TRANSMISSION OF EXTERNAL SHOCKS IN THE RBII MODEL

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ABSTRACT

The paper gives an overview of recent work in the development of the RBII macroeconomic model, focussing on adjustments designed to reflect the post-deregulation financial environment. Changes to the RBII model have been made in two main areas. First, a clearing market for short-term funds has been introduced, making interest rates much more responsive to open market operations. Secondly, a number of adjustments have been made so as to model debt accumulation (both domestic and external) in more detail. The properties of the revised model are illustrated in simulations of a variety of domestic and external shocks. These simulations also serve to illustrate the implications of alternative assumptions about the short term operating objectives of monetary policy.

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1. Introduction

This paper gives an overview of recent work in the development of the RBII macroeconomic model, focussing on adjustments designed to reflect the post-deregulation financial environment. The original version of the model, called RBA76, was presented by Jonson, Moses and Wymer (1976); that model and subsequent versions presented by Jonson and Trevor (1981), Jonson, McKibbin and Trevor (1981 and 1982) and Fahrer, Rankin and Taylor (1984), have been extensively used in simulation analysis. The latter version of the model was estimated using a data period ending at 1980; the structure of the model was thus designed specifically for the pre-deregulation environment.

In the period since deregulation of the financial sector and the floating of the Australian dollar, interest rates and exchange rates have become highly flexible in response to news concerning both domestic and external conditions. This transition to flexibility of financial prices poses a problem for the macroeconomic modeller. Equations estimated using data prior to the beginning of 1984 are unlikely to be reliable in predicting the behaviour of key financial variables in the post-float, post-deregulation period. At the same time, we do not yet have sufficient data to estimate the new structural relationships.

In a recent attempt to address these problems in the context of the RBII model, Fahrer and Rankin (1984) advocated the selective use of imposed parameter adjustments in the financial sector of the model in order to illustrate the possible impact of financial deregulation on the economy as a whole. Their adjustments included a market clearing mechanism for the exchange rate, a respecification of the bond rate equation, and a small number of parameter adjustments in the monetary sector. This approach assumes that parameters in the real sector of the model have been unaffected by financial developments, an assumption which seems reasonable at least as a first approximation. Less easily defended are the specific parameter adjustments which are imposed, and to which we will add in the present paper. All are more or less arbitrary in the sense that they are not econometrically estimated (for the reason already described), being based instead on "sensible guesses" about the parameters concerned. But we argue that if we wish to have a model which remains relevant for forecasting and policy analysis, such an approach is preferable to retaining financial sector equations which are known to be outdated.

In this paper the work of Fahrer and Rankin is extended by considering structural adjustments to the RBII model in two main areas. First, a much greater degree of interest rate flexibility is introduced through a clearing market for short-term funds, representing recent developments in the domestic cash market.[1] Secondly, the accumulation of public and external debt is endogenised, as are interest payments on both debts. Taken together, these changes have important implications for the way in which external shocks are transmitted to domestic variables in the model, as well as having implications for the long run effects of fiscal policy. The paper investigates these implications.

The remainder of the paper is set out as follows. Section 2 describes in detail the most important changes to the structure of the model. Section 3 investigates the simulation properties of the adjusted model, paying particular attention to the transmission of shocks arising from changes in external conditions. Some conclusions and issues for further work are set out in the final section.

2. Structural Adjustments

In order to limit the possibilities for arbitrary changes to the model, we have tried to adhere to the principle of making minimal structural adjustments to RBII consistent with attaining a small number of clearly defined objectives. These objectives were:

(a) greater interest rate flexibility, particularly in short-term rates;
(b) full endogeneity of debts and of debt service costs;
(c) dynamic stability.

An additional adjustment, discussed in Section 2.3, incorporates a measure of output adjusted for the terms of trade into the model. However, equations for the real sector, which presumably is least affected by deregulation, remain substantially unchanged from those given in Fahrer and Rankin (1984).[2] Some "tuning" of the new parameters was carried out using simulation analysis to check that the above objectives were satisfied, and that the economic responses for the model as a whole appeared sensible.

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1. For a discussion of developments in the cash market in the post-float period see Macfarlane (1986).

2. Hereafter, the "1984 version" of RBII.

This section describes in detail the most important differences between our model and the 1984 version. The full model specification is given in appendix 1.

2.1 Interest Rate Equations

Traditionally the RBII model has specified all interest rates as partial adjustment processes. This reflected the institutional fact that, for most of the 1970's, bank interest rates were subject to regulation, and interest rates on government securities were administratively determined. Consequently, interest rates in RBII were not regarded as market clearing prices in the short run. The 1984 version of the model respecified the bond rate equation to be consistent in the long run with quantity setting, rather than price setting, operations by the central bank; however a partial adjustment process on the bond rate was retained. Other interest rates in the model were determined by slow adjustment towards weighted averages of the bond rate and exogenous overseas rates. In simulation the structure generated quite slow interest rate responses to changes in policy variables and in external conditions.

It has become clear that this kind of structure is no longer an accurate representation of interest rate determination in Australia. At the short end of the market, interest rates are now highly flexible in clearing the market for short-term funds. In recognition of this, short-term interest rates are now determined in a clearing cash market.[3] The cash market is defined by two equations (numbered as in the model specification in appendix 1).

Central bank balance sheet indentity (supply of cash):

$$DC \equiv G - T + IPD - DB + DR \qquad (17)$$

3. A detailed account of the operation of the cash market in Australia is given in Reserve Bank (1985). For the purposes of the RBII model, the aggregate "cash" corresponds with banks' currency holdings, exchange settlement accounts, and deposits with authorised dealers. Since the latter are not modelled, their accounts are treated in RBII as though consolidated with the central bank.

where G = nominal government expenditure ($=P_g g_1 + Pg_2 + Pc$)

T = nominal tax revenue ($= T_1 + T_2$)

IPD = interest on public debt

B = stock of government securities held by the private sector

R = foreign exchange reserves

D = differential operator

Demand for cash:

$$\log C = c_o + \log M - \beta_{40} r_s \tag{20}$$

where r_s = short-term interest rate

M = money stock (M3)

The demand for cash is thus a function of a scale variable (the money stock) and the short-term interest rate. The short-term interest rate is thought of as representing either a 90 day bill rate, or an average cash (overnight) rate over a period of one quarter. Equations (17) and (20) are intended to capture some essential features of the deregulated money market. With a freely floating exchange rate, the variable defined by (17) is controllable, and can be used as an instrument to influence short-term interest rates. Rates respond flexibly to clear the cash market in each period.

