

**Monetary Policy in the Treasury Macroeconomic (TRYM)
Model of the Australian Economy
Uncertainty, Expectations and Policy Credibility**

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The views expressed are those of the authors and should not be taken as implying similar views on the part of the
Department of the Treasury or the Commonwealth Government.

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The TRYM Model

The TRYM model is a small macroeconomic model developed by the Australian Treasury for policy and sensitivity analysis and to produce projections which are one input into the Department's forecasting process. The model has a core of key macroeconomic relationships that are estimated using quarterly time series data. The estimated equations are linked together by a larger number of accounting identities. The model could be described as broadly new Keynesian in its dynamic structure but with an equilibrating long run. Activity is demand determined in the short run but supply determined in the long run. There are 25 estimated equations, 3 financial market identities, 2 default response functions for monetary and fiscal policy and about 20 behavioural identities with 60 accounting identities linking these key behavioural relationships. In constructing TRYM, effort has been directed towards ensuring consistency between and within sectors, with 16 of the model's 25 behavioural equations being jointly estimated with other equations. Care has also been taken to identify separate demand and supply curves where possible. Most equations are estimated with either error correction or partial adjustment specifications with an identifiable long run. This allows the construction of a steady-state representation of the model's equations. The steady-state version of the model is simulated to provide model consistent future values for forward looking variables such as the exchange rate. Details of the model are contained in Commonwealth Treasury (1996a) "Documentation of the TRYM Model" and (1996b) "The Macroeconomics of the TRYM Model".

1. INTRODUCTION

This paper provides an outline of how monetary policy affects activity and inflation in Australia in the TRYM model. In particular it outlines the linkages between monetary policy changes and effects on activity and inflation. It discusses uncertainty around those linkages and how this might affect policy formation. Finally it discusses the role of expectations and credibility in the financial and labour markets in the model's estimates of monetary policy effects.

Section 2 discusses the response of financial market variables to changes in monetary policy and the linkage between these variables and the effects on activity and inflation. In particular it focuses on the default interest rate reaction function and its linkage to the long term bond rate and the exchange rate. The default interest rate reaction function is of course only one of a range of interest rate reactions that could be imposed on the model, and this point is demonstrated by comparing results from the default reaction to those that would be obtained using Taylor's rule. Given the interest rate reaction outlined in *Section 2.2*, *Section 2.3* provides a brief overview of the overall effect on the monetary policy contraction on the model, and then proceeds to examine the linkages to investment, consumption, activity and inflation in some detail.

Section 3 discusses the uncertainty that surrounds some of the responses to changes in monetary policy both in the short to medium term and in the long term. In the long term, the model displays both money neutrality and money super neutrality - monetary policy affects demand in the short to medium term but has no effect in the long term. However, these results depend on the assumptions of an exogenous NAIRU, an exogenous rate of productivity growth and an exogenous risk premium. In the short to medium term the impacts on activity depend on the extent to which interest rates impact on private demand, and the extent to which the changes in the exchange rate associated with the tightening impact on net exports. The uncertainty around monetary policy outcomes on both inflation and activity is argued to depend largely on the extent to which the exchange rate (and hence import prices and net exports) responds to the interest rate change, and the extent to which wages respond to changes in unemployment.

Section 4 discusses the role of expectations in the financial, labour and product markets in generating monetary policy effects. TRYM assumes that inflation expectations are adaptive in the product and labour markets and quasi rational in the financial market. The adaptive expectations in the labour and product markets are the key to the short to medium-run effects generated by monetary policy shocks. If expectations in these markets were forward looking and responded to credible changes in monetary policy than the short to medium run output costs associated with any inflation target would be much smaller. In contrast making expectations in financial markets adaptive has much less impact on the real effects on activity and unemployment of a monetary policy change.

2. MONETARY POLICY LINKAGES

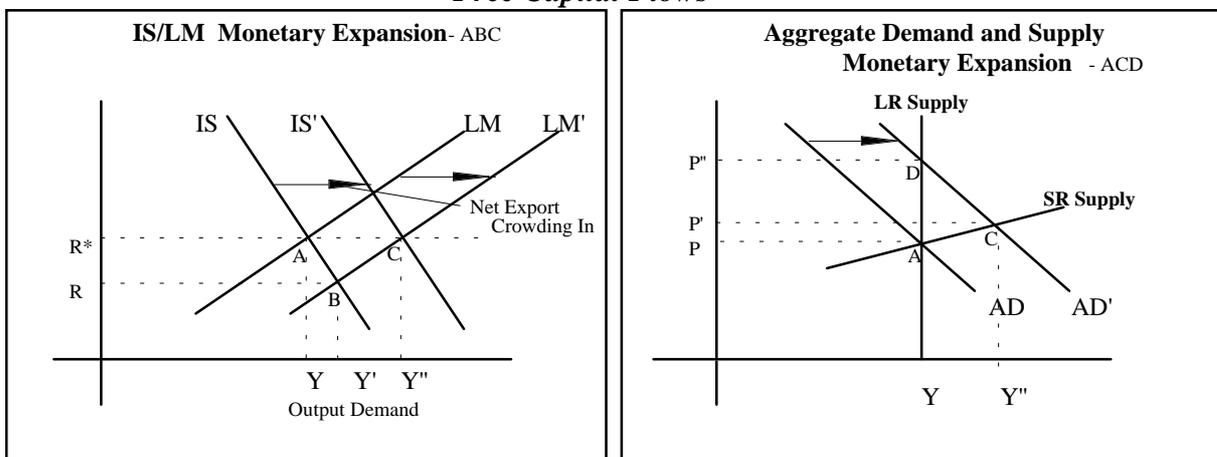
2.1 Introduction

The effects of monetary policy in TRYM have many similarities to the standard dynamic Mundell-Fleming and Dornbusch style theoretical models. Powell and Murphy (1996) provide a very thorough and detailed examination of the similarity of the Murphy Model dynamic responses to results from simple Dornbusch models, Mundell Fleming models, and the steady state properties of the model to those of a neoclassical growth model. Many of the same points could be made in relation to TRYM, and simple theoretical models are clearly the key to understanding the much more complicated full model results.

Perhaps the key difference between the model's results and those that can be derived from these simpler models is the existence within the model of fully articulated stock/flow accounting. This means that changes in flows lead to changes in stocks and any flow equilibrium has a corresponding stock or asset market equilibrium. Introducing stock or asset market effects often alters equilibrium outcomes sometimes in counter intuitive ways. It also has a marked effect on short to medium term results by introducing stock adjustment cycles into the demand dynamics.

The standard comparative-static Mundell Fleming results from a monetary policy change in a small open economy with a floating exchange rate and free capital flows are shown in Figure 1. The intuition behind the results of TRYM policy simulations is essentially the same as that underlying the effects of policy changes shown. The initial equilibrium points in Figure 1 correspond with the TRYM baseline where the economy is on a steady-state balanced growth path and both stocks and flows are in equilibrium. The short run aggregate supply curve is deliberately drawn relatively flat as wages and prices take some time to react to excess demand pressures in the model. There is very little effect on prices in the first one or two quarters. As a result, output is largely demand determined in the short term. In the long run, underlying supply growth in the model is equal to adult population growth plus trend growth in labour productivity. If there are no changes in exogenous variables, such as world commodity prices or world interest rates or domestic agricultural conditions, and domestic policy settings are stable then the model will eventually settle on the steady state growth path.

Figure 1: Monetary Expansion in a Small Open Economy with a Floating Exchange Rate and Free Capital Flows



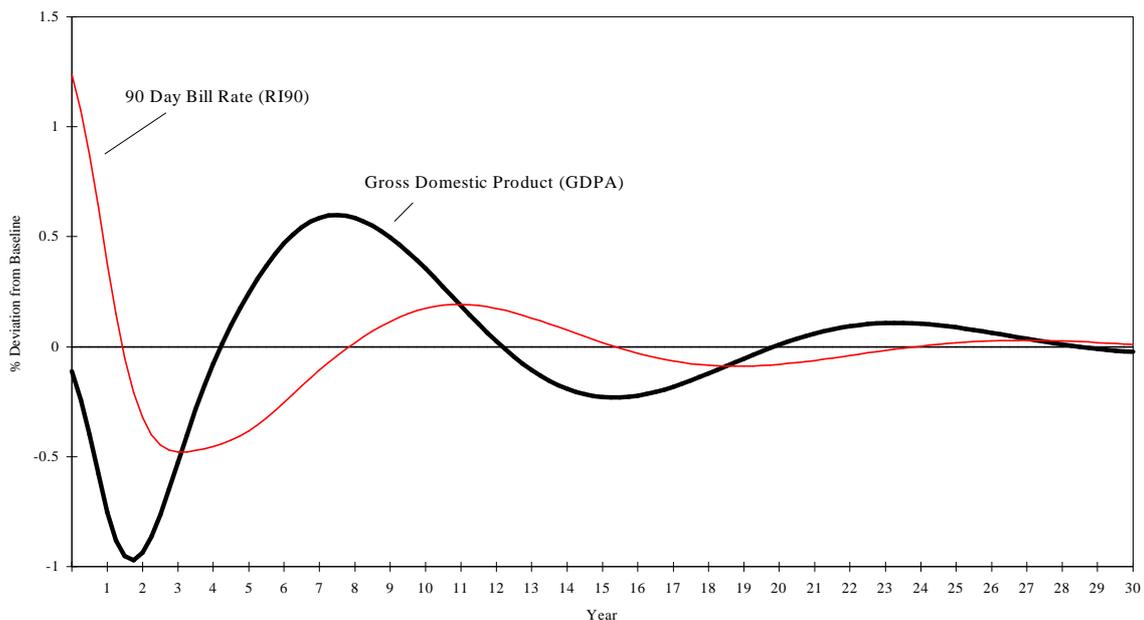
Monetary Expansion - The initial monetary expansion (injection of liquidity) shifts the LM curve (representing money market equilibrium) to the right, leading to lower interest rates. Lower interest rates stimulate investment and demand and

lead to a lower exchange rate, an improvement in the trade balance and a positive contribution from net exports. As a result of the effects on net exports the IS curve moves to the right augmenting the initial shift in the LM curve. Aggregate demand moves to the right. As the starting point A is on the long run (LR) supply curve (where unemployment equals the NAIRU), the increase in activity reduces unemployment below the NAIRU. The increase in demand leads to wage pressures in the labour market and price pressures in the product market as demand outstrips supply. With wage pressures in the labour market plus increasing margins in the goods market, general price levels rise. Unless there is a further injection of liquidity, the real money supply falls to the point where the expansionary monetary effects are unwound. If wealth effects or government net bonds are zero the classical dichotomy (money neutrality) holds in the long run.

The standard balance of payments equilibrium (BP) curve is assumed to be horizontal in the above, reflecting the assumption of perfectly mobile international capital flows (covered interest parity).

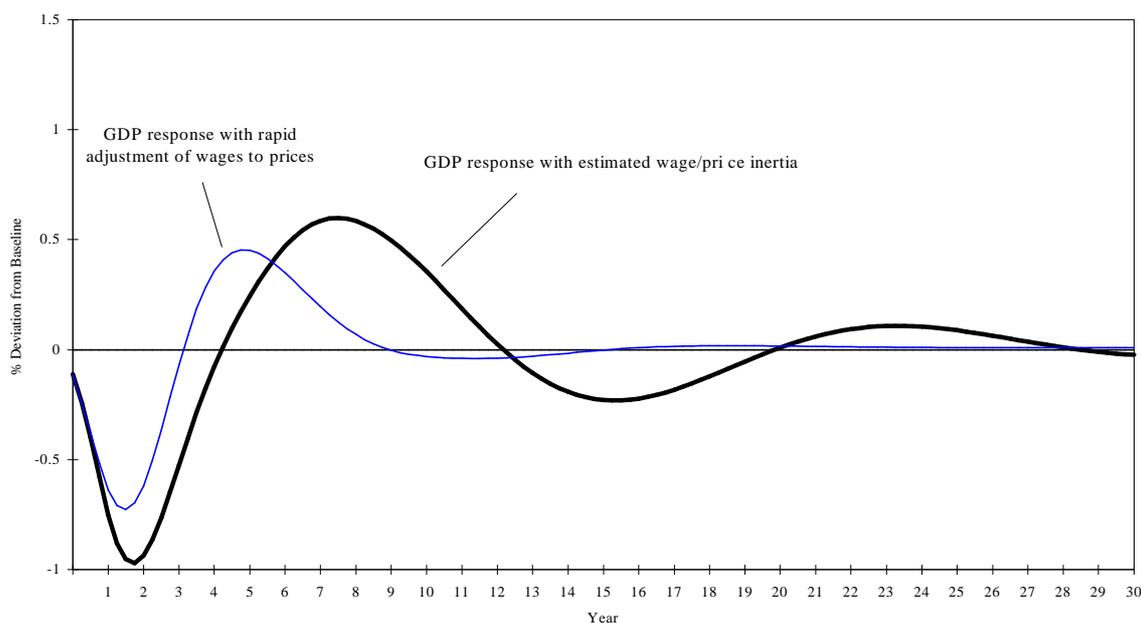
As mentioned above one of the key differences between the results that are derived from simple comparative static analysis like that in Figure 1 and those from TRYM is the necessity of reaching equilibrium in asset markets in TRYM. The initial downward phase following the tightening reduces the capital stock below its equilibrium level. This generates a shortage of capacity as GDP growth picks up following the downturn leading to an acceleration in investment and an upward phase in the cycle where the capital stock is restored to its equilibrium. These dynamic cyclical effects are very important for policy analysis because they mean that the short-term effects of policy and the short term trade offs are not the end of the story. It may be possible to generate highly desirable outcomes in the short term but at the cost of storing up problems for the future.

Figure 2: Dynamic Effects of a Monetary Policy Tightening



Stock adjustment cycles are of course not the only influence on the cyclical dynamics following a monetary shock. The stock adjustment dynamics are augmented by various adjustment lags in the product and labour markets and by the default fiscal reaction (which was agreed to be left 'on' for the purpose of the current conference's model comparisons). Of the adjustment processes that augment the cyclical effects perhaps one of key areas is wage and price adjustment. The degree of wage/price inertia coming from the wage and price equations has a large effect both on the amplitude and the frequency of the cycles being generated by the model. This can be seen by speeding up the wage response to price changes in the wage equation and re simulating the monetary tightening. The results are shown in Figure 3 below. It indicates that with a more rapid wage response (less money illusion) the stock adjustment cycles are smaller and less protracted.

Figure 3: Dynamic Effects of a Monetary Policy Tightening with Different Degrees of Wage Price Inertia



2.2 Financial Responses to a Monetary Policy Shock

The financial market in TRYM is represented by a money demand equation, a money supply rule, a bond yield equation and an exchange rate equation. The money demand equation is inverted (so that the short term interest rate is a function of money demand) and combined with the money supply rule to form an interest rate reaction function. A detailed outline on the financial market specifications is contained in Appendix A.

