 (0)	0.0 (0)
	4	5.4 (6)	76.3 (15)	13.9 (13)	3.9 (3)	0.5 (3)
y	8	3.3 (7)	85.7 (17)	7.6 (16)	3.2 (4)	0.2 (5)
	12	2.2 (7)	90.1 (18)	5.1 (18)	2.3 (4)	0.3 (5)
	20	1.4 (7)	94.0 (20)	3.1 (18)	1.4 (4)	0.1 (5)
	32	0.9 (7)	96.2 (22)	1.9 (18)	0.9 (4)	0.1 (5)
	1	2.0 (2)	0.1 (2)	83.3 (4)	14.5 (4)	0.1 (4)
	4	0.7 (4)	0.2 (2)	77.2 (6)	21.8 (6)	0.1 (6)
e	8	2.4 (9)	0.3 (3)	71.8 (12)	25.4 (12)	0.1 (10)
	12	4.6 (9)	0.3 (6)	69.0 (16)	26.0 (12)	0.1 (10)
	20	7.7 (9)	0.4 (6)	65.9 (16)	25.9 (16)	0.1 (16)
	32	10.1 (9)	0.4 (6)	63.8 (20)	25.6 (16)	0.1 (16)
	1	8.7 (3)	3.0 (4)	15.7 (3)	68.1 (5)	4.5 (2)
	4	22.2 (9)	4.4 (12)	16.2 (10)	54.5 (15)	2.7 (6)
p	8	28.8 (11)	3.9 (14)	14.4 (12)	51.7 (18)	1.2 (7)
	12	30.8 (11)	3.6 (14)	13.3 (12)	51.6 (20)	0.7 (7)
	20	32.0 (11)	3.4 (15)	12.4 (13)	51.7 (20)	0.5 (7)
	32	32.7 (12)	3.3 (15)	12.0 (14)	51.8 (21)	0.2 (9)
	1	0.2 (5)	0.1 (6)	1.1 (8)	50.4 (8)	47.8 (10)
	4	1.0 (8)	1.0 (12)	2.1 (15)	81.6 (12)	14.3 (6)
m	8	6.4 (11)	1.9 (14)	2.8 (11)	80.0 (15)	8.9 (6)
	12	13.2 (11)	2.6 (15)	3.4 (16)	74.3 (12)	6.5 (8)
	20	23.5 (11)	3.4 (15)	4.0 (19)	64.4 (12)	4.7 (8)
	32	32.3 (12)	4.1 (15)	4.4 (19)	56.0 (18)	3.2 (9)

[a] The figure 0.1 denotes the contribution to the forecast error variance that is less than or equal to 0.1% but greater than zero. Figures in parentheses are one-standard errors computed using 300 bootstrap replications of the structural model.

At a horizon of 32 quarters, this shock accounts for 33% of the forecast error variance in prices.

Finally, the fifth panel reports the relative contribution of each shock in accounting for fluctuations in nominal money. The money supply shock explains at least 50% of the forecast error variance in nominal money at all horizons. However, as the forecast horizon increases, the world interest rate shock becomes more important. At a horizon of 32 quarters, this shock accounts for 32% of the forecast error variance in nominal money, whereas the money supply shock accounts for 56%. At the one quarter horizon, the money demand shock explains a large fraction of the forecast error variance of nominal money. Specifically, it accounts for 48% of the forecast error variance in nominal money, while the money supply shock accounts for 50%.

IV. SUMMARY AND CONCLUDING REMARKS

This paper has set out to evaluate the empirical relevance of the Mundell–Fleming small open-economy model with reference to Australia since the collapse of the Bretton Woods system of fixed exchange rates. Based on this model, the five structural shocks are identified as: a world interest rate shock, an aggregate supply shock, an IS shock, a money supply shock and a money demand shock. A VAR model is then estimated for the nominal interest rate, real output, the nominal exchange rate, prices and nominal money. The dynamic responses of these variables to the structural shocks are estimated and compared to the model predictions. Econometric identification of the underlying structural shocks was achieved by using long-run exclusion restrictions suggested by the long-run solution of the model, together with a contemporaneous restriction on the interactions between the variables.