The introduction of a clearing market for a very narrow cash aggregate is in some ways a departure from earlier formulations of the RBII model. Taken in conjunction with the floating exchange rate, as introduced in the 1984 version, we now have a small but highly important sector of the model which is always in (partial) equilibrium. This departure is a recognition of changed circumstances in both markets, and should not be viewed as inconsistent with the general disequilibrium underpinnings of the model as a whole. In particular, the cash market does not equilibrate the demand and supply of the conventional monetary aggregates, and the buffer stocks of money and inventories continue to play an essential role in the dynamics of the model. In specifying a small subset of clearing markets within a context of lagged adjustment in the economy as a whole, RBII is consistent with many conventional open economy models (for example Dornbusch (1976)), which typically assume continuous partial equilibrium in some financial markets, while allowing other markets to be temporarily out of equilibrium.

The cash market submodel determines the short-term interest rate. The long-term rate is determined by the equation

$$Dr_l = \gamma(r_s - r_l) \tag{18}$$

ie, as a long-run weighted average of short-term rates. In the long run, this equation is consistent with the expectations theory of the term structure, since it requires an elimination of divergences between the two rates in the steady state.[4] This consistency would carry over to the short run if expectations about future short rates were formed adaptively.

The above equations are sufficient to determine the partial equilibrium values for interest rates, given the market operations of the central bank. It remains for us to define a rule for determining those operations. In principle, any well defined rule would suffice to complete the monetary sector of the model. For the purposes of this paper, we define market operations as a linear function of five indicator variables: the inflation rate, the rate of GDP growth, the rate of money supply growth, the short interest rate, and the exchange rate. Policy regimes in which market operations are a function of the interest rate or the exchange rate alone, can be considered as special cases. This is not intended as an attempt to represent actual policy rules, but as an example of how a policy rule can be assumed to close the model.

2.2 Debt Accumulation and Debt Servicing

The RBII model contains two important debt variables: these are the stock of government bonds, and the stock of net external debt. Servicing costs on both debts have usually been treated as exogenous.[5] For short-run analysis this is probably a useful simplification, but the assumption becomes increasingly unrealistic for analysis over longer time horizons, particularly in periods when current account and budget balances are not close to zero.

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4. Empirical work on the term structure by Tease (1986) supports the expectations hypothesis in Australia in both the short run and the long run.

5. Public debt interest was endogenous in the 1976 model specified by Jonson, Moses and Wymer (1976) but this feature was dropped from later versions.

(a) External debt

In the case of external debt, two adjustments are necessary. First, the capital flow equilibrium condition and the balance of payments identity are rewritten in US dollar, rather than Australian dollar, units. Assuming for the purposes of the model that all external debt is denominated in foreign currencies,[6] this allows us to calculate the endogenous debt servicing term as a product of the quarterly interest rate and the net external debt in US dollars. Thus the term

$$1/4r_w(F(US\$)_{-1} + F(US\$)_{g-1} - R(US\$)_{-1})$$

is added to the current account, where

r_w = "World" interest rate (10 year US bond rate)
F = external private sector debt in \$A
F_g = external public sector debt in \$A
R = foreign exchange reserves, valued in \$A
(US\$) denotes valuation in US\$ by dividing the relevant variable by the exchange rate.

The second adjustment involves recognising the implications of exchange rate movements for the valuation of the stock of external debt. The capital flow equation (equation 14) is expressed as a partial adjustment towards the desired stock of debt in US\$, rather than \$A, units.

$$DlogF(US\$) = \alpha_{14}\ log(P.\hat{F}(US\$)/F(US\$)\ (=\alpha_{14}log(P\hat{f}/E.F(US\$))$$

$$log\hat{f} = f_o + logy + \beta_{46}(r_s - r_{eu}) - \beta_{47}\xi$$

$$\xi = log\ (\hat{E}/E) = (P/EP_w)$$

where
y = output
P = price level
E = exchange rate
P_w = World price index
r_{eu} = eurodollar interest rate.

6. In fact the ratio is about three quarters.

In this revised specification, behaviour is governed by adjustment towards the equilibrium value of net debt in real Australian dollars. Changes in the exchange rate will influence this behaviour both through the conventional expectations effect, captured by the term ξ, and through the revaluation of the existing stock of debt, which directly affects the ratio of desired to actual debt in Australian dollars.

(b) Public Debt

Endogenous public debt is included in the model using the formula

$$IPD = r^*B_{-1}$$

where IPD = nominal interest on public debt
B = nominal stock of bonds held by the private sector
r* = weighted average interest rate on bonds outstanding.

The average interest cost r* is not of course directly observable, and is approximated by a distributed lag of past values of r_t. A strictly accurate measurement of this cost would require a complicated disaggregation of the stock of bonds by issue date, in order to determine the exact weights on past interest rates; this refinement seems unlikely to yield important gains in accuracy and has not been attempted. (The simplification used here was suggested by Helliwell (1977)).

Recent literature on debt financing has highlighted an important source of potential instability in models with endogenous debt servicing costs [7]. With constant monetary and fiscal policies, a given stock of debt will automatically grow at a rate of r*, as the debt is rolled over in each period and new debt is added to cover interest payments. If the interest rate is higher than the economy's natural growth rate, the debt to GDP ratio in such a model will grow without bound. Typically this accumulation is very slow and can be safely ignored when considering questions of a purely short-run

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7. Buiter (1981) provides a comprehensive analysis of these issues.

nature. In general however the debt accumulation problem represents a powerful argument against the long-run exogeneity of monetary and fiscal policies. We would expect policy variables to react so as to ensure that the debt to GDP ratio is bounded, a result which may be achieved either by long run monetisation of debt, or by fiscal action to ensure that debt service costs are at least partly tax-financed.

In order to accommodate this argument, we postulate that one of the following reaction functions operates.

(i) $\quad D\log g_1 = -J\beta_{58}\, D\log(B/Py) \qquad \beta_{58} > 0$

(ii) $\quad Dt_{11} = J\beta_{59}\, D\log(B/Py) \qquad \beta_{59} > 0$

(iii) $\quad D\lambda_2 = J\beta_{60}\, D\log(B/Py) \qquad \beta_{60} > 0$

where g_1 = real government current spending
t_{11} = income tax rate
λ_2 = permanent growth rate of money stock[8]
J = dummy variable equal to zero for the first n periods, increasing smoothly to one thereafter.