2.2.1 90 Day Bill Rates - Default Monetary Policy Response

TRYM uses the interaction of the demand and supply of monetary transaction balances to determine short term interest rates (RI90). Increasing expenditure is assumed to lead to an increase in money (transactions) demand. Thus, an increase in GNE in real terms or an increase in the price of GNE (domestic prices) is assumed to increase money demand. Money (transactions) supply is composed of three elements: currency in the hands of the non-bank private sector; non-interest bearing current deposits of all banks; and a fixed proportion of interest bearing current accounts of all banks. Nominal money supply is assumed to grow at a constant rate in simulations. This is equal to equilibrium supply side growth (productivity and population growth) plus an exogenous inflation target. The default monetary policy setting, therefore, reflects non-accommodating monetary policy. In terms of Figure 1 the LM curve is unchanged. In the face of a demand shock, the monetary authorities maintain the specified rate of growth in the money supply, allowing short term interest rates to adjust. As noted, the money demand equation is inverted and combined with the money supply rule to form the interest rate reaction.

There are a large number of problems in modelling money demand, given: (a) institutional changes in the financial market in history; (b) measurement difficulties in estimating both the money supply measure and an appropriately weighted measure of transactions demand, and (c) estimation problems due to the possible presence of simultaneity bias among other things. The interest rate response is, very difficult to tie down precisely and should be interpreted with caution.

However, the precise size of the interest rate response, so long as it is broadly sensible, may not be that important in model forecasting or policy analysis applications. (Similar arguments apply to the default fiscal policy reaction function mentioned below.) For example, in both forecasting and policy analysis applications the interest rate reaction function is normally turned off. In using the model for policy analysis the constant money growth rule is replaced by a control algorithm which sets interest rates¹ to maximise a desired objective function (eg desired levels for unemployment, inflation and the current account deficit). As a result, the money supply is effectively endogenised. In these circumstances the money supply could be removed from the model without any significant effect on the model's results. Similarly, in using the model to produce short-term projections an interest rate profile is normally targeted and the money supply effectively endogenised (reflecting the way monetary policy is set in practice in Australia). Therefore we do not tend to regard the slope of the money demand function as a key model parameter. Rather it is the reaction of the other variables in the model to interest rate changes that is of real interest to us.

The reaction function should not be interpreted as a Treasury view of how monetary policy actually works. Ultimately, it is no more than a simple, transparent and stable way of allowing interest rates to respond to changes in the economy. It represents a simple mechanism that enables short term interest rates to reflect developments in the demand and supply of funds (savings and investment), possible changes in monetary policy, inflation and real activity. As with the default fiscal policy mechanism, the default interest rate reaction can be modified according to the purpose of the model application.

2.2.2 Similarity of Default Interest Rate Reaction to Taylor's Rule

There are a obviously a number of different ways that an interest rate reaction function could be specified in a model like TRYM ranging from the Bundesbank style monetary targetting (where growth in the money supply is an intermediate target and acts as a anchor for expectations) to the adoption of simple rules such as those proposed by Taylor (1993) and (1996). The current form could possibly be thought of as corresponding to the Bundesbank money rule approach given that it depends on a set growth rate for the money supply (unchanged LM curve). However it is interesting to note that there is not necessarily a great difference between this specification and ones which completely omit the money supply as in the current Murphy model specification or as in Taylor's rule. This follows from the fact that in model simulations (as opposed to history) there is a fixed relationship between nominal expenditure and money demand (and hence a fixed relationship between the money supply and the equilibrium price level). Hence, within the context of a model simulation, price level targetting would imply monetary targetting and vice versa. Moreover, an inflation target that is achieved on average over the course of the cycle implies an average rate of increase in prices and hence an equilibrium price level.² Thus setting a fixed money supply growth rate as in the present reaction function is not necessarily greatly different to setting an average inflation target for interest rates where the money supply is either treated as endogenous (as in present monetary policy arrangements) or ignored entirely (as in MM2's specification).

The clearest demonstration of this is to substitute Taylor's rule for the present reaction function and observe what happens. The standard form of Taylor's Rule is as follows:

¹ The present algorithm does this by adjusting the money supply to obtain a desired interest rate profile see Louis (1995).

² The only practical difference in the context of a model simulation is that the price level target yields a greater penalty on persistent cyclical variations in inflation. A given deviation on the inflation rate maintained over a number of quarters will lead to a much larger deviation of prices from their equilibrium level.

$$R = \pi + \alpha (Y - Y^*) + \beta (\pi - \pi^*) + v$$

Or in real interest rate terms:

$$(R - \pi) = \alpha (Y - Y^*) + \beta (\pi - \pi^*) + v$$

Where:

R = nominal short term interest rate

$Y - Y^*$ = the output gap or the difference between actual and target output levels.

$\pi - \pi^*$ = the difference between the actual and target inflation rates

α, β = imposed parameters in the reaction function - Taylor suggests values of 0.5 for both

v = equilibrium real interest rate

The effect of replacing the default monetary policy reaction function with Taylor's rule is shown in Figures 2 and 3 below. Figure 2 shows the interest rate reactions under the alternative specifications to a temporary demand shock while Figure 3 shows the reaction to a supply-side productivity shock. In both cases the shocks are to a steady state or equilibrium baseline and the results expressed in deviation from baseline terms.

Figure 4: Alternative Interest Rate Reaction Functions
Responses to a Temporary Demand Shock

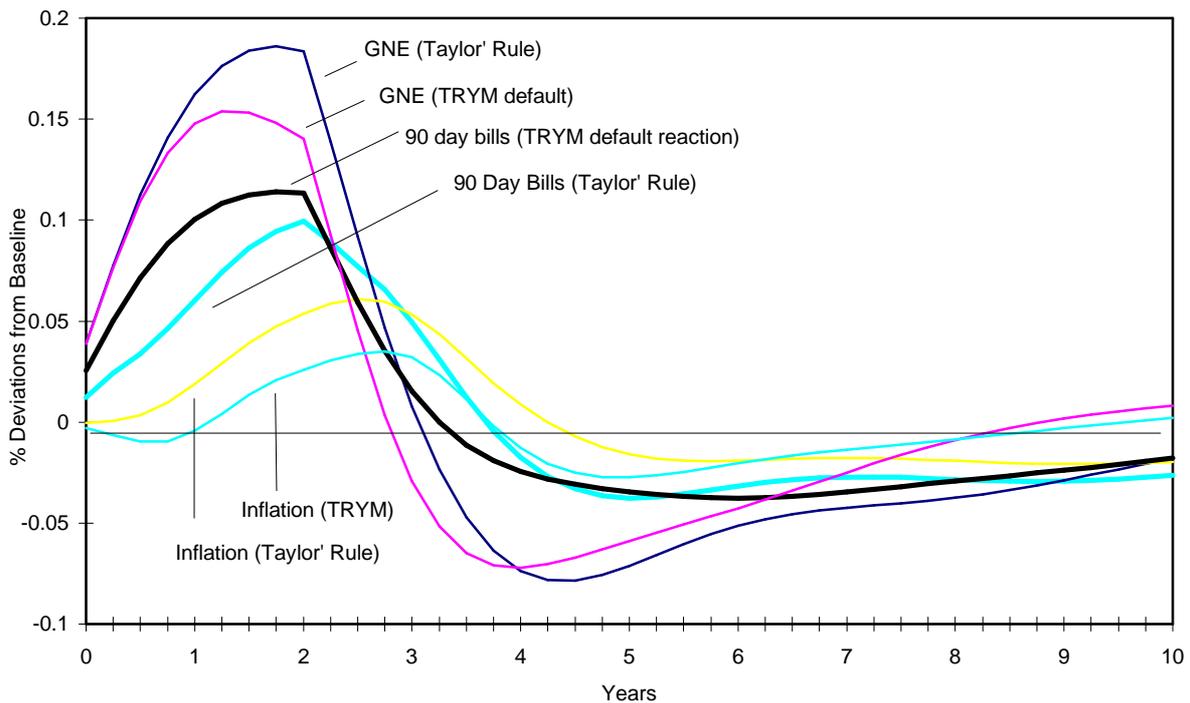
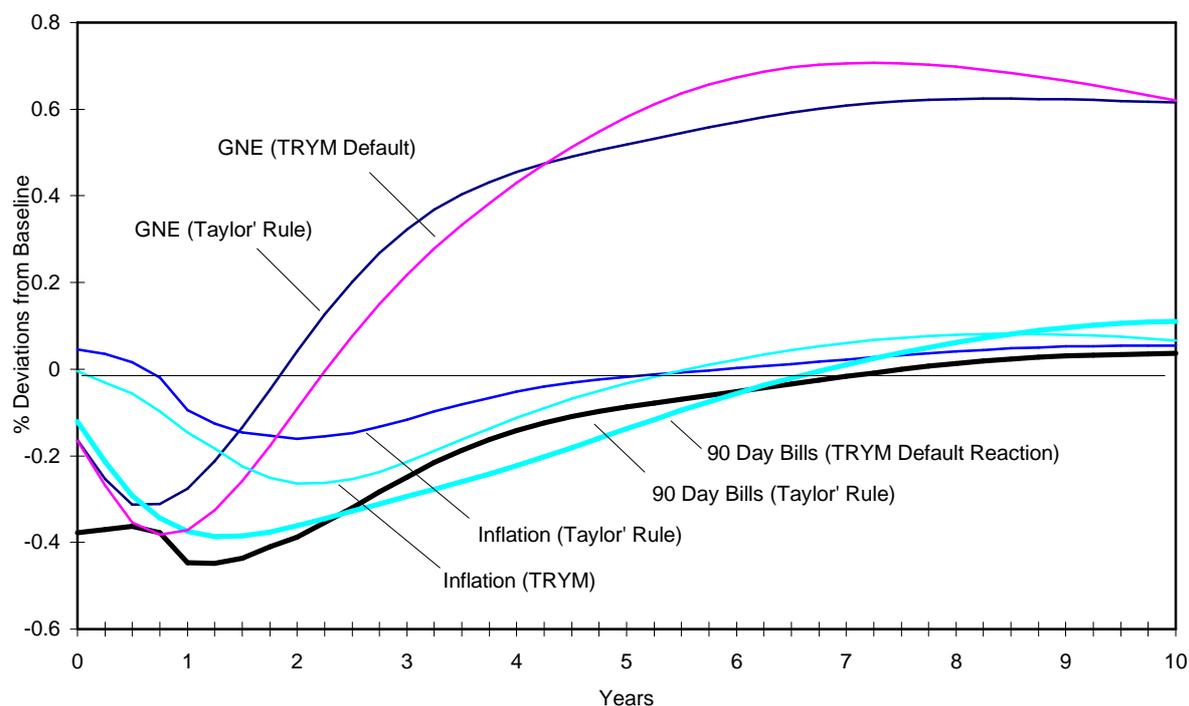


Figure 5: Alternative Interest Rate Reaction Functions
Responses to a Supply-Side Productivity Level Shock



As can be seen the figures show that the interest rate reactions are not greatly different in the alternative specifications. The TRYM default reacts by more in the demand shock case, while Taylor's rule reacts by more in the supply shock case. Why is this so? It is not difficult to see that Taylor's rule implies an equilibrium growth rate for nominal GDP equal to productivity growth (which would be the equilibrium growth of target GDP) plus the inflation target. TRYM's money growth rule, as argued above, can be interpreted in a number of ways including as a target for nominal GNE growth equal to productivity growth plus the inflation target. Given that estimated trend productivity growth is fixed in model simulations, this translates into an inflation target and excess demand (GNE) target. In so far as the reactions of GNE and GDP to a shock are similar, the default reaction function will produce similar results for interest rates, to those stemming from Taylor's rule. In the case of the temporary demand shock, GNE rises by a much larger amount than GDP leading to a greater interest rate response from TRYM's default reaction function. In the case of the productivity level shock capacity utilisation falls immediately whereas GNE takes a while to respond leading to a larger initial reaction from Taylor's rule.³

Neither Taylor's rule nor the default reaction function are being put forward here as representing how monetary policy has been set in Australia. As discussed above, the default interest rate reaction in TRYM is no more than a simple, transparent and stable way of allowing interest rates to respond to changes in the economy. The argument made above is that the form of the assumed interest rate reaction may not be particularly important in terms of the way the model is used, as it is generally overridden in policy analysis and forecasting applications.

³ The larger initial interest rate reaction leads to a fall in the exchange rate and an increase in import prices in the first few quarters. This produces the small rise in inflation in the first few quarters in the Taylor's rule case.

The rules versus discretion debate is not one we would wish to enter here in any detailed way. We would note however that both the rules above are backward looking compared to the explicit forward looking nature of current policy setting. Also the differences in responses between the different shocks above tends to suggest that it would be difficult to formulate a rule that would work in all circumstances. An argument might be made that the policy response should depend not only on the outlook, but also on the type of shock (demand side or supply side, domestic or external, permanent or temporary) that is viewed to be driving the outlook.

2.2.3 10 Year Bond Rates and Inflation Expectations

Real 10 year bond rates (RIGL) are assumed to be a weighted average of real domestic short term rates and real world long term bond rates. In all cases, real rates are derived by subtracting inflationary expectations (FIE) from nominal rates. Domestic inflationary expectations are measured in history by the difference between the yield on non-indexed and indexed 10 year Treasury bonds. The domestic real short term rate must ultimately equal real world long rates. In the absence of monetary or other shocks the world lending rate ultimately determines our borrowing rate. Therefore, the domestic long term rate also ultimately moves to equal the world long rate (adjusted for risk).

The nominal bond rate is equal to the real rate plus inflationary expectations. The 10 year inflation expectations derived by the model are close to being 'model consistent' in most simulations. The expectation for the price level in 10 years time is based on the equilibrium price level in 10 years time (derived from the steady state model). Because the price level usually would not have reached equilibrium in the simulation within 10 years, the inflation expectations assumed will usually therefore not be precisely model consistent - but should usually be close to being so.

The nominal 10 year bond rate 'jumps' with any shock that affects the equilibrium price level. The real bond rate, however, only moves gradually with real 90 day bill rates. The real component is adaptive or backward looking, while the nominal component is forward looking.

The above solution to bond rate determination is largely adopted for convenience. It is possible to alter simulation procedures to solve the model using rational expectations and various modifications thereof. Ryder et al (1993) provide an example of a world trade shock with model consistent expectations in the financial market.

2.2.4 Exchange Rate Reaction

As with the money demand equation and the bond yield equation, obtaining satisfactory explanations for the behaviour of the exchange rate is fraught with difficulty. Theory suggests that expected exchange rate movements (the difference between the current and expected future exchange rate) should be related to the difference between domestic and overseas interest rates. However, in practice, it is difficult to produce a satisfactory fit of the exchange rate using this simple uncovered interest parity (UIP) situation (although covered interest parity is found to hold⁴). In particular, there is great uncertainty associated with the reasons for short term movements in the exchange rate (possibly due to the activity of 'noise traders' and chartists). Part of the problem in obtaining a model of the exchange rate which is consistent with UIP relates to the difficulty of

⁴ For example, see Blundell-Wignall et al (1993).

modelling the future equilibrium rate. In theory, the equilibrium rate should be affected by a range of factors such as commodity prices (and therefore mineral discoveries), inflation and inflation expectations here and overseas and domestic savings and investment balances. However, it is difficult to know whether movements in some of these variables (commodity prices in particular) are (or are judged to be) permanent or transitory. Moreover, because of the possibility of time varying risk premia it is difficult in practice to measure directly the expected future course of either real interest rates or inflation. There are further measurement problems with world interest rate and inflationary expectations. There is also only a relatively short period of data since the floating of the exchange rate in Australia upon which the uncovered interest parity theory can be tested.