Our results indicate that the Australian evidence matches closely the predictions of the Mundell–Fleming small open-economy model. A positive money supply shock leads to a temporary fall in the domestic interest rate, a temporary rise in real output, a permanent increase in the price level and a permanent depreciation of the nominal exchange rate. As to the responses of the nominal exchange rate to the other structural shocks, a positive shock to IS and money demand appreciates the rate, while a positive shock to the world interest rate depreciates it, consistent with the model predictions. The levels of the interest rate and prices fall in response to a positive aggregate supply shock, but rise in response to a positive IS shock.

The variance decomposition is also used to measure the relative importance of each shock to investigate sources of the observed economic fluctuations. The world interest rate shock accounts for most of the forecast error variance in the domestic interest rate at all horizons. The aggregate supply shock explains most of the variation in real output at all horizons. IS and money shocks explain little of the variation in real output even in the short run. For the nominal exchange rate, the IS shock accounts for most of the variability in the rate, while the money supply shock also contributes, but to a far lesser extent. The money supply shock explains at least 50% of the forecast error variance of prices and nominal money at all horizons. But the world interest rate shock also becomes important as the forecast horizon increases, and accounts for approximately one third of the fluctuations in prices and nominal money at long horizons.

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APPENDIX

This appendix presents a simple version of the Mundell–Fleming small open-economy model under flexible exchange rates. The model is specified by the following equations:

$$y_t = \phi_1(e_t - p_t) - \phi_2[r_t - E_t(\Delta p_{t+1})] + v_t^{is} \quad \text{(A1)}$$

$$m_t^d = p_t + \phi_3 y_t - \phi_4 r_t + \phi_5 e_t + v_t^{md} \quad \text{(A2)}$$

$$m_t = v_t^{ms} \quad \text{(A3)}$$

$$m_t^d = m_t \quad \text{(A4)}$$

$$\Delta p_t = \phi_6[y_t - (y^N + v_t^{as})] \quad \text{(A5)}$$

$$E_t[\Delta e_{t+1}] = r_t - (r^* + v_t^{fr}) \quad \text{(A6)}$$

where:

r^* = world nominal interest rate
y^N = natural level of output or full-employment level of output
Δ = difference operator
E = expectational operator.[5]

All parameters (ϕ_i) are assumed to be positive, except for ϕ_5, which will be explained below.

Equation A1 is an open-economy IS equation in which the demand for domestic output is positively associated with the real exchange rate $(e_t - p_t)$, and negatively with the real interest rate. The structural shock v_t^{is} is assumed to capture shocks to domestic absorption such as fiscal policy shocks and terms-of-trade shocks. The money demand and supply functions are given in Equations A2 and A3, respectively, and the solution to Equation A4 is the LM curve representing domestic money-market equilibrium. Equation A5 is a price adjustment equation where prices adjust whenever the demand for domestic output deviates from the natural or full-employment level of output. Equation A6 is the relation for uncovered interest rate parity.

Inclusion of the exchange rate in the money demand function (Equation A2) has been a feature of an increasing number of studies. Earlier writers like Mundell (1963) conjectured that '[t]he demand for money is likely to depend upon the exchange rate in addition to the interest rate and the level of income' [p. 484]. Arango and Nadiri (1981), McKinnon (1982), Cuddington (1983), Bahmani-Oskooee and Pourheydarian (1990), and McNown and Wallace (1992) are among the studies which include the exchange rate to determine money demand in open economies. Arango and Nadiri, and Bahmani-Oskooee and Pourheydarian further claim a portfolio-adjustment effect for the expected sign on the exchange rate in the money demand function. That is, depreciation of domestic currency leads to substitution of domestic assets for foreign assets (as it increases the prices of foreign assets valued in domestic currency and simultaneously reduces the prices of domestic assets), which results in an increased demand for domestic currency. They argue that this substitution effect is reinforced by the wealth effect and the supply-side effect that also lead to an increase in demand for domestic currency. (Also see McGibany and Nourzad, 1995 for a discussion.) In what follows, we assume that the parameter ϕ_5 is positive, in which the portfolio-adjustment effect operates as a main working mechanism.[6]