The J variable incorporates an arbitrary assumption about the length of time that is allowed to elapse before the debt to GDP ratio influences policy settings in the model. These reaction functions provide us with a framework for addressing questions concerning the long-run implications of fiscal policy in a consistent way.

2.3 A measure of the value of output adjusted for the terms of trade

The Australian Statistician[9] has recently begun publishing a series on the real value of output adjusted for the terms of trade. In the terminology of

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8. λ_2 is normally regarded as a constant. In order to allow for endogenous inflation when this reaction function is used, λ_2 is made an endogenous variable. This has meant that the effects of changes in λ_2 on the constant terms in equations for endogenous nominal variables, and on the values of exogenous nominal variables, have had to be explicitly specified.

9. Quarterly Estimates of National Income and Expenditure, March Qurter, 1986 (ABS 5206.0)

RBII, we define this measure as

$$y_T = y + \frac{xP_x}{EP_i} - x$$

where y_T = real output adjusted for the terms of trade

y = real GDP

x = exports at constant prices

P_x = price of exports

P_i = price of imports

The variable y_T is intended to measure the purchasing power of national income, which will differ from the standard measure of constant price GDP when substantial variations in the terms of trade occur. In order to capture the effects of movements in the terms of trade on consumer demand and on investment, it is the adjusted variable that we use to measure output in the consumption and investment equations.

3. Simulation Properties

A full specification of the simulation model is presented in Appendix 1. As was discussed in the previous section, the simulation properties of the model depend on the policy reaction function which specifies the way in which open market operations influence the supply of cash. The level of these operations may depend on a variety of key variables. For the purpose of illustrating the properties of the model, two extreme cases are considered. In the first case, market operations are assumed to react so as to hold the money supply unchanged in response to shocks (referred to as the "money rule"); in the second case, it is the exchange rate which is held (the "exchange rate rule"). A third case, in which the reaction function is specified in terms of several indicator variables (the "multi-variable rule"), is also reported. The exact specification of the reaction functions is shown in Appendix 1.

The properties of the model are examined by analysing responses to three exogenous shocks:

- a permanent non-accommodated fiscal shock, equivalent to 1 per cent of initial GDP;

- a temporary 3 per cent increase in world interest rates, lasting for six quarters;
- a permanent 5 per cent decline in the terms of trade.

Simulations are reported for a period of 40 quarters over the forecast period. Results are reported in terms of deviation from baseline.

The above simulations are performed using the version of the model in which there are no policy reactions to the accumulation of government debt. Debt accumulation effects are considered separately in a fourth simulation which shows the effect of the fiscal shock when debt is fully endogenous and a long-run tax financing mechanism is in operation.

(a) A permanent non-accommodated fiscal expansion

Simulated responses to a non-accommodated fiscal shock are shown in figures 1-5. The case where the money stock forms the objective of open market operations is discussed first. Output increases, with the multiplier peaking initially at 5 quarters and dying out very slowly thereafter. Crowding out is caused by the rise in interest rates, and through direct supply-side effects on investment. The peak multiplier of about 0.7 is a little lower than in earlier versions of RBII, due to the rapid interest rate and exchange rate responses which are now present.

Short-term interest rates respond immediately to the fiscal shock, rising by about 1 per cent in the first year; long rates respond more slowly. Associated with the rise in short-term interest rates is an appreciation of the exchange rate caused by the influence of interest rates on the capital account; the exchange rate movement contributes to crowding out through its effect on net exports. The appreciation is short-lived, however, and gives way after the first year to a depreciation of the exchange rate as the current account moves into deficit, driven by aggregate demand. Over the medium term, there is a real depreciation, although this moderates towards the end of the period as output declines towards baseline and the current account improves. Consumer prices move with the exchange rate, falling initially due to the appreciation and rising thereafter. Longer simulations confirm that all variables eventually return to baseline.

A Permanent Non-Accommodated Fiscal Shock

FIGURE 1 OUTPUT

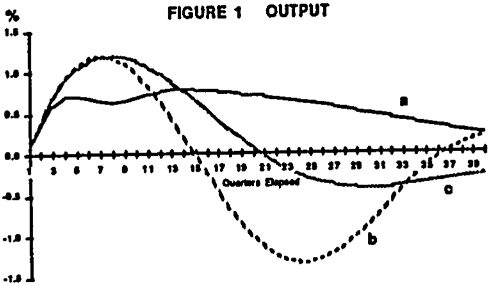


FIGURE 2 CONSUMPTION DEFLATOR

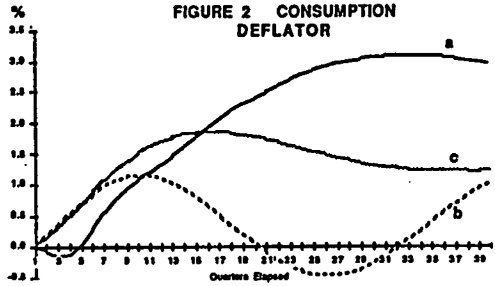


FIGURE 3 SHORT RATE

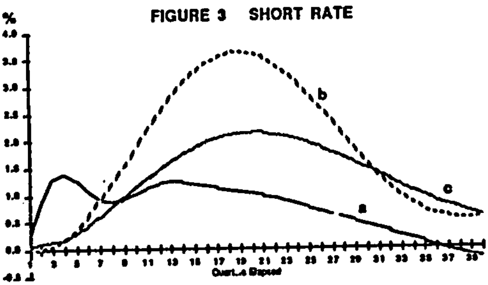


FIGURE 4 EXCHANGE RATE

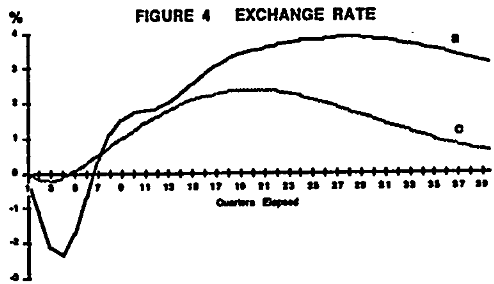
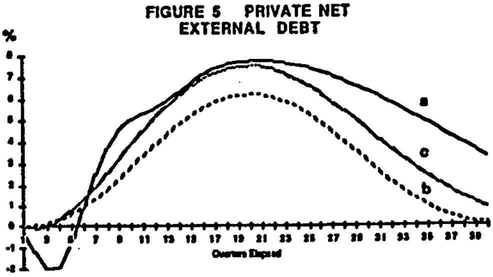


FIGURE 5 PRIVATE NET EXTERNAL DEBT



a. money rule;
b. exchange rate rule;
c. multivariable rule.