The approach taken in TRYM is to impose an uncovered interest parity condition so that the exchange rate (RETWI) is determined by the 'risk-adjusted' differential between domestic and world 10 year bond rates and the expected equilibrium exchange rate in 10 years time. A 10 year time horizon is chosen to be consistent with the bond yield equation. This is represented by the following equation.

$$RETWI_{(t)} = 10*(RIGL_{(t)}-WRIGL_{(t)}-RIP) + RETWIX_{(t+10)}$$

where:

RIGL	=	Australian 10 year bond rate
WRIGL	=	world 10 year bond rate
RIP	=	interest rate differential on Australian debt
RETWI	=	\$A trade weighted index (log*100)
RETWIX	=	equilibrium RETWI (log*100)

and time (t) is in years

The equilibrium exchange rate (RETWIX) in TRYM is calculated using the steady state version of the model. In equilibrium, the exchange rate adjusts to the point where exports and imports (the trade balance) adjusts to balance the current account and net income deficits implied by domestic saving and investment decisions in equilibrium, (which in turn imply an equilibrium level of net external liabilities to GDP).

Under the framework in TRYM, a wide range of factors can influence the current exchange rate either through the equilibrium exchange rate or through the 10 year bond rate. For example, a permanent increase in the terms of trade will raise the equilibrium exchange rate. It will also raise domestic demand and, hence, domestic interest rates. Both effects will tend to raise the current exchange rate.

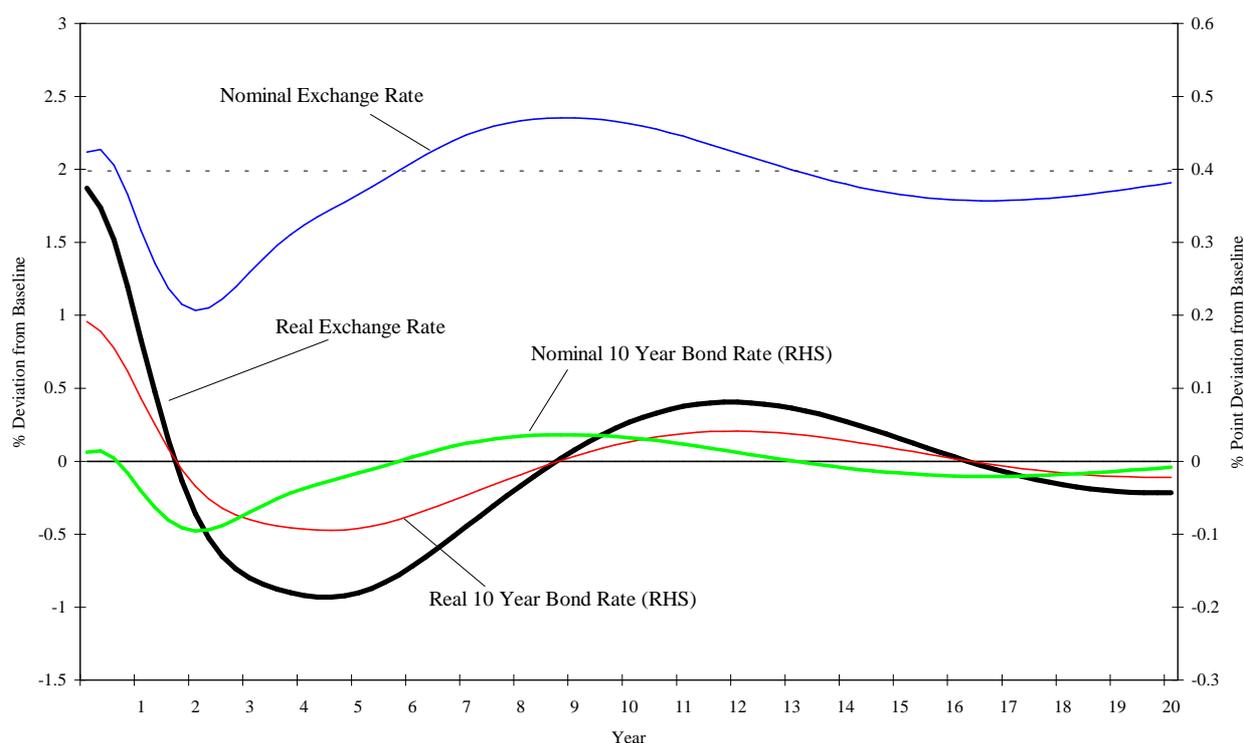
TRYM's exchange rate jumps in response to a permanent monetary change in a similar way to that in the dynamic model of Dornbusch (1976). TRYM has all of the central elements of the simple Dornbusch model but with the uncovered interest parity condition using the real long term bond yield, rather than the short term interest rates.⁵ The exchange rate movement in TRYM therefore depends directly on the relationship in TRYM between the short term interest rate change caused by the monetary policy change and the consequent change in long bond yields. The nominal long rate can be thought of as comprising a real component and an inflationary expectations component. The real long rate will rise with a monetary tightening as real short rates rise. However, inflationary expectations might fall. As a result, in TRYM, the effects of a monetary policy change on the real

⁵ Moreover, expectations relating to the real component of long bonds are adaptive in TRYM whereas expectations in the Dornbusch model are rational.

long bond rate and on inflationary expectations are roughly offsetting. Even though the shock will change the short term interest rate, the long bond yield will usually be little affected.

Because TRYM's uncovered interest parity condition uses the long bond rate, there will usually be no overshooting in the exchange rate driven by an increase in the Australian bond yield relative to the world yield. The change in the nominal exchange rate is roughly proportional to the change in the money supply for any given shock. The exchange rate then moves in the short run from this equilibrium level depending on movements in the economy - particularly, changes in expenditure relative to output and hence to trend money supply growth. The response of the exchange rate to the monetary tightening is shown in Figure 6 below:

Figure 6 Real Exchange Rate and the Real 10 Year Bond Rate



The discussion above relates to changes in nominal interest rates and the nominal exchange rate consequent on a monetary policy change in TRYM. However, monetary policy in TRYM influences the real economy via its effect on real interest rates and the real exchange rate rather than nominal rates. The interesting thing about the jump in the nominal exchange rate, as described above, is that it leads to an initial appreciation in the real exchange rate as the domestic price level is sticky in the short term. The appreciation reflects an expected future change in the price level rather than the current change. In real terms, the exchange rate rises immediately. Thus, in TRYM the real exchange rate will appreciate by around two per cent for a monetary tightening that produces a 1 percentage point change in the real 90 day bill rate, and the real bond rate will increase immediately by roughly a quarter of a percentage point.

2.3 Interest Rate Effects on Activity and Inflation

The reaction of the model to the monetary tightening implemented for the purposes of the comparison is shown in Figures 7 and 8 below. The specific form of the monetary policy shock shown is a one-off 2 per cent reduction in the money supply. This leads to a jump in short term interest rates and the exchange rate - analogous to the right hand panel in Figure 1.

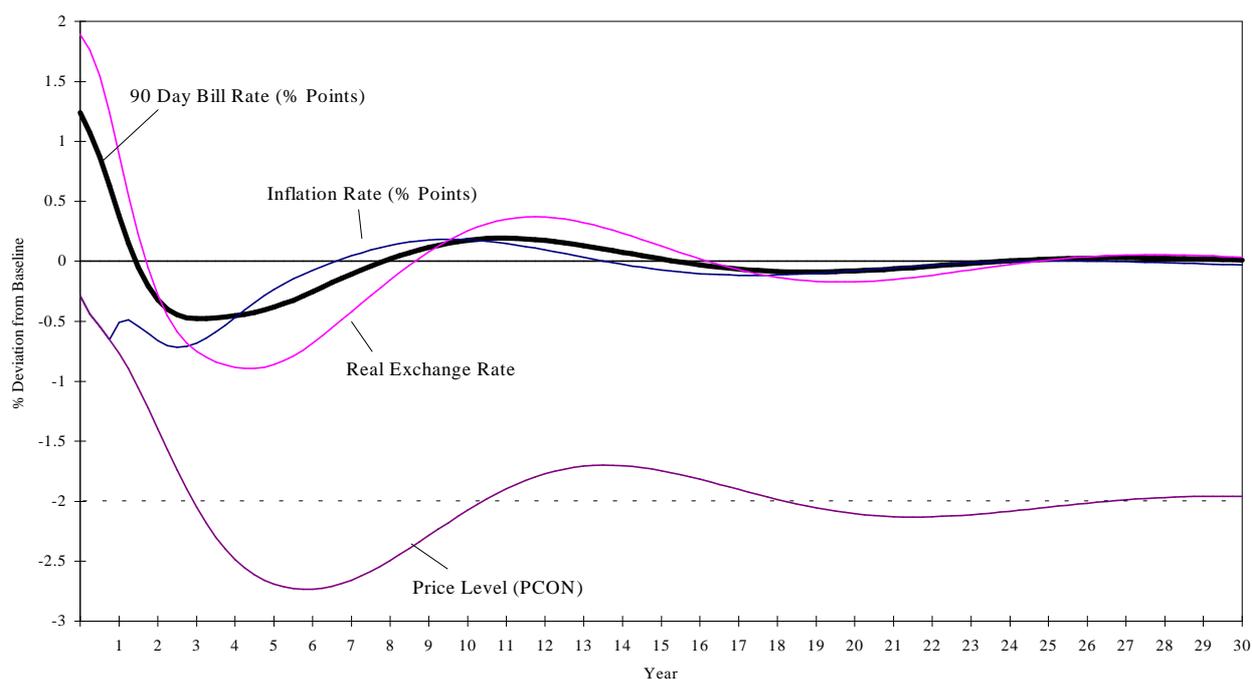
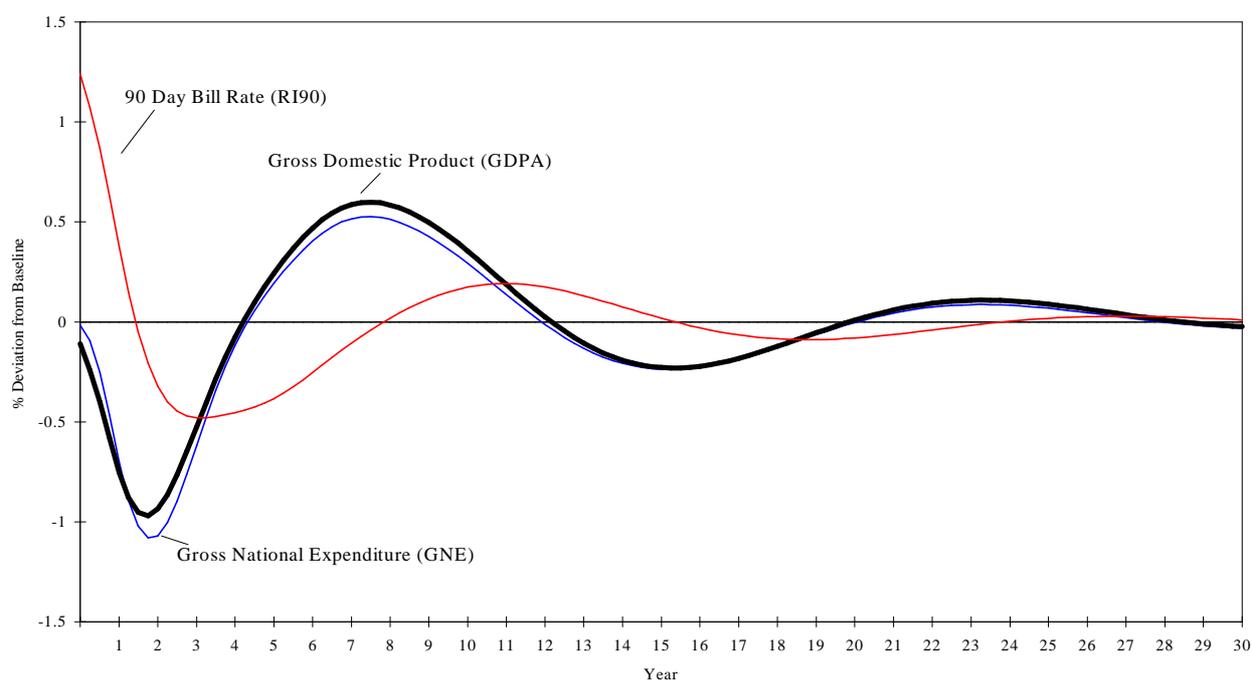
2.3.1 Overview

The contraction of the money supply leads to a rise in interest rates in the first year (Figure 7). However, this interest rate increase is unwound as the price level falls and the real money supply returns towards its original level. The interest rate increase is completely unwound after the second year.⁶

The increase in interest rates dampens gross national expenditure (GNE) - via lower investment and consumption - leading to lower import demand. However, the lower real exchange rate accompanying the falling interest rates stimulates net exports, offsetting the lower import demand. As a result, net exports (and the CAD) are relatively unaffected and GNE and GDP move together (Figure 8). The short term interest rate does not taper towards its original level, but overshoots. This is due to the lagged adjustment processes on the demand side and inertia in business and dwelling investment. As mentioned above, the initial stimulus to investment sets up a stock adjustment cycle in investment. As output is unaffected in the long run and the capital/output ratio must return to its long run level, any initial increase in investment must be unwound and most of this unwinding occurs in the first contractionary phase after the shock.

The shock is characterised by an expansionary phase, a contractionary phase and then a phase where GNE and GDP broadly taper towards equilibrium (involving dampened oscillations). The effects of the money shock over one year take up to ten years to work their way out of the system.

⁶ It is unwound before the full price effects flow through (before the price level rises by 4 per cent) because demand is expanding. Interest rates react to movements in nominal GNE in TRYM. As both prices and quantities are increasing, the interest rate effects of the monetary expansion will be unwound before the price effects flow through fully.