The economy is in long-run equilibrium when $y_t = (y^N + v_t^{as})$ and $r_t = (r^* + v_t^{fr})$. Consequently, $\Delta p_t = 0$ and $\Delta e_t = 0$ in long-run equilibrium. Using these, equilibrium in the product market and in the money market are, respectively, obtained as:

$$y^N + v_t^{as} = \phi_1(e_t - p_t) - \phi_2(r^* + v_t^{fr}) + v_t^{is} \quad \text{(A7)}$$

$$v_t^{ms} - p_t = \phi_3(y^N + v_t^{as}) - \phi_4(r^* + v_t^{fr}) - \phi_5 e_t + v_t^{md} \quad \text{(A8)}$$

For simplicity, assume that $y^N = r^* = 0$, from which v_t^{as} and v_t^{fr} represent the stochastic processes for the natural level of output and the world interest rate, respectively. The long-run solution of the model is obtained by combining Equations A3, A5, A6, A7, and A8, and shows the long-run effects of the structural shocks on the series as:

$$\begin{pmatrix} r_t \\ y_t \\ e_t \\ p_t \\ m_t \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ (\phi_2 + \phi_1\phi_4)/\zeta_1 & (1 - \phi_1\phi_3)/\zeta_1 & -1/\zeta_1 & \phi_1/\zeta_1 & -\phi_1/\zeta_1 \\ (\phi_1\phi_4 - \phi_2\phi_5)/\zeta_1 & -(\phi_1\phi_3 + \phi_5)/\zeta_1 & \phi_5/\zeta_1 & \phi_1/\zeta_1 & -\phi_1/\zeta_1 \\ 0 & 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} v_t^{fr} \\ v_t^{as} \\ v_t^{is} \\ v_t^{ms} \\ v_t^{md} \end{pmatrix} \quad \text{(A9)}$$

where $\zeta_1 = \phi_1(1 + \phi_5)$. The implications of Equation A9 are consistent with those found in the conventional Mundell–Fleming model (e.g. $\phi_5 = 0$). To save space, we do not

[5] The rest of the variables in the model were defined in the preceding text.
[6] On the other hand, McKinnon (1982) and McNown and Wallace (1992) emphasize the currency substitution effect such that a depreciation leads to a fall in domestic money demand as investors seek to obtain foreign currencies in anticipation of a further depreciation.

repeat them but refer readers to Obstfeld (1985), Mark (1990), Lane (1991), and Clarida and Gali (1994) for details.

As mentioned in the text, there are two noticeable exceptions to the implications of conventional Mundell–Fleming model, mainly due to the inclusion of the exchange rate in the money demand function. First, in response to a money supply shock, prices and the nominal exchange rate change by the same magnitude $[1/(1 + \phi_5)]$ in the long run but by less than a unit change of the shock. Subsequently, the money supply shock can have a long-run effect on real balances $(m_t - p_t)$ of $\phi_5/(1 + \phi_5)$. When $\phi_5 = 0$ as in the conventional model, prices, the nominal exchange rate and money all increase by one unit in response to a unit shock in the money supply, leaving real balances unaffected in the long run. Second, IS shocks have a long-run effect on the price level by $[\phi_5/\phi_1(1 + \phi_5)]$. In the conventional model, the IS shock has no long-run effect on the price level. Both implications appear to be supported by the empirical evidence presented in this paper.

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