When the exchange rate rule is followed, the model produces much bigger swings in output. Looser monetary conditions prevail initially, so that interest rates increase only marginally and the exchange rate does not appreciate. This reduces the decline in investment over the first two years and increases the size of the fiscal multiplier under this regime to over one. After about two years, higher domestic demand begins to put downward pressure on the current account and on the exchange rate. To maintain the exchange rate, interest rates continue to increase, peaking after 18 quarters at roughly 3.5 per cent above baseline. This magnifies the crowding out effect and output falls below baseline after fifteen quarters. The contraction arising from these effects turns out to be larger in magnitude than the initial expansion.

As might be expected, the third case, in which market operations are specified as a function of several variables, produces an outcome somewhere between the two extremes. The policy rule is equivalent to a partial accommodation of the fiscal shock in the early stages, slowing the rise in interest rates and tending to increase the immediate expansionary effects on output and prices. After about three years, the tendency for the exchange rate to depreciate implies a tightening of monetary conditions and rising interest rates. By allowing some of the burden of adjustment to fall on the exchange rate, this policy rule moderates the swings in output that would occur under the exchange rate policy rule.

(b) A temporary rise in world interest rates

Responses to a temporary rise in world interest rates are graphed in figures 6-10. The rise in world interest rates has two immediate effects: it increases debt servicing costs, thereby adding to the current account deficit; and it induces a portfolio shift into foreign-denominated assets.

The domestic interest rate responses depend upon the policy rule which is being used. Interest rates rise least under the monetary rule, and most under the exchange rate rule. In the latter case, the rise in short-term domestic interest rates must be immediate, and must be greater than the rise in overseas rates in order to maintain portfolio balance with an unchanged exchange rate. The shock is therefore highly contractionary in the short to medium term, with both consumption and investment being crowded out due to higher interest rates. Under the monetary rule, on the other hand, there is a

A Temporary Shock to World Interest Rates

FIGURE 6 OUTPUT

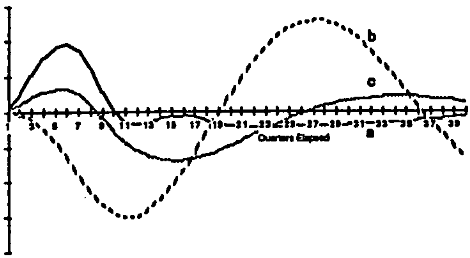


FIGURE 7 CONSUMPTION DEFLATOR

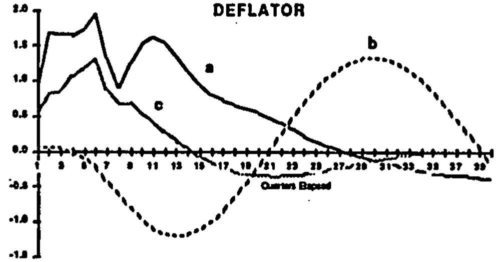


FIGURE 8 SHORT RATE

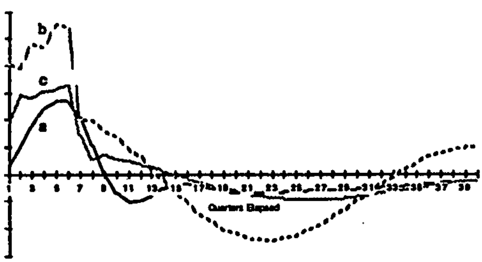


FIGURE 9 EXCHANGE RATE

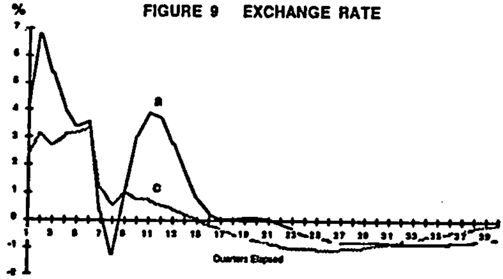
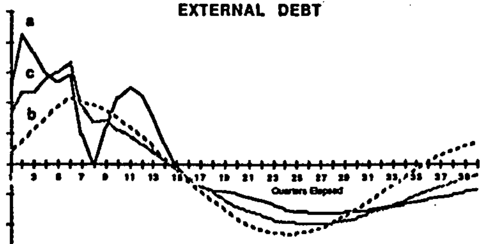


FIGURE 10 PRIVATE NET EXTERNAL DEBT



a. money rule;
b. exchange rate rule;
c. multivariable rule.

short-run expansion of output because the main burden of adjustment to the change in external conditions is placed on the exchange rate. The depreciation leads to a strong demand stimulus through net exports.

Results for all three policy rules show a sizeable build up of net external debt in the early stages. This is due to the effect of world interest rates on debt service costs. When the exchange rate is allowed to depreciate, there is a reinforcing valuation effect on the debt.

(c) A permanent decline in the terms of trade

Simulation results for a 5 per cent decline in the terms of trade are shown in figures 11-15. The effects of the shock are clearly contractionary for each of the cases we consider. There are three channels through which these effects operate. Most important is probably the net export channel. This is particularly powerful for the case when the exchange rate rule is in force, since the necessary relative price adjustments are slow to operate and a substantial initial fall in export volumes occurs. Under the monetary rule, on the other hand, the exchange rate depreciates quickly to around its new long run equilibrium, about 5 per cent lower than baseline. This tends to halt the decline in exports much more quickly.

The other main channels through which terms of trade effects operate are through consumption and investment. Both are reduced in response to the shock because disposable income and profitability are each measured in "terms of trade adjusted" units.

With the price level about 2 per cent higher, and the nominal exchange rate about 5 per cent lower, the results appear to indicate that a real depreciation of about 3 per cent is consistent with the new long run equilibrium in the model; this is suggested by the apparent convergence under the monetary rule to a real depreciation of around that magnitude. Under the exchange rate rule, substantial cyclical behaviour is still evident at the end of the ten year period; this policy rule tends to force adjustment onto quantities rather than prices, thus slowing the convergence to long run equilibrium.