Figure 7: Temporary Monetary Tightening**Figure 8: Temporary Monetary Tightening**

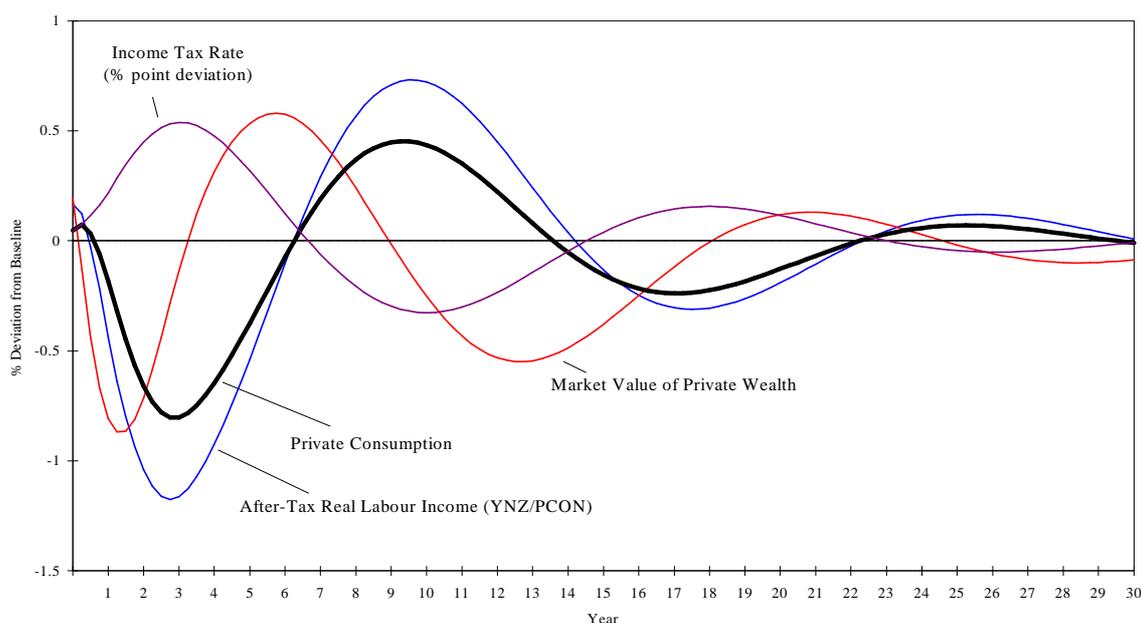
2.3.2 Private Consumption

Movements in private consumption (CON) are dominated in the short term by fluctuations in household income. The TRYM measure of household income is restricted to after-tax labour income (wages) and government transfers (pensions and benefits). In the long run, consumption adjusts to a level consistent with a desired saving ratio. The equation also contains a wealth term. The inclusion of wealth provides a channel through which fluctuations in the property and financial

markets can influence consumption behaviour. For example, a real increase in the market value of dwellings or business assets, which together account for about 80 per cent of wealth, will tend to boost consumption. Thus, when the market valuation of the business and dwelling capital stock is high - that is when Q-ratios are high - consumer confidence will also be high.

Figure 9 below shows the response of private consumption to the monetary shock. Movements in after-tax labour income account for most of the deviations in private consumption although an increase in the market value of wealth (in turn due to an increase in market valuation ratios) adds to the initial stimulus to consumption.

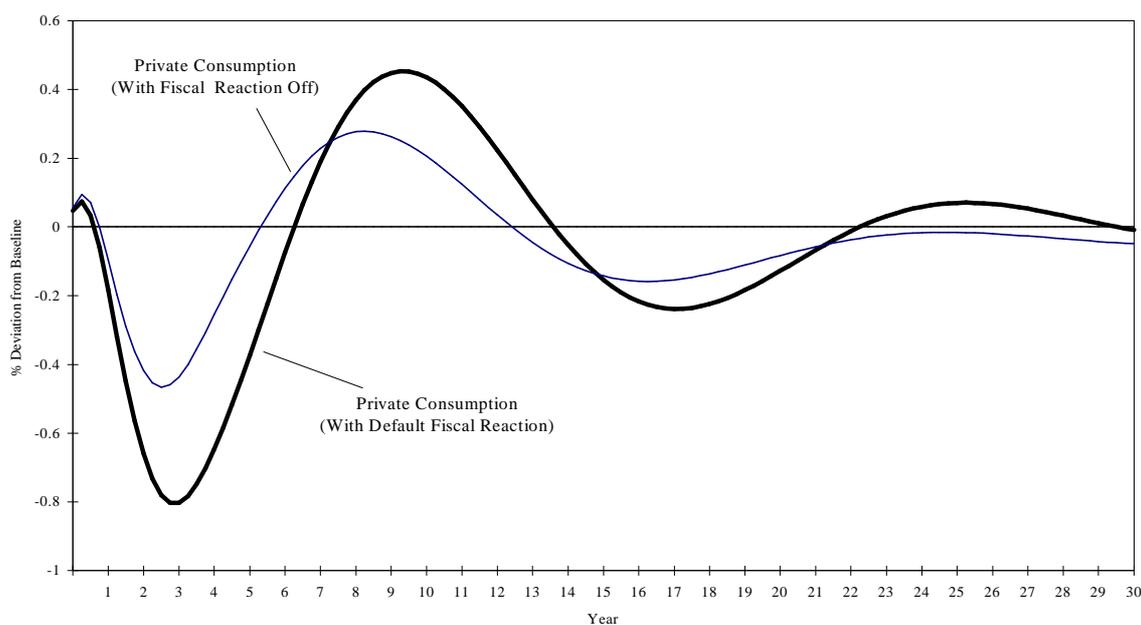
Figure 9: Deviations in Consumption and Selected Explanators



It is notable that a large proportion of the change in after labour income is due to the response of income tax rates in turn determined by the fiscal policy reaction function. The default fiscal policy response function adjusts income tax rates (on labour income, RTN, and capital income, RTK) in response to movements in public sector debt. It is designed to ensure that the public debt to GDP ratio (RWDGT) returns to its set target value in the long run. A consistent long run fiscal policy target ensures the comparability of model simulations of different economic shocks. It also ensures that there is a unique long run solution to model simulations.

There is ample scope in the TRYM model to alter this response mechanism. It could be re-specified, for example, so that governments reduce a deficit by cutting expenditure in a variety of ways, by raising a variety of indirect and direct taxes or by some combination of expenditure cuts and increases in revenue. Different lags between the decision to change fiscal policy and when policy is actually changed can be incorporated into the response mechanism. Furthermore, the target deficit to GDP ratio and the speed at which policy reacts to achieve this target can be changed. Figure 10 below shows the difference in the consumption response if the fiscal policy reaction is turned off.

Figure 10: Consumption Response with Fiscal Reaction Turned Off



The figure indicates that the fiscal reaction has quite a significant influence on consumption, and plays a significant role in generating the cyclical response.

2.3.3 Business Investment

In the long run, business investment (IB) is assumed to adjust to a point where the expected rate of return on the capital stock is equal to the required rate of return. This steady state equilibrium is achieved by the Q-ratio term (the expected rate of return over the required rate of return) in the business investment equation. The expected rate of return is derived from the production function parameters given the current capital stock and the current real wage (adjusted for trend productivity). The required rate of return is assumed to be equal to the real user cost of capital - the real long term bond rate adjusted for risk plus capital depreciation.

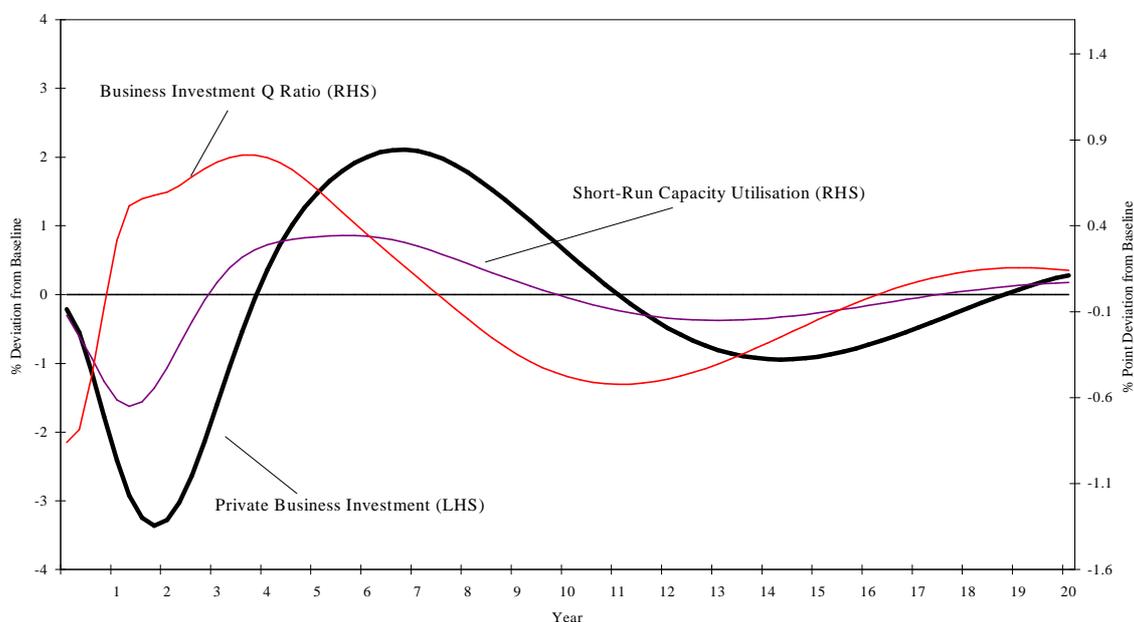
In the short term, capacity utilisation and inertia are important determinants of investment. When potential short run supply is greater than demand, the immediate short term return from additions to capacity will be low. Hence, capacity utilisation appears to have significant effects on the timing of investment (although uncertainty or cash flow constraints may also be playing a role). At the same time, there are significant time-to-build lags in some components of business investment, such as office building. A single project may stretch over a number of years. As a result, there is a significant correlation between investment in the current quarter with investment in the previous quarter. Lagged dependent variables are introduced into the equation to capture this inertia.

Capacity utilisation and inertia dominate the short term movements in business investment in TRYM. A given change in capacity utilisation will have roughly ten times the effect of an equivalent change in the Q-ratio in the short term.⁷ However, in the long term, the Q-ratio pulls investment and the capital stock back to their equilibrium level. Together with the capacity

⁷ Short run capacity utilisation, GBA/GSTAR, and the Q-ratio are both measured as ratios and are both equal to one in equilibrium.

utilisation term, the Q-ratio ensures that in the steady state the capital stock is growing in line with adult population and underlying productivity of the economy as a whole. The figure below shows the response of business investment in the simulation.

Figure 11 Business Investment and Selected Explanators



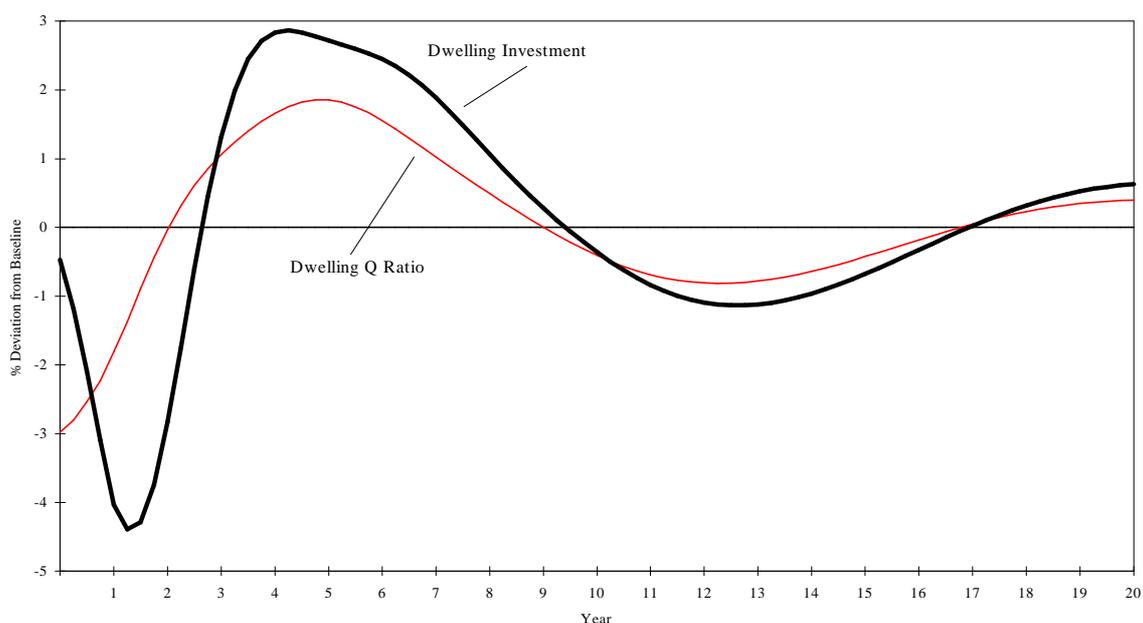
As can be seen, while the Q ratio deviations are larger than those of capacity utilisation the movements in investment appear to be dominated by the movements in utilisation, and inertia in the lag structure of the investment equation.

2.3.4 Dwelling Investment

The TRYM dwelling investment equation assumes that the expected rate of return on investing in housing relative to the user cost of dwelling capital (the Q-ratio, QDW) is a key determinant of dwelling investment (IDW) in the long term. In the short term, the level of the capital stock is constrained by time-to-build factors. This leads to a significant amount of inertia in dwelling investment which is captured by a series of lags (up to four quarters). These lead to significant cyclical dynamics (as in a cobweb cycle).

The rate of return of dwelling investment is assumed to be driven by the price received for rental services relative to the price of business investment. The dwelling user cost of capital is calculated as a weighted average of short term and long term interest rates, adjusted for inflationary expectations, plus dwelling depreciation. The incentive to invest in housing (QDW), based on the ratio of the expected rate of return and the user cost of capital, affects investment with lags of up to one year or more. The dwelling stock adjusts to the point where QDW equals one in the long term.

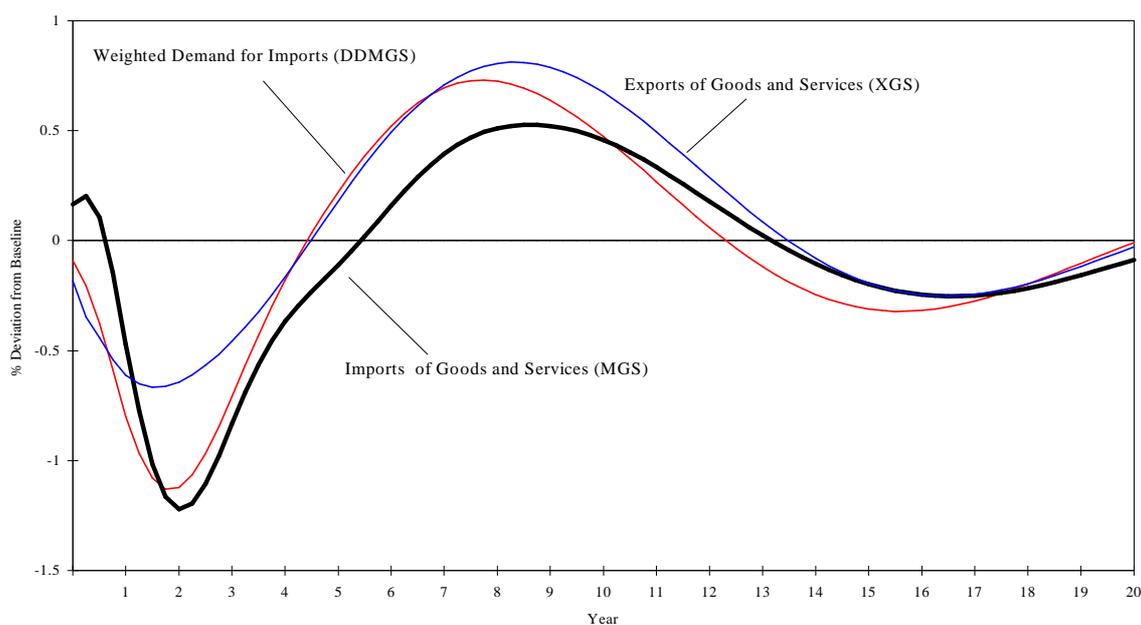
The figure below shows the response of dwelling investment in the shock.

Figure 12 Dwelling Investment

The figure indicates that the movements in dwelling investment are very much driven by movements in the Q ratio (due to changing interest rates), but with the lag structure of the equation influencing the timing of the cycles.

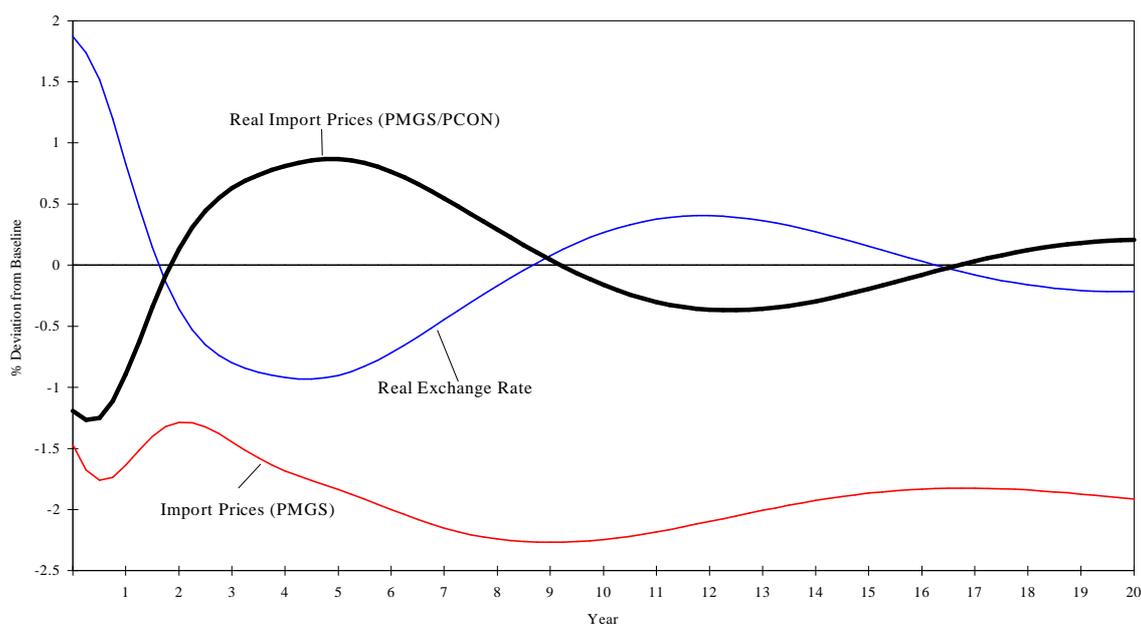
2.3.5 Demand and Net Exports

The effects on consumption, investment dwellings and stock building, aggregate into relatively large effects on GNE and the weighted demand term for imports DDMGS. Normally the reaction of imports to changes in demand is around two to one in the short term. However with the increase in the real exchange rate (see Figure 5) makes imports less expensive leading to a substitution effect, offsetting the effects of the lower demand. At the same time the fall in competitiveness in combination with falling domestic supply leads to a fall in exports that roughly matches the fall in imports. As a result net exports and the current account deficit are broadly unchanged as a result of the shock. Figure 13 below shows the response of import and export volumes to the shock.

Figure 13 Domestic Demand, Imports and Exports

2.3.6 Exchange Rate and Import Prices

The combined effect of the significant changes in demand and lack of offset to net exports leads to a similar profile between GNE and GDP. The activity effects translate relatively directly to unemployment, with GDP falling by around 1 per cent after two years, and unemployment rising by almost half a percentage point. The effects on activity and unemployment translate into lower demand and wage pressure on prices, but perhaps the largest effects in the simulation come from movements in the exchange rate and import prices. These are shown in Figure 14 below:

Figure 14. Real Exchange Rate and Import Prices

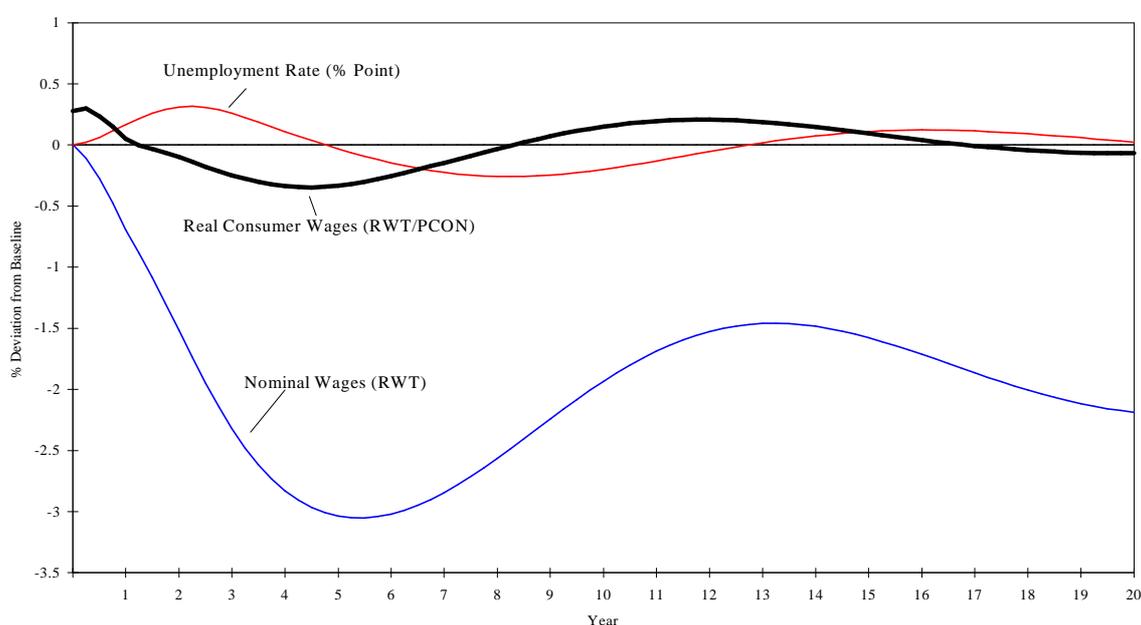
The figure shows that import prices jump immediately with the shock as a result of the exchange rate jump noted above. This produces a short term impact on consumer price inflation which is

unwound as the real exchange rate falls, and the deflationary impact of lower demand and higher unemployment takes over.

2.3.7 Wage Response

Figure 15 below shows the reaction of real wages to higher unemployment. As unemployment rises real wages fall. (The initial jump is due to the unanticipated effects of the exchange rate jump on consumer prices.) The peak effect on inflation is roughly of the same magnitude as that of import prices (taking into account that imports represent 21 per cent of domestic demand.) However, the peak effect occurs after about four years, in contrast to the peak effect of import prices that occurs within the first year.

Figure 15: Unemployment and Wage Inflation



2.3.8 Overall Response

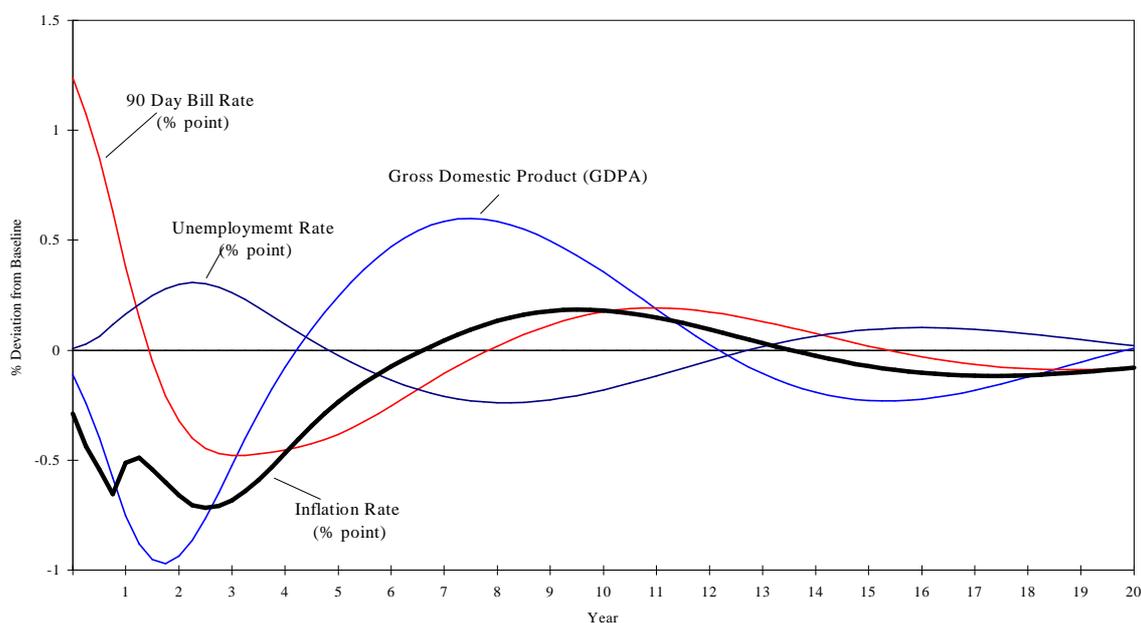
TRYM estimates the lag between a temporary change in interest rates and the peak effect on inflation to be a little over 2 years (although there is a substantial effect within the first year due to import prices). This can be seen in Figure 16 which shows the effect of a temporary increase in interest rates on GDP and inflation. The main initial impact on inflation in TRYM comes via the effect of interest rate changes on the exchange rate and, hence, import prices (the exchange rate rises and import prices fall)⁸. These import price effects are unwound as real interest rates fall back to

⁸ The overall magnitude of monetary policy effects may have changed in recent years for a number of reasons: for example, the higher indebtedness of the household sector, on the one hand; and lower indebtedness of the corporate sector and increased prevalence of fixed (and capped) loans, on the other. Moreover, TRYM uses the National Accounts measure of consumer price inflation (PCON) to measure inflation in the wage equation. This measure is much more akin to the underlying rate than the headline CPI (it does not include mortgage interest charges). In so far as the inflation expectations of wage earners are affected by the headline CPI, the effect of a given change in monetary policy on nominal wage demands may not be fully captured by the model. All of these are examples of possible structural changes not captured at the aggregate level and highlight the need for judgement (ideally based on more detailed analysis) in interpreting model results.

equilibrium levels.⁹ After the first year, the main dampening effect on inflation comes from the lagged effects of interest rates on unemployment and wage demands and on capacity utilisation and price pressures. As can be seen, the peak effect on activity comes after around 6 quarters. The peak effect on inflation necessarily lags the activity effects.

The TRYM results are based on historical relationships and the standard caveat applies that lags may have increased or decreased in recent years. A number of structural changes have occurred that may have impinged on the timing and scope of monetary policy effects. These include, for example: the more transparent operation of monetary policy (including explicit announcement of interest rate changes since early 1990); the increasing penetration of imports into the domestic economy; and changes in the wage system and the time taken to complete and wage negotiations.

Figure 16: Response in the level of Real GDP and Consumer Price Inflation



⁹ The rise in interest rates is progressively unwound as money demand declines in line with the lagged response of the real economy and prices to higher interest rates.

3. UNCERTAINTY IN THE MODEL'S RESPONSES

There is a range of uncertainty around most of all of the model responses discussed above. It is normally easy to think of factors not explicitly modelled in a specific equation which may be leading to structural changes in the size of the response. For example changes in household gearing may be influencing the cash flow position of some household cohorts and leading to a changed response of consumption to interest rate changes. Similarly, the business investment equation does not contain a direct measure of cash flows or credit constraints, despite the increasing focus in the literature on credit as a transmission mechanism for monetary policy changes.

All of the relationships discussed above and more are subject to some uncertainty. However, it is the contention here that the endogenous demand components are not the key areas of uncertainty in the model responses. The investment and consumption responses may be a little higher or a little lower depending on the particular factor that is of concern, but the magnitude of the responses given the changes in activity and incomes seems broadly sensible. Rather than focus on endogenous movements in the GDP components we prefer to focus on three key areas that are subject to a particularly high level of uncertainty and which appear to generate large differences in the model's responses. These are: (a) the exchange rate response to changes in interest rates (b) the wage response to changes in unemployment; and (c) the expectational response to the change in policy. The exchange rate and wage responses are discussed below. The role of expectations in generating the model's responses and estimates of output/inflation trade offs re discussed in Section 4.

3.1 Exchange Rate

One of the most difficult areas to model is the exchange rate. As Paul Krugman (1993) noted in a recent survey article:

‘The theory of exchange rate determination has never recovered from the empirical debacle of the early 1980s. ... Quantitative policy analysts must have something to determine exchange rates in their empirical models, so they either have an exchange rate equation that more or less fits the data, or simply impose some mechanism, but they make little pretence that they have solved the riddle of exchange rates’.

The exchange rate equation in TRYM is based on an imposed uncovered interest parity condition using ten year bonds. The difference between the expected exchange rate in ten years time and the current exchange rate is a function of the difference in the current interest rates, adjusted for risk, of domestic and world ten year bonds.

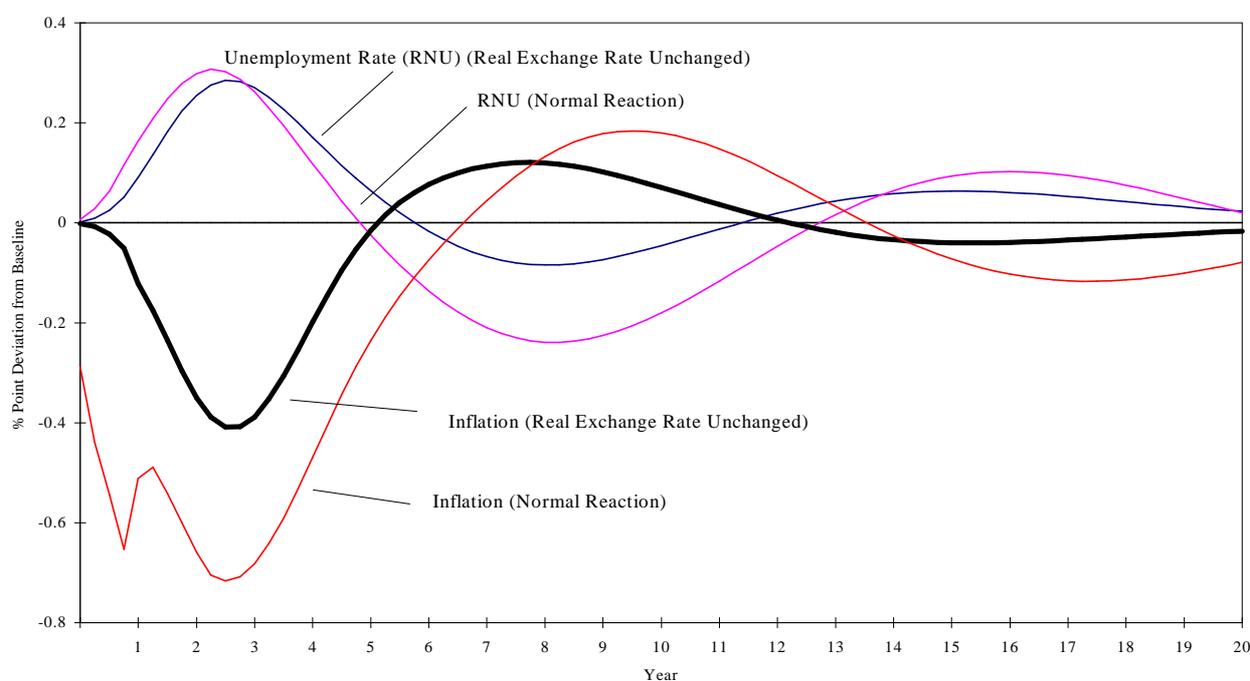
While this condition is imposed, movements in the exchange rate do broadly accord with observed relationships in history. For example, the equilibrium exchange rate in TRYM moves with changes in the terms of trade and changes in the equilibrium saving and investment position. The elasticity of the response of the equilibrium exchange rate to a change in the terms of trade is around 0.8, broadly consistent with that found by Blundell-Wignall et al (1993). Any effect on the equilibrium exchange rate is immediately reflected in the spot rate via the interest parity condition. Similarly the interest parity condition when combined with the bond yield equation, does imply a broadly reasonable response of the exchange rate to movements in short term interest rates. The ten year bond rate is calibrated to increase by about 15 basis points initially - and by about 20 basis points after two years - for every percentage point increase in the real 90 day bill rate. As a result, both the nominal and real exchange rates increase more than proportionally in response to a given increase in the 90 day bill rate due to monetary tightening. A 1 percentage point increase in the 90 day bill rate will normally lead to an increase of around 2 per cent in the exchange rate.