A Permanent Decline in the Terms of Trade

FIGURE 11 OUTPUT

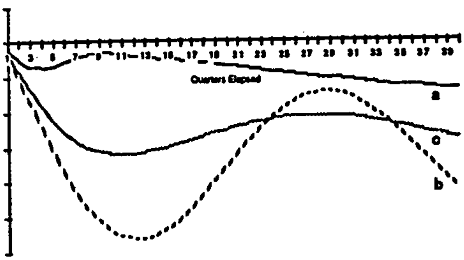


FIGURE 12 CONSUMPTION DEFLATOR

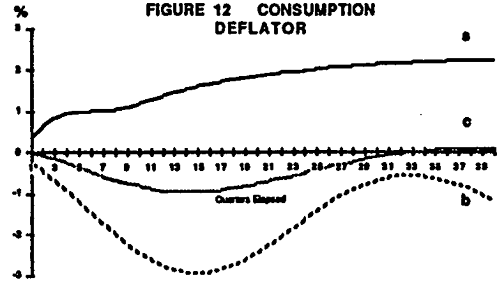


FIGURE 13 SHORT RATE

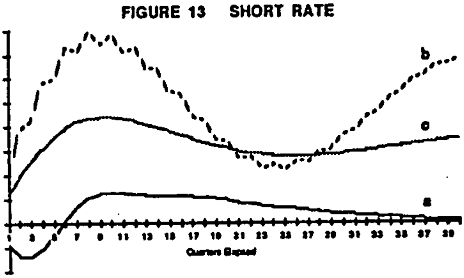


FIGURE 14 EXCHANGE RATE

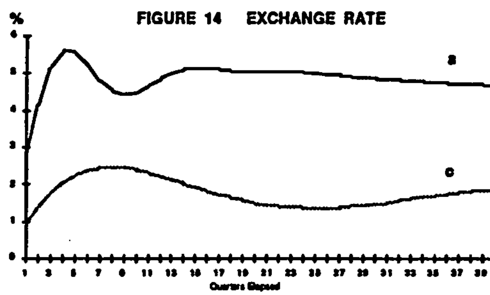
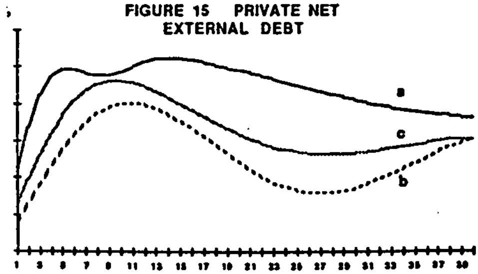


FIGURE 15 PRIVATE NET EXTERNAL DEBT



a. money rule;
b. exchange rate rule;
c. multivariable rule.

A Fiscal Shock with Endogenous Public Debt

Money rule

Multivariable rule

FIGURE 16 OUTPUT

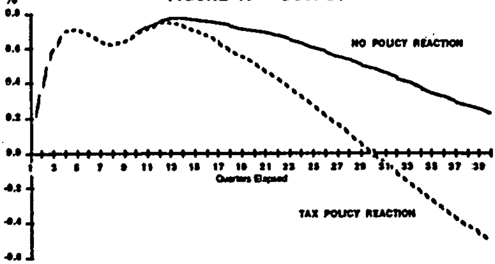


FIGURE 20 OUTPUT

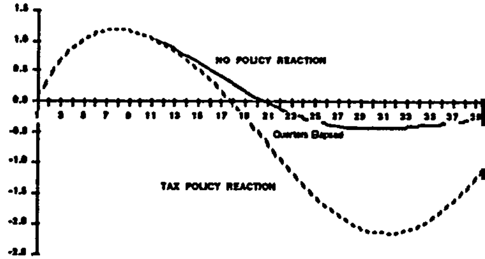


FIGURE 17 SHORT RATE

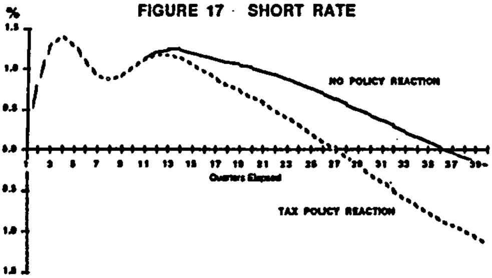


FIGURE 21 SHORT RATE

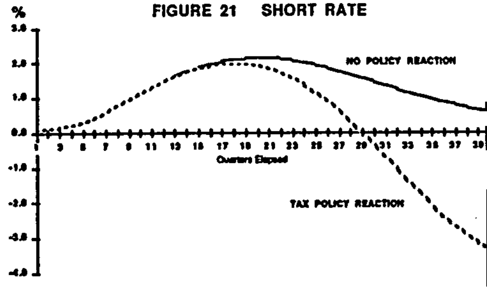


FIGURE 18 EXCHANGE RATE

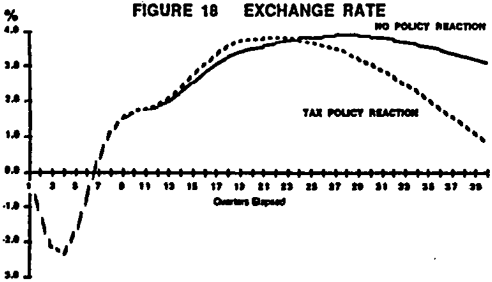


FIGURE 22 EXCHANGE RATE

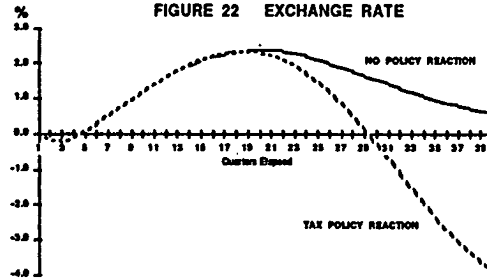


FIGURE 19 DEBT/GDP RATIO

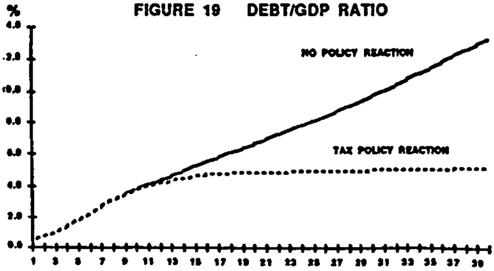
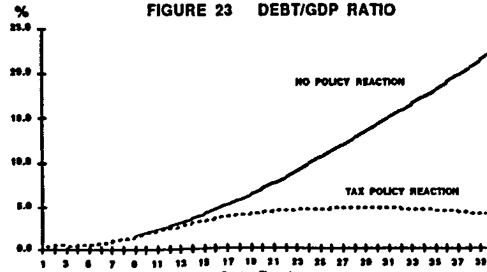