While there is little doubt that the exchange rate responds to fundamental influences such as commodity prices and the domestic interest rate structure, there is great uncertainty over short term movements. This uncertainty is sometimes attributed to the existence of ‘noise traders’ and chartists in the financial markets and, hence, to the lack of ‘speculative efficiency’ in the short term. If speculative efficiency held, the short term change in the exchange rate would, on average, be equal to the market's expectation derived from short term interest differentials. However, there appears to be mounting evidence against speculative efficiency in the short term. As Krugman notes:

‘Most people would view the assumption of speculative efficiency [as] something that must be maintained in the face of seemingly unfavourable evidence. In my view, the situation is even worse: there is no plausible way to reconcile the assumption of speculative efficiency with the data’.

While covered interest parity seems to have a fair amount of empirical support, and indeed must be true by arbitrage, there have been a number of papers over recent years questioning the validity of uncovered interest parity in the Australian context (eg Gruen and Menzies (1991), Gruen and Gizycki (1993)) and by implication the validity of the speculative efficiency hypothesis. There must be a fairly significant degree of uncertainty, therefore, in how the exchange rate responds to any given monetary tightening in any given circumstance. This can have quite significant effects on the transmission of the monetary shock both to activity and prices. (Recall how the Mundell-Fleming results change when the exchange rate is fixed.) To provide a feel for how large the effects are Figure 17 shows the results of the monetary policy tightening where the real exchange rate is held unchanged.

Figure 17: Monetary Shock with an Unchanged Real Exchange Rate

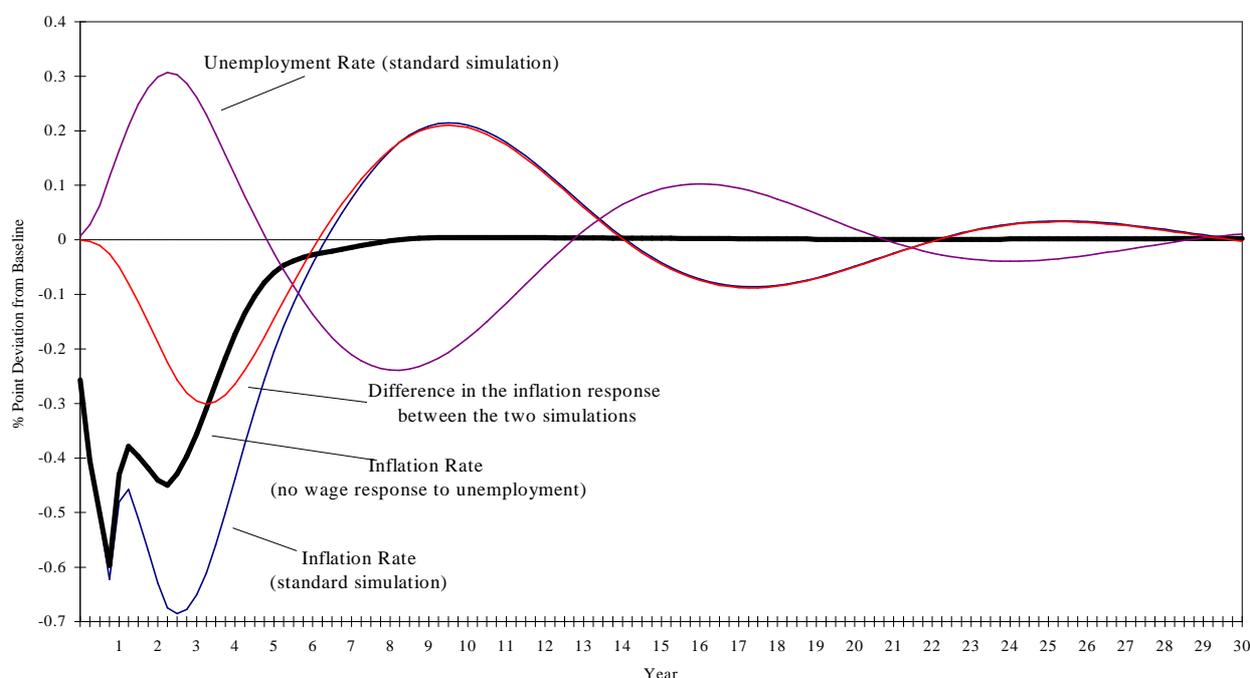


3.2 Wages

The other key area of uncertainty is in the response of wages to any particular shock. Given the institutional features of the Australian labour market obtaining precise estimates of the effect of unemployment and changes in unemployment on wage inflation.).

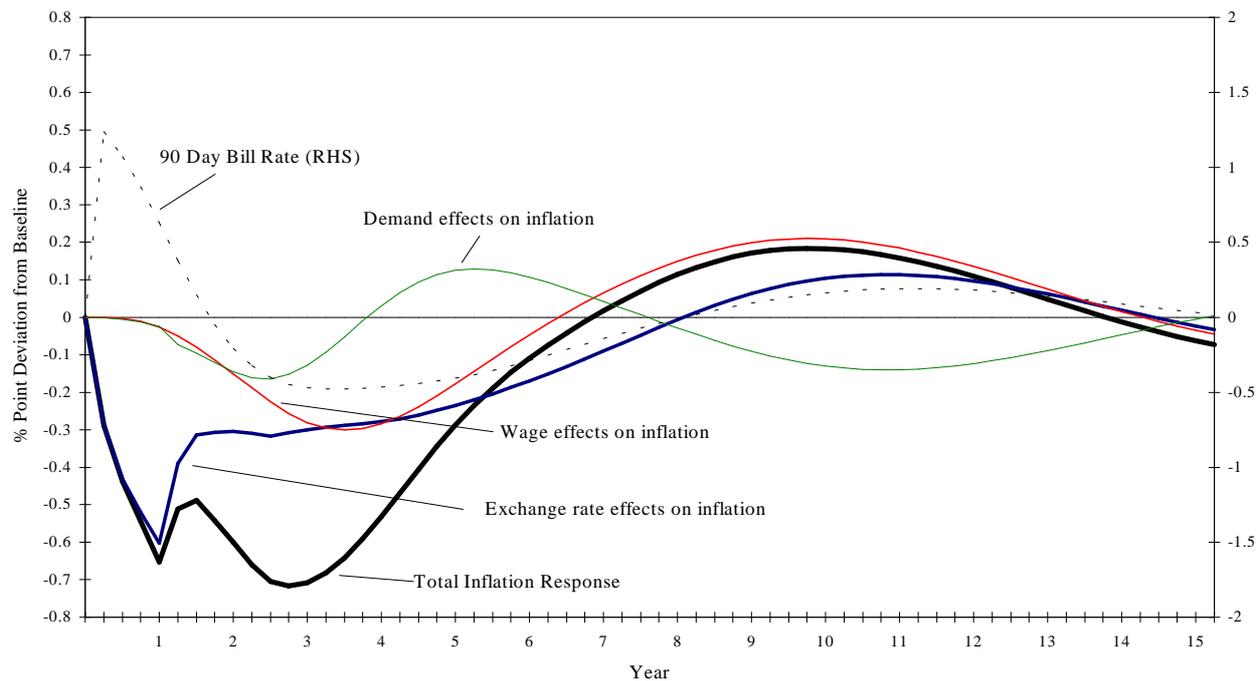
The model's wage equation is specified in the form of a expectations augmented Phillip's curve but including a change in unemployment term (and other modifications) to capture persistence effects. In common with other Australian wage equations, the specification does not fully capture the various institutional influences on wage-setting behaviour and only explains around half of the quarterly variation of wages. Clearly, with the recent changes to the industrial relations system, reforms to cross-industry union structures, falling union membership and increasing international competition, the wage response to changes in activity and unemployment may have changed. To show the sensitivity of the models monetary policy response the Figure below shows the simulation results if there is no response of wages to increases in unemployment.

Figure 18: Monetary Policy Tightening without Wage Response to Unemployment



The figure indicates that the inflation response is smaller, but at the expense of more protracted effects on activity. In combination with the simulations discussed above (Figure 3) the results tend to suggest that the wage response, in combination with the exchange rate response are the pivotal linkages in generating the monetary policy effects on inflation. This is shown in the chart below which uses the results above to provide a rough decomposition of the monetary policy effects in TRYM. Clearly the exchange rate response plays an important role in the short term, while the wage response is the most important factor in the medium term. Uncertainty in these responses therefore generates a significant amount of uncertainty over the timing and scale of the total response.

Chart 18(b): Broad Decomposition of Effects on Inflation in a Temporary Monetary Tightening.



Note: Results are derived by switching off the wage and exchange rate responses in the simulation and hence do not account for some interaction terms. The demand effects are derived as a residual.

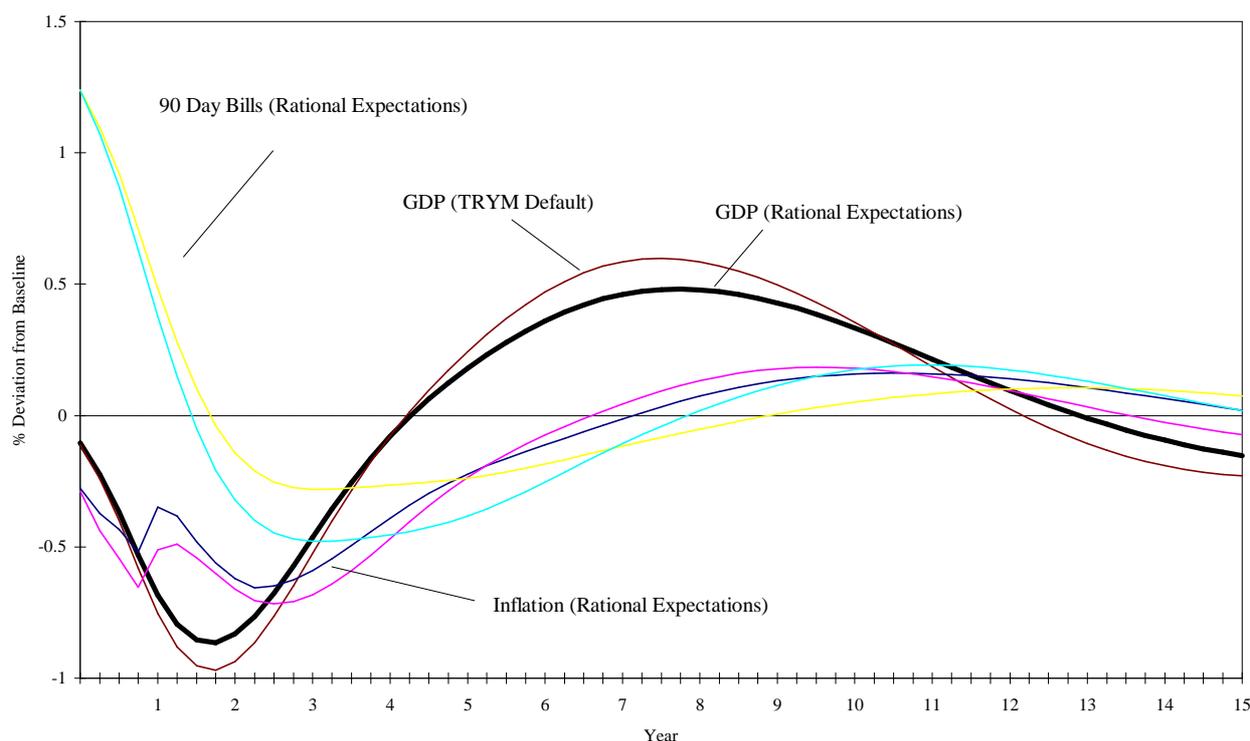
4. ROLE OF EXPECTATIONS

Expectations obviously play a critical role in the transmission of monetary policy to activity and inflation. The model's default (with forward looking financial markets but adaptive behaviour in the product and labour markets) presents one plausible way in which expectations can be formed. But the model is also useful for examining the question of what effect would result if expectation formation was different in the different markets? The debate around monetary policy credibility (central bank independence, and the rules versus discretion debate) centers on the role of monetary policy credibility on the activity/inflation trade off.¹⁰ What is the role of expectations in different markets in generating credibility effects on the activity cost of reducing inflation? If the credibility effects on the trade off exist where would they be found? To help illustrate some of the theoretical answers to these questions Sections 4.1 and 4.2 look briefly at results (particularly the output costs) from the "inflation level" (or lower inflation target) simulation run for this conference, but with different specifications for inflation expectations in the financial market and the labour market respectively.

4.1 Financial Market Expectations

As noted above TRYM assumes that inflation expectations are quasi rational in the financial market. What happens if the simulation procedure is changed so that the financial market is fully rational/model consistent? There are a number of ways of solving the model with rational expectations and we have recently developed an algorithm to speed up the process considerably in the TSP operating environment. (The procedure is outlined in Appendix B). Figure 19 below shows the reactions with quasi rational expectations, and with fully rational expectations. As can be seen, for a money shock the quasi rational specification is a good approximation of fully rational behaviour. This is consistent with the results of Malakellis and Transom (1995) using TRYM. However, quasi rational or quasi model-consistent expectations are not always a good approximation of rational expectations. Ryder et al (1993) for example show the difference in response with a terms of trade shock in TRYM.

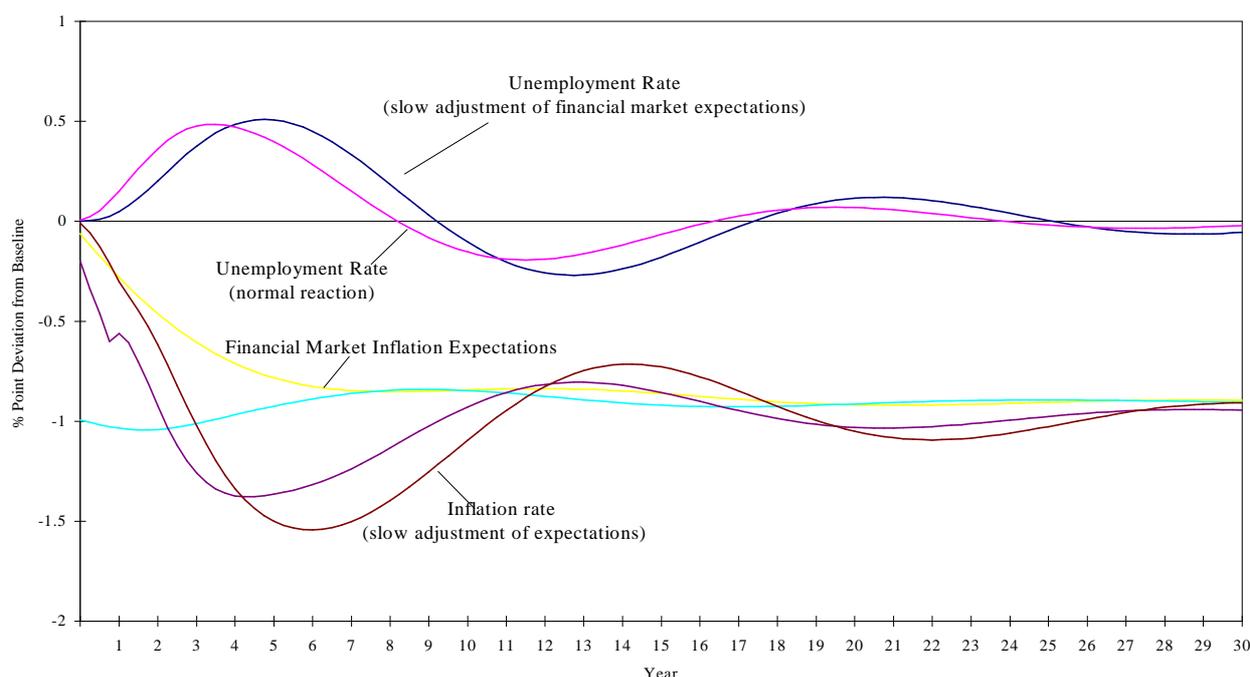
¹⁰ Debelle and Fisher (1994) provide a good summary of the arguments.

Figure 19: Monetary Shock with Rational Expectations

The small difference between the rational and quasi rational specifications suggested that we could reasonably safely proceed to looking at the role of expectations in the financial market on the output inflation trade offs embodied in the inflation target shock. In particular we were interested in what effect partial adjustment would have in financial markets - where the market's inflation expectations only adjusted slowly rather than immediately jumping down as in the rational/quasi rational case. Our theoretical priors were that without changes in the expectational behaviour in wage setting and price setting behaviour, changing the financial market expectation specification would have little effect on the output inflation trade off. It might change the timing of the adjustments but the size of the adjustment cost would still be the same.

Again the change is relatively simple to implement, and the figure below shows what happens if the fall in inflationary expectations in financial markets are only gradual rather than jumping down immediately in the fully-credible rational/quasi-rational case.

Figure 20. Inflation Target Shock with Partial Adjustment in the Financial Markets

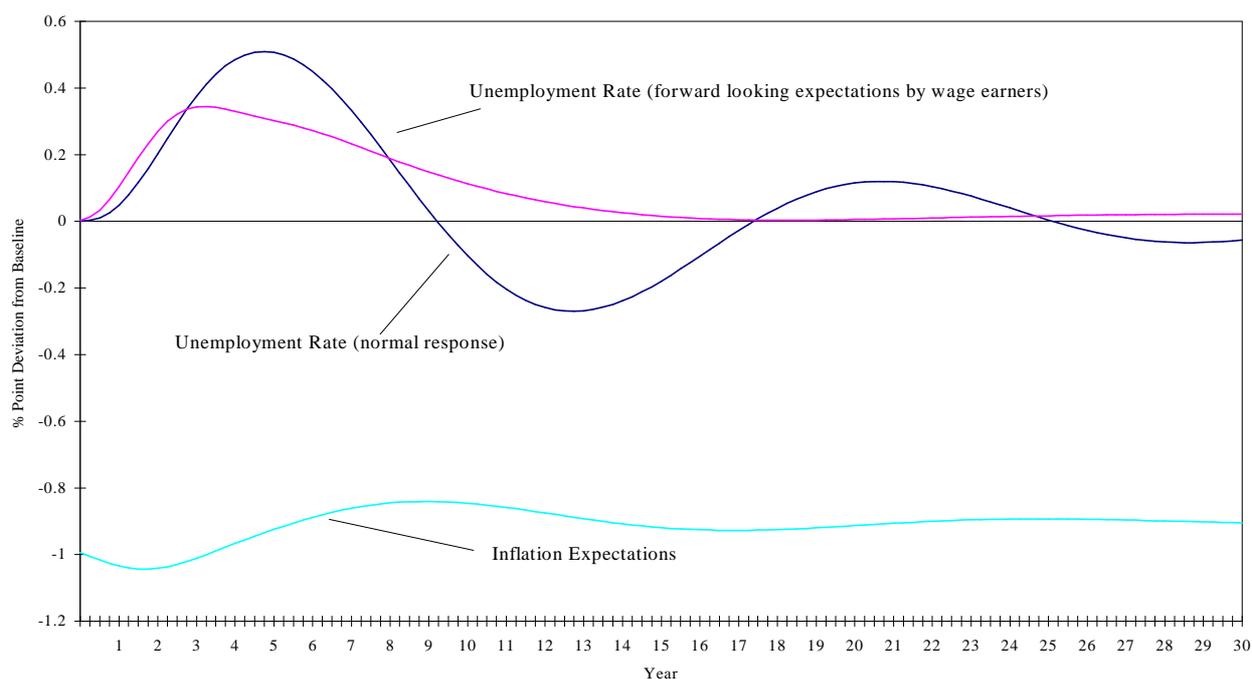


The figure shows that our priors (for once) appeared to be correct. The more gradual fall in inflation expectations leads to a phase shift in the response (largely because the real exchange rate does not jump by as much initially in the second case) - but without any change in expectational behaviour in wage setting or price setting the dislocation involved in reducing the rate of growth of prices and wages is about the same.

4.2 Labour Market Expectations

In contrast to the relatively minor differences in results between rational, quasi rational and adaptive expectations in financial markets, there can be quite significant effects from changing expectational specifications in the product and labour markets. (Recall that with the Dornbusch results if the domestic price level adjusts instantaneously there is no exchange rate jumping, and no effects on real variables.) The figure below indicates what happens when the adaptive price expectations specified in the TRYM wage equation are replaced with forward looking price expectations as specified in the financial market.

Figure 21: Inflation Target Shock with Forward Looking Behaviour in the Labour Market



The unemployment dislocation involved in the shock with forward looking expectations in the labour market is much lower than when expectations are adaptive. Unemployment still rises because of the inertia in price setting behaviour. If prices also adjusted rapidly in a forward looking way there should be very little in the way of dislocation in real activity or unemployment in the model in response to the inflation target shock.

5. SUMMARY / CONCLUSIONS

As can be seen from the differences in results above generated by imposing different assumptions, there is significant uncertainty surrounding both the size and the timing of effects from changing monetary policy. However this is not to say that different results are equally valid, or that any one of a range of effects is equally likely to occur. The model results are always conditional. They are conditional on the assumptions that are fed into the model. For a given set of assumptions, the models give a best guess of the likely response of the economy to monetary policy changes. Rather than being seen as a negative, the ability to produce and understand a range of results should be seen as a positive. The models should not only be able to produce a reasonable best guess on the average response of the economy to a monetary policy change, but also provide information on how that response would change in different circumstances, including under different assumptions.

Thus the models help to open up the monetary policy transmission black box and provide some quantitative feel for the factors that influence the “long and variable lags involved in monetary policy” that are often asserted but less often analysed in a systematic way.

The analysis above has attempted to use the model to trace through the linkages of monetary policy transmission, and to show how the monetary policy response would change in different circumstances. In contrast to the usual focus on the uncertainty around endogenous consumption and investment reactions (the volatile components of which tend to be imported) the paper has attempted to highlight:

- The role of the exchange rate. The exchange rate reaction plays a major role in the transmission of the monetary shock to activity and inflation via its effects on net exports in the case of activity, and via its effect on import prices in the case of the inflation outcomes. Imports as a proportion of GDP have increased by almost fifty per cent from levels around 15 to 16 per cent 10 years ago to 22 per cent today as the economy has become more closely integrated into the Asian region. As a result the exchange rate channel of influence has increased in importance, as has monetary policy itself, and the model results help to demonstrate this. However, while it is an increasingly important channel of influence, the exchange rate reaction is also highly uncertain, and the model can also help in interpreting what this uncertainty implies for policy making.
- The role of wages. The wage response is important to both the timing and the scale of monetary policy effects on activity, unemployment and inflation. The second round effects on inflation in the model simulations largely result from the reaction of wages to changes in activity, unemployment and lagged prices. Thus the long and variable lags of about 2 years appear to mainly depend on the speed of the wage reaction. The timing of the wage response to changes in activity and inflation also appeared to have a significant effect on the size and timing of the cyclical dynamics observable in the simulations. Thus the wage response seems to be a critical linkage for both the size and the timing of monetary policy effects. Again there is a significant degree of uncertainty around the wage reaction, particularly in the current changing institutional environment.
- The role of expectations. Expectational behaviour in the labour and product markets (wage setting and price setting) appear to be the key to generating the trade off benefits that are said to accrue to monetary policy credibility. Monetary policy credibility in the financial markets may affect the timing of the monetary policy response but will have little effect on the output/inflation trade off unless it translates into credibility in labour and product market wage bargaining and price setting behaviour. The model can be used to provide some feel for the

size of the effects on the trade off under different assumptions, and highlights the importance of a policy focus on shaping inflation expectations not only in financial markets but also in the wage bargaining process and in firms' price setting behaviour.

The results shown in the paper have attempted to give a feel for the sensitivity of monetary policy results to the factors discussed by changing particular linkages or assumptions and showing the results. Perhaps a more systematic feel for the uncertainties involved and their implications for policy setting would be gained by running the stochastic simulations advocated by Fair (1994). We hope to do some work along these lines in the future. However even in that case I suspect we would not be able to reach what Keynes disparagingly (and correctly) referred to as a state of certainty by the application of the calculus of probability - "reducing uncertainty to the same calculable status as certainty itself." The models, however, should be able to provide some feel for the nature and implications of those uncertainties, and in so doing, help to inform the policy debate.

APPENDIX A THE FINANCIAL MARKET IN TRYM

B.1 Background

Deregulation of the financial market, the floating of the exchange rate and removal of exchange controls in the 1980s have both increased the importance of financial markets to economic behaviour and led to simpler financial market specifications in macroeconomic models. In comparison with earlier NIF models, NIF88 contained a relatively small financial sector. This trend has been continued in the development of the TRYM model¹¹, resulting in a simpler and more transparent treatment of the interaction of the financial market with the real economy.

The financial market as modelled consists of an estimated money demand equation, a money supply growth rule (these two are combined to form an interest rate reaction function which gives the 90 day bill rate) and three behavioural identities for:

- a term structure equation (linking 10 year bond rates with 90 day bill rates and world 10 year bond rates);
- a forward looking inflationary expectations identity which determines current inflationary expectations from the equilibrium price level (assumed to be the price level obtained from the steady state version of the model 10 years hence), and
- an uncovered interest rate parity condition for the current exchange rate (RETWI), which determines RETWI from the future equilibrium exchange rate (RETWIX) derived from the steady state version of the model.

B.2 Money Demand and Short Term Interest Rates

The literature on money demand equations over the last two decades is extensive. It has concentrated on the instability of relationships, the impact of financial deregulation and innovation and the relevance of particular definitions of money aggregates. These studies have tended to highlight the unsatisfactory nature of most existing money demand equations. However, from a modelling viewpoint, some tool is required to link the financial sector to the real economy and a money demand equation as an interest rate reaction function has traditionally achieved this purpose. Money is also required in a macroeconomic model in the analysis of fiscal policy. Transparent analysis of the interrelationships between the various macroeconomic markets is an important requirement of such models.

A simple money demand function is estimated. The inverted long run component of this equation is used as a simple, transparent and stable default monetary policy rule to determine the current level of short run nominal interest rates. A rise in nominal demand relative to money supply will increase the 90 day bill rate.

¹¹ Some of the reduction in size is illusory. The TRYM financial sector is not necessarily less detailed. It is, in fact, more detailed in terms of portfolio allocation of foreign liabilities. The difference mainly comes from behavioural equations in NIF being replaced by identities in TRYM. The identities, in turn, are normally driven by simplifying assumptions, eg that risk adjusted rates of return are equalised across sectors.

The money supply measure used is that of transaction balances (FM1Z). This aggregate is defined as currency in the hands of the non-bank private sector plus non-interest bearing current deposits of all banks plus a fixed proportion of interest bearing current accounts of all banks.

- This aggregate attempts to measure money balances held for transactions purposes rather than as a store of wealth. It therefore concentrates upon traditional payment instruments such as cash and cheques. The spread of EFTPOS facilities will gradually render this definition less relevant.
- The weighting on interest bearing current accounts reflects the fact that these accounts earn a return and therefore may be held as a store of value rather than for transactions purposes. Weighting these deposits takes some account of their own interest rate effect, without adding additional interest rates to the model. An appropriate weight on current accounts may be one minus the ratio of their own yield to the yield on a benchmark non-monetary asset. The fixed weight has consequently been estimated at 1/3 based upon the average yield on interest bearing cheque accounts (own yield) and 90 day bank bills (benchmark yield).

B.3 Money Demand Equation

In the long run, the ratio of money to nominal transactions (FM1Z/GNEAZ), or the inverse of money velocity, is modelled as a function of nominal short term interest rates (RI90) and a shift dummy for structural change (Q813). The shift dummy allows for the reduction in the minimum maturity requirement on trading bank certificates of deposit from 90 to 30 days in August 1981 (Q813 set to 0 from 1981(3) and 1 before). This change is likely to have made money substitutes more attractive (lowering money demand). Q813 should, therefore, have a positive coefficient.

$$\ln\left[\frac{\text{FM1Z}}{\text{GNEAZ}}\right] = -c_0 - c_1 \times \text{RI90} + c_2 \times \text{Q813}$$

This relationship will not hold instantaneously due to adjustment lags. An error correction dynamic specification was estimated relating changes in real transaction balances to changes in real demand, adjusted for steady state bias, and the deviation from the long run desired level.

The following equation was estimated:

$$\begin{aligned} \Delta\ln\left[\frac{\text{FM1Z}}{\text{PGNEA}}\right] &= a_1 \times [\Delta\ln(\text{GNEA}) - \text{GR}] \\ &- a_0 \times \left\{ \ln\left[\frac{\text{FM1Z}(-1)}{\text{GNEAZ}(-1)}\right] - c_0 - c_1 \times \text{RI90}(-1) + c_2 \times \text{Q813}(-1) \right\} \end{aligned}$$

Results

Sample: 1975(3) to 1995(3)

Parameter	Interpretation	Estimate	t-Statistic
a ₁	nominal transactions	0.673	3.84
a ₀	error correction	0.322	5.38
c ₀	long run constant	0.815	26.53
c ₁	interest rates	0.014	6.25
c ₂	dummy variable	0.074	4.92

Diagnostic Statistics

R² = 0.43

SE = 1.86%

DW = 2.01

Box-Pierce Q (1-8th order auto correlation)

6.07

Jarque-Bera Test for Normality

0.25

Chow Test for Parameter Stability

2.06

Ramsey's Reset Test

1.09

Breusch-Pagan Heteroscedasticity Tests:

Trend

1.21

Y-Hat

0.87

Joint

2.92

* Indicates the test has failed at the 5% confidence level.