FIGURE 23 DEBT/GDP RATIO



(d) An endogenous policy response to government debt accumulation

In this section we reconsider the transmission of a fiscal shock when government debt is fully endogenous. As was pointed out in section 2, this implies the necessity of specifying an additional policy rule which effectively controls the growth of debt. Three alternative mechanisms of debt control were suggested; for the purposes of this section, we assume the endogenous tax rate mechanism operates. This means that the income tax rate is raised, with a lag, in response to a long run increase in the public debt to GDP ratio, thus allowing the ratio to be stabilised. We assume a two year lag in the policy response.

Simulations are conducted under two alternative assumptions about monetary policy: in figures 16-19, a monetary rule is assumed, and in figures 20-23 a multivariable rule for market operations is assumed. Each graph shows responses to the fiscal shock with and without the assumption of tax adjustments to control the growth of debt.

The results show fiscal expansion to be a much less attractive policy than it had appeared when debt accumulation effects were not taken into account. With no tax adjustment, the debt to GDP ratio rises by around 6 percentage points over the 10 year period in response to the shock, and follows a divergent trend. When endogenous tax adjustments are introduced, the average income tax rate rises by about two percentage points after three years, allowing the debt to GDP ratio to be stabilised about two percentage points above baseline. The increase in the tax rate is sustained throughout the simulation period. Under the assumption that the debt to GDP ratio is stabilised at an increased level, a permanent increase in the tax rate is needed to meet the higher debt service costs. This of course is purely illustrative, and assumes that the government sector makes no adjustments on the spending side and that no change in the steady state inflation rate occurs.

The increase in taxation has conventional contractionary effects, causing a downturn in output during the second half of the simulation period that is larger in absolute size than the initial expansion arising from the fiscal stimulus.

4. Conclusions

The paper has outlined a series of structural adjustments to the RBII model, designed to reflect recent developments in Australian financial markets and to improve the accuracy of RBII's treatment of debt. These changes represent a continuation of earlier model development work by Fahrer and Rankin (1984), by introducing continuous clearing into a second market (the cash market) in addition to the foreign exchange market. In keeping with the spirit of earlier versions of RBII, these clearing markets are embedded in a macroeconomic structure of general disequilibrium.

Our simulation results suggested a number of important properties of the revised model:

- the introduction of greater interest rate flexibility tends to reduce the size of the fiscal multiplier, due to increased effects of interest rate movements on consumption and investment;
- public sector debt is not stable in the model unless it is controlled by a policy rule which responds to the debt to GDP ratio;
- when debt responses are incorporated into the model, the fiscal multiplier is much reduced and becomes negative after about 5 years.

These results come from a simulation model in which many of the parameters are imposed rather than estimated. We argued that this was unavoidable given the nature of the process of structural change in Australia's financial sector. Nonetheless, uncertainty about the appropriate values for the new parameters is such that results should be treated with caution. As more data accumulates for the post-deregulation environment, we would expect to be able to learn more about the currently unknown parameters through further empirical work.

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RBII (1987) SIMULATION MODEL SPECIFICATION[1]

1. Household Expenditure

$$D\log(d) = \alpha_1 \log(\hat{d}/d) - \beta_1 \log(P\hat{m}/M)$$

$$\hat{d} = d_o y_d e^{-\beta_2[(r_\ell/4.0) - D\log P]}$$

$$y_d = y_T - T_1/P + c$$

$$y_T = y + x\left(\frac{P_x}{EP_i}\right) - x$$

$$P_d = P_{d_o}[EP_i(1+t_3)]^{\beta_3} P^{(1.0-\beta_3)}$$

$$\hat{m} = m_o \, y e^{-\beta_6 r_s}$$

2. Rate of Growth of Business Fixed Capital Stock

$$Dk = \alpha_2 (\hat{k} - k)$$

$$\hat{k} = \beta_7 \hat{k}_1 + (1-\beta_7)\hat{k}_2$$

$$\hat{k}_1 = \beta_8 (mpk - r_k) - \beta_9 (D\log P - (\lambda_2 - \lambda_1))$$

$$\hat{k}_2 = D\log K_{minv} - (\lambda_2 - \lambda_1)$$

$$mpk = \beta_{10} (y_T - g_1)/K$$

$$r_k = (r_\ell/4.0) - D\log P$$

3. Stock of Dwellings

$$D\log K_h = \alpha_3 \log(\hat{K}_h/K_h) + \beta_{11} \log(L/\phi_o N)$$

$$\hat{K}_h = K_{h_o} y_d e^{-\beta_{12} r_\ell}$$

---

1. A subscript of zero (o) indicates a constant. D is the differential operation d/dt, e is the exponential operator, and log is the logarithmic (to base e) operator. A variable with a hat (^) above it indicates the desired value of the variable. All parameter values are positive.

4. Exports of Goods and Services

$$D\log x = \alpha_4 \log(\hat{x}^d/x) - \beta_{13} \log(\hat{v}/v) + \beta_{14}\, QDS - \beta_{71} \log(W/P_x\, e^{\lambda_4 t})$$

$$\hat{x}^d = x_o^d\, x_w (EP_{wx}/P_x)^{\beta_{16}}$$

$$\hat{v} = v_o s_p^e$$

5. Imports of Goods and Services

$$D\log i = \alpha_5 \log(\hat{i}/i) + \beta_{17} \log(\hat{v}/v)$$

$$\hat{i} = [i_o[P/EP_i(1.0+t_3)]^{\beta_{18}} e^{\beta_{19} Q_i}](s^e - y_f)$$

6. Domestic Production

$$y = y_{nf} + y_f$$

$$D\log y_{nf} = \alpha_6 \log(\hat{y}_{nf}/y_{nf}) + \beta_{20} \log(\hat{v}/v)$$

$$\hat{y}_{nf} = [1.0 - (i/(s^e - y_f))]\, (s^e - y_f)$$

7. Price of Domestic Production

$$P = [(1.0 + t_6)P_{bt}]^{\beta_{21}} [P_x]^{(1-\beta_{21})}$$

$$D\log P_{bt} = \alpha_7 \log(\hat{P}_{bt}/P_{bt}) - \beta_{22} \log(\hat{Pm}/M) + \beta_{23} \log(\hat{v}/v)$$

$$\hat{P}_{bt} = P_{bt_o} [1.0/(1.0-\beta_{10})] WL(1.0+t_4)/\bar{y}$$

$$\bar{y} = y_o\, e^{\lambda_3 t}\, L^{(1.0-\beta_{10})}\, K^{\beta_{10}}$$

8. Price of Exports of Goods and Services

$$D\log P_x = \alpha_8 \log(\hat{P}_x/P_x) + \beta_{24} \log(\hat{v}/v)$$

$$\hat{P}_x = P_{x_o}(P^{\beta_{25}})(EP_{wx})^{(1.0-\beta_{25})}$$

9. Price of Government Current Expenditure

$$D\log P_g = \alpha_9 \log(\hat{P}_g/P_g)$$

$$\hat{P}_g = P$$

10. Average Weekly Earnings

$$D\log W = \alpha_{10} \log(\hat{W}/W) + \beta_{29} \log(L/\phi_o\hat{N}) - \beta_{32} \log(\hat{Pm}/M)$$

$$+ \beta_{30} \log(w_a/w_{a_o} e^{[\lambda_2-\lambda_1+\lambda_4]t}) + \beta_{31}(D\log w_a - [\lambda_2-\lambda_1+\lambda_4])$$

$$\hat{W} = W_o(1.0-\beta_{10})\, P_d\hat{Y}_{nf}/L$$

11. Rate of Growth of Labour Demand

$$D\ell = \alpha_{11}\,(\hat{\ell}-\ell)$$

$$\hat{\ell} = \beta_{34}\,(mp\ell - \beta_{35}w_r)$$

$$mp\ell = (1.0-\beta_{10})\,\hat{Y}_{nf}/L$$

$$w_r = W(1.0+t_4)/P_{bt}$$

12. Labour Supply

$$D\log N = \alpha_{12} \log(\hat{N}/N) + \beta_{36} \log(L/\phi_o N)$$

$$\hat{N} = N_o Z$$

13. Net Australian Private Capital Owned by Overseas Residents

$$D\log USF = \alpha_{14}\log(P.\hat{USF}/USF)$$

$$\hat{f} = f_o\, ye^{\beta_{46}(r_s - r_{eu})}\, e^{-\beta_{47}\xi}$$

$$\hat{USF} = \hat{f}/E$$

$$\xi = \log(\hat{E}/E)$$

$$\hat{E} = P/P_w$$

14. Bank Advances

$$D\log A = a_{15}\log(\hat{A}/A) + \beta_{50}\, D\log(Py) + \beta_{51} QA$$

$$\hat{A} = A_o(1.0-h)M$$

15. Personal Income Taxes

$$D\log T_{11} = \alpha_{16}\log(\hat{T}_{11}/T_{11}) + \beta_{53}\,(D\log\hat{T}_{11} - \lambda_2)$$

$$\hat{T}_{11} = T_{11_o}\, t_1 WL$$

$$t_1 = t_{11}(W/W_o e^{[\lambda_2 - \lambda_1 + \lambda_4]t})^{\beta_{54}}$$

16. Short Rate

$$\log C = c_o + \log M - \beta_{40} r_s$$

17. Long Rate

$$r_\ell = \beta_{55} r_{\ell-1} + (1-\beta_{55}) r_s$$

18. **$A/$US Exchange Rate (when solved for E)**

$$DUSR - \frac{P_x x}{E} + P_i i + \frac{1}{4} r_w (USF_{-1} + USF_{g-1} - USR_{-1}) - DUSF - DUSF_g - USOT = 0$$

$$USF = F/E$$

$$USOT = OT/E$$

19. **Foreign Reserves**

$$USR = R/E$$

$$USRT = USR$$

20. **Net Australian Government Capital Owned by Overseas Residents in US Dollars**

$$USF_g = F_g/E$$

21. **Money Identities and Policy Rules**

$$DC = (P_g g_1 + Pg_2 + Pc - T_1 - T_2 + IPD + DMISC1 + DMISC2) - DB + E\,(DUSR - DUSF_g)$$

$$DB = (P_g g_1 + Pg_2 + Pc - T_1 - T_2 + IPD + DMISC1 + DMISC2) + DA - DCr$$

$$DCr = DM - E(DUSR - DUSFg)$$

$$DM = DM_T - \beta_{60}(E-E_T) + \beta_{61}(r_s-r_{sT}) - \beta_{62}(DlogP-[\lambda_2-\lambda_1]) - \beta_{63}(Dlogy - \lambda_1)$$

$$T_1 = T_{11} + T_{12}$$

$$T_{12} = t_5 CTB$$

$$T_2 = T_{21} + T_{22}$$

$$T_{21} = t_2 Pd$$

$$T_{22} = T_{22_o} t_4 WL$$

22. Inventories

$$Dv = y + i - s$$

$$= y + i - d - DK - DK_h - x - g_1 - g_2 - g_3 - sd$$

23. Expected Sales

$$D\log s^e = \alpha_{22}\log(s/s^e)$$

$$s = d + x + DK + DK_h + g_1 + g_2 + g_3 + sd$$

24. Private Expected Sales

$$D\log s_p^e = \alpha_{23}\log(s_p/s_p^e)$$

$$s_p = s - g_1$$

25. Business Fixed Capital Stock

$$D\log K = k$$

26. Labour Demand

$$D\log L = \ell$$

27. Endogenous Interest Paid on Government Debt

$$IPD = (r_\ell^*/4)\ B_{-1} + MISC3$$

$$r_\ell^{*2} = \beta_{72} r_\ell + (1-\beta_{72}) r_{\ell-1}^*$$

---

2. r_ℓ^* is generated recursively with a starting value of r_ℓ.

Policy Reaction Functions[3]

28. Money Growth Rate Instrument

$D\lambda_2 = J$[4] $\beta_{56}\,\mathrm{Dlog}(B/PY)$

29. Government Expenditure Instrument

$$\mathrm{Dlog}\ g_1 = -J\ \beta_{58}\ \mathrm{Dlog}(B/PY)$$

30. Income Tax Rate Instrument

$$Dt_{11} = J\ \beta_{59}\ \mathrm{Dlog}(B/PY)$$

---

3. When public debt is endogenous, one of the reaction functions is included as a mechanism of debt control.

4. J is zero for the first 2 years of a simulation and then gradually increases to unity over the 4 years following that.

VARIABLES USED IN RBII[1]

A	bank advances to private sector
B	government bonds held by private non-bank groups
c^*	real cash benefits to persons
C	stock of same day funds held by banks
Cr	domestic credit
CTB*	effective company tax base
d	real household consumption expenditure
E	exchange rate ($A/$US)
F	net Australian private capital owned by overseas residents
F_g^*	net Australian government capital owned by overseas residents
F	net Australian private capital owned by overseas residents
g_1^*	real government current expenditure
g_2^*	real government capital expenditure
g_3^*	real public authorities capital expenditure
h^*	required liquidity ratio of the banking sector
i	real imports of goods and services
IPD*	interest payments on government debt
k	proportionate change in the real stock of business fixed capital
k_1	proportionate change in the real stock of non-mining business fixed capital
k_2	proportionate change in the stock of mining business fixed capital
K	real stock of business fixed capital
K_h	real stock of dwellings
K_{minv}^*	stock of mining capital
ℓ	proportionate change in employment
L	employment
m	real stock of money (M/P)
mpk	marginal product of capital
$mp\ell$	marginal product of labour
M	stock of money (M3)
M_T^*	target stock of money (M3)
MISC1*	miscellaneous item associated with money formation
MISC2*	miscellaneous money item in the Commonwealth budget deficit
MISC3*	miscellaneous item associated with interest payments on government debt
N	labour supply
P	price of domestic output
P_{bt}	price of domestic output net of indirect taxes
P_d	consumption deflator
P_g	price of government consumption expenditure
P_i	Australian import prices ($US)
P_w^*	world prices ($US)
P_{wx}^*	world price of Australian export goods ($US)
P_x	Australian price of exportable goods and services
QA*	synthetic variable for growth of bank advances, 1973
QDS*	synthetic variable for U.S. dock strike, 1969
Q_i^*	synthetic variable for growth of imports, 1974–1980
r_ℓ	long-term interest rate
r_s	short-term interest rate
r_{eu}^*	interest rate on 90-day Eurodollar bills
r_k	real marginal cost of capital
r_w^*	interest rate on 10-year US government bonds
R^*	gold and foreign exchange reserves
s	sales
s^e	expected sales
s_p^e	private expected sales
sd*	real statistical discrepancy
t^*	time trend starting in 1959(3)
t_{11}^*	index of income tax rate schedule
t_2^*	average rate of tax on consumption
t_3^*	average rate of tariffs
t_4^*	average rate of payroll tax
t_5^*	statutory company tax rate
t_6^*	average rate of tax on expenditure
T_1	receipts of direct taxes
T_{11}	receipts of personal income tax
T_{12}	receipts of company tax
T_2	receipts of indirect taxes
T_{21}	receipts of sales tax
T_{22}	receipts of payroll tax
v	real stock of inventories of goods
w_a^*	index of real award wages
w_r	real marginal cost of labour

1. An asterisk (*) next to a variable indicates that it is exogenous.

W index of average earnings

x real exports of goods and services

x^d real demand for exports of goods and services

x^s real supply of exports of goods and services

$x_w{}^*$ real world exports of goods and services

y real domestic output (net of depreciation)

$\bar{y}$ real normal domestic output (net of depreciation)

y_d real disposable income

$y_f{}^*$ real farm output (net of depreciation)

y_{nf} real non-farm output (net of depreciation)

y_T terms of trade adjusted real domestic output (net of depreciation)

Z^* population of working age

ξ expected rate of depreciation

TABLE A1: PARAMETER VALUES

Parameter	Value	Parameter	Value
α_1	0.112	β_{24}	0.019
α_2	0.688	β_{25}	0.231
α_3	0.024	β_{29}	0.200
α_4	0.834	β_{30}	0.048
α_5	0.100	β_{31}	0.381
α_6	0.700	β_{32}	0.044
α_7	0.413	β_{34}	0.081
α_8	0.538	β_{35}	2.406
α_9	1.435	β_{36}	0.139
α_{10}	0.232		
α_{11}	2.169	β_{40}	0.750
α_{12}	0.130	β_{46}	2.000
α_{14}	1.000	β_{47}	2.000
α_{15}	0.206	β_{50}	0.500
α_{16}	0.415	β_{51}	0.029
β_1	0.029	β_{53}	0.558
β_2	0.300	β_{54}	1.000
β_3	0.200	β_{55}	0.900
β_6	0.500	β_{59}	10.000
β_7	0.934		
β_8	0.489	β_{71}	0.700
β_9	0.391	β_{72}	0.100
β_{10}	0.400		
β_{11}	0.009		
β_{12}	1.019		
β_{13}	0.030		
β_{14}	0.061		
β_{16}	0.500		
β_{17}	0.100		
β_{18}	1.065		
β_{19}	0.015		
β_{20}	0.188		
β_{21}	0.928		
β_{22}	0.079		
β_{23}	0.180		

STEADY STATE GROWTH RATES

Variable	Notation	Growth Rate
$d, K, K_h, x, i, y, v, g_1^*, g_2^*, g_3^*, c^*,$ $s^e, s_p^e, sd^*, y_f^*, x_w^*, Y_T$	λ_1	(.012)
$P, P_x, P_g, P_i^*, P_w^*, P_{wx}^*$	$\lambda_2 - \lambda_1$	(.009)
W, w_a^*	$\lambda_2 - \lambda_1 + \lambda_4$	(.0165)
N, L, Z^*	$\lambda_1 - \lambda_4$	(.0045)
Trend rate of technical progress	λ_3	(.0045)
Trend rate of growth of labour productivity	$\lambda_4 = \lambda_3/(1-\beta_{10})$	(.0075)
$B, F, A, T_{11}, R, C, M, Cr, CTB^*, F_g^*,$ IPD, MISC1, MISC2, MISC3, $M_T^*,$ K_{minv}^*	λ_2	(.021)
$E, E_T^*, r_\ell, r_s, r_{s_T}^*, r_w^*, r_{eu}^*, k, \ell,$ $h^*, t_{11}^*, t_2^*, t_3^*, t_4^*, t_5^*, t_6^*$	-	(0.0)

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