Interpretation

The equation passes all of the diagnostic tests, and seems to have well determined coefficients. The coefficient on the dummy term is significant, suggesting that the demand for money structurally shifted in the September quarter 1981. The timing of this shift may not be precisely determined by the dummy variable as many structural changes took place in the early 1980s, such as deregulation of bank deposit rates (December quarter 1980), the move to a tender system for Treasury bonds (September quarter 1982), the more widespread use of ATMs and changes to various regulations on financial institutions' borrowing practices.

The interest sensitivity of real money balances is significant and would seem to be a plausible estimate, suggesting that increasing short term interest rates by 1 percentage point would decrease the demand for money by around 1.4 per cent in the long run.

Estimation results did not support the inclusion of changes in short term nominal interest rates ($\Delta RI90$). The term was usually implausibly signed and insignificant, perhaps reflecting lags in the translation of changes on short term rates to rates available to small investors.

B.4 The Default Monetary Policy Response Mechanism

The TRYM model needs to have a default interest rate reaction function to determine how interest rates respond to developments in the economy and interventions by the monetary authorities. Interest rates change in response to fluctuations in demand, saving and investment, and injections or withdrawal of funds by the monetary authorities, among other things. The way in which interest rates react to a demand shock, for example, depends on whether the monetary authorities accommodate the shock (maintain a stable short term interest rate through a change in liquidity) or

whether the authorities take a non-accommodating stance (maintain the money supply, allowing short term interest rates to adjust).

- Traditionally, macroeconomic models invert a money demand function to form an interest rate reaction function. The absence of a contemporaneous interest rate change term in the TRYM equation precluded inverting the money demand function to obtain the short run reaction of interest rates to changes in nominal transactions (essentially nominal GNE) relative to money.
- In the TRYM model, it is assumed that the money supply is set to grow at a rate that accommodates the underlying supply growth of the economy plus an exogenous inflation target. This money supply level is substituted into the long run component of the money demand equation which is then inverted to form an interest rate reaction function.

This results in the interest rate reaction function:

$$RI90X = \frac{1}{c_1} \times \left\{ -\ln \left[\frac{FMIZ}{GNEAZ} \right] - c_0 + c_2 \times Q813 \right\}$$

The crucial parameter in this function is the interest sensitivity of money demand (c_1). The function implies that a decrease in nominal transactions of 1 per cent would decrease short term interest rates by 0.68 percentage points.

This formulation of the interest rate reaction function means that, in the absence of exogenously imposed changes to the money supply, the default in model simulations is for monetary policy to be non-accommodating. That is, money supply grows at a constant rate equal to the underlying growth of supply plus an exogenous inflation target. The interaction of this money supply growth rule (corresponding to a medium to long run inflation target of the monetary authorities) and the quarter-by-quarter demand for money determined by the model determines the quarter-by-quarter level of short term interest rates. The money growth rule does not necessarily represent how monetary policy *would* or *should* be conducted. The main uncertainties surrounding the interest rate reaction relate to how the monetary authorities will react and whether the inverted money demand equation adequately captures the interest rate response to non-accommodated fluctuations in demand.

There is a significant degree of uncertainty over the short term response of interest rates to a demand shock. This follows from the fact that the interest rate reaction function is derived from the long run component of the money demand function. It might, thus, be regarded as a desired, or full information, response. Moreover, while monetary policy is assumed to be non-accommodating over the medium term, it might be accommodating in the short term due to lags in recognising movements in demand. Given this uncertainty over the timing of the response, a parameter called MPOLRES has been included to allow partial adjustment of short term interest rates (RI90) towards full information short term rates (RI90X). If MPOLRES is set to one then interest rates respond immediately to changes in demand. If MPOLRES is set to around 0.5, RI90 lags RI90X by one to two quarters. Values close to zero would be consistent with accommodating monetary policy in the short to medium term but with interest rates adjusting consistent with non-accommodating policy in the long run.

$$RI90 = (1 - MPOLRES) \times RI90(-1) + MPOLRES \times RI90X$$

B.5 Inflationary Expectations and the Exchange Rate

Inflationary expectations and the exchange rate are modelled assuming that economic agents display some form of forward looking behaviour. The model assumes that:

- agents in the financial market know enough about the fundamental structure of the economy to form judgements about the equilibrium exchange rate. In the short run they may make errors (sometimes systematic) but in the long run they are model consistent; and
- agents assume that the equilibrium exchange rate will be achieved within the next ten years.

B.6 Exchange Rate Identity

The exchange rate is modelled using a long run uncovered interest parity identity. This identity relates the deviation in the quarterly exchange rate from its long run equilibrium level (RETWIX) to the differential between the Australian ten year bond rate (RIGL) and that for the rest of the world (WRIGL), adjusted for the average differential between Australian and world real interest rates since the 1980s (RIP).

$$RETWI = RETWIX(+40) \times \exp \left\{ 10 \times \ln \left[1 + \frac{RIGL - WRIGL - RIP}{100} \right] \right\}$$

- In the short run, the exchange rate will jump in line with changes in ‘fundamental factors’ that affect the equilibrium exchange rate or with changes in interest rate differentials. In the absence of further shocks, it will then move in parallel with movements in long term interest differentials towards its new equilibrium level (RETWIX). Real long term bond yields, in turn, move in accordance with changes in real short term rates (as discussed in section B.8).
- In the long run, interest differentials are zero (adjusted for the historical real interest differential) and the exchange rate is at its equilibrium level.

B.7 Inflationary Expectations Identity

Inflationary expectations are formed by agents looking forward ten years to the equilibrium price level (PGNEAX), comparing this with the current level of prices (PGNEA) and then evaluating the average rate of inflation over the coming ten years.

$$FIEX = \exp \left\{ \frac{1}{10} \times \ln \left[\frac{PGNEAX(+40)}{PGNEA} \right] \right\} \times 100 - 100$$

As with the interest rate reaction, actual inflationary expectations FIE are linked to FIEX using a partial adjustment mechanism:

$$FIE = (1 - a_1)FIE(-1) + a_1 \times FIEX$$

The default value for a_1 is set at 0.9.

B.8 Ten Year Bond Yield Equation

The final component of TRYM's financial sector is the long term bond yield equation. It relates the yield on domestic ten year bonds (RIGL) to world ten year bond rates (WRIGL), world inflationary expectations (WFIE), local inflationary expectations (FIE) and domestic short term interest rates (RI90).

As a small open economy with free capital flows the world real long bond rate is the main determinant of the domestic real long bond rate in the medium to long run. For modelling purposes, an interest rate differential (RIP) has been included to take account of the apparent persistent differential between the model's measures of domestic and world real interests rates since the early 1980s. This should not be interpreted as a risk premium since the differential is likely to have been influenced by measurement problems involved in deriving world bond rates and inflationary expectations data, as well as differences in the tax on the differing inflationary component of the bond rate here and overseas. The differential has been set at 2 per cent, which is close to the average differential between the model's before tax domestic and world real bond measures since 1980.

$$\begin{aligned}
 RIGL = & RIGL(-1) + FIE - FIE(-1) \\
 & + a_1 \times [RI90 - FIE - (RI90(-1) - FIE(-1))] \\
 & + a_2 \times [WRIGL - WFIE - (WRIGL(-1) - WFIE(-1))] \\
 & + a_3 \times \{ c_1 \times RI90(-1) + (1 - c_1) \\
 & \times [WRIGL(-1) - WFIE(-1) + RIP + FIE(-1)] \\
 & - RIGL(-1) \}
 \end{aligned}$$

The equation is possibly clearer when rearranged to be expressed in real interest rate terms:

$$\begin{aligned}
 \Delta R R I G L = & a_1 \times \Delta R R I 90 \\
 & + a_2 \times \Delta W R R I G L \\
 & + a_3 \times [(W R R I G L(-1) - R R I G L(-1) + R I P) \\
 & - c_1 \times (W R R I G L(-1) - R R I 90 X(-1) + R I P)]
 \end{aligned}$$

where:

$$\begin{aligned}
 R R I G L & = R I G L - F I E \\
 R R I 90 & = R I 90 - F I E \\
 W R R I G L & = W R I G L - W F I E
 \end{aligned}$$

The equation is specified in an error correction format, explaining the real component of the nominal bond rate. Contemporaneous changes in the equilibrium domestic real short term interest rate (RI90X-FIE) and in world real bond rates have been included to provide an instantaneous reaction to any variation in domestic monetary policy and developments in world financial markets.

The equation is calibrated to emulate movements in bonds in history while preserving sensible simulation properties for the model as a whole. The error correction structure ensures that, in the absence of monetary shocks, the domestic real bond rate converges on the world real bond rate (adjusted for the differential observed in history). The model is particularly sensitive to values chosen for a_3 and c_1 . The long run parameter c_1 determines the extent to which 10 year bonds respond to movements in 90 day bill rates, while a_3 determines the speed of the response. Both could be expected to vary depending on market expectations of the likely duration of short term

interest rate movements and views about the cause of any particular movement. The difficulty in modelling long bond rates stems from the fact that these views are unobserved in history. It is difficult to gauge what information is shaping market expectations. As the long term interest rate has direct effects in the equations dealing with dwelling investment, business investment, private consumption and the exchange rate, values chosen for a_3 and c_1 (as well as those for MPOLRES above) are important for how the model responds to changes in monetary policy. Assumptions about these variables play a significant role in determining the interest rate reaction to a given shock.

Results

Parameter	Interpretation	Estimate	t-Statistic
a_1	change in RRI90X	0.150	3.67
a_2	change in world bonds	0.256	2.74
a_3	error correction	0.15	N/A
c_1	weight on RRI90X in long run	0.2	N/A

The treatment of the long term interest rate in TRYM is an important focus for further development. Recent work (not yet incorporated) has concentrated on improving the measures used for world bond rates and inflationary expectations and experimenting with various expectational assumptions in simulating the model.

APPENDIX B: RATIONAL EXPECTATIONS IN TRYM

INTRODUCTION

The TRYM model¹² has recursive (adaptive) expectations specified in the household and business sectors and “quasi-rational” expectations specified in the financial sectors. That is, financial sector agents form their expectations of the future price level and exchange rate (both ten years ahead) in a forward looking fashion. However rather than setting these expectations to be consistent with the dynamic path taken by the model, they are set at values taken from a corresponding steady state simulation.

A slight inconsistency becomes apparent when one realises that the specification of the term structure of interest rates (between ten year bonds and ninety day bank bills) has been done in a backward looking fashion. The existing specification does not ensure the equivalence in returns from investing in a sequence of ninety day bank bills for ten years with holding a ten year bond for its duration. This situation can produce unbelievable results from some shocks and forecasting applications, simply because it can lead to large and persistent arbitrage opportunities across the yield curve in the model.

It is obviously desirable to have rational expectations specified in the financial markets in particular, as this sector faces the largest monetary incentives to form accurate expectations. While the present quasi-rational specification produces accurate approximations of fully rational results under some circumstances (monetary policy shocks for example), at the other extreme can produce totally unrealistic results in other situations (a permanent change in government outlays for example). The model has been run with rational expectations using a shooting procedure in the past (see for example Ryder et. al. (1993)), but this was very time consuming and computationally cumbersome.

Given the desire to have rational expectations specified in the model as a standard option, the challenge was to find a solution method that was efficient as well as convenient to maintain. This has been achieved by following a modified version of the extended path methodology suggested by Fair and Taylor (1983) and employing a Newtonian style algorithm that uses a numerical Jacobean matrix. The practicality of this approach has been enhanced by reducing the number of observations over which the entire model must be simulated by ten years and by making some simplifying assumptions when constructing the numerical Jacobean.

When simulating the model with rational expectations the forward looking expectational variables are treated as being exogenous for each iteration of the algorithm. Therefore, a method of solving the model in a recursive fashion, that is observation by observation moving forwards through time is required. For this purpose the TRYM model is solved using the package Time Series Processor (TSP) version 4.3. Such a package also needs to be able to conduct basic matrix operations such as multiplication and inversion.

In the following section of the paper the algorithm will be briefly described, the next section will outline how the Jacobean matrix has been constructed and discuss the approximations used to reduce the number of model simulations needed to construct it. The next section describes how the terminal conditions have been treated and outlines a suggestion that reduces the number of time periods over which the model must be simulated.

¹² See The Macroeconomics of the TRYM Model (1996).

THE ALGORITHM

The model to be solved can be represented as follows;

$$y_t = f \{y_{t-1}, y_{t-2}, \dots, y_{t-h}, x_t, x_{t-1}, \dots, x_{t-m}, E_t(z_{t+s})\} \quad (1)$$

where, y_t is the vector of endogenous variables at time t,
 x_t is the vector of exogenous variables at time t,
 z_{t+a} is a subset of the endogenous variables (the expectational variables), and
 $E_t(z_{t+s})$ is the expected value of these expectational variables at time t+s, formed at time t.

In the financial sector of the TRYM model the three expectational variables (z_{t+s}) are the ten year ahead price level (PGNEA) and exchange rate (RETWI) and the ten year geometric average of the 90 day bank bill interest rate. If the average 90 day interest rate is thought of as being calculated ex poste, then all three expectational variables can be treated as looking ten years ahead of the time they are formed.

The specification of the TRYM model (with quasi-rational expectations in the financial sector) can be summarised as being eighty one identities, and twenty nine behavioural equations which are almost entirely specified as error correction models (ECMs) or partial adjustment models. Overall the model is almost linear in terms of its explanatory variables. The slight non linearities that are present come from the wages equation which is specified as an expectations augmented Phillips curve, and the unfilled vacancies, unemployment equation which influences employment and average hours worked.

The objective function to be minimised is the sum of squared expectational errors, or

$$\sum_{t=s}^n (z_t - E_{t-s}(z_t))^2 \quad (2)$$

where s is the number of time periods ahead that the expectations are looking (in TRYM s =ten years or 40 quarters).

Starting with three initial “guesses” of the paths taken by the expectational variables, the model is simulated treating these expectations as though they were exogenous. Using the results from this simulation, the expectational errors are calculated and stacked into a vector; as follows,

$$\boldsymbol{\varepsilon}^1 = \begin{bmatrix} z_t - E_{t-s}(z_t) \\ z_2 - E_{2-s}(z_2) \\ . \\ . \\ z_n - E_{n-s}(z_n) \end{bmatrix} \quad \mathbf{E} = \begin{bmatrix} \boldsymbol{\varepsilon}^1 \\ \boldsymbol{\varepsilon}^2 \\ \boldsymbol{\varepsilon}^3 \end{bmatrix} \quad (3)$$

where the superscript on \mathcal{E} denotes which of the three expectational variables the path of errors corresponds to (either the exchange rate, the price level or interest rates). The order in which the variables are stacked is irrelevant as long as it is consistent with that used when constructing the Jacobean matrix (described below).

A set of suggested changes to the paths taken by the expectational variables through the simulation period is then given by the familiar ordinary least squares regression expression;

$$\begin{bmatrix} \Delta E(z^1) \\ \Delta E(z^2) \\ \Delta E(z^3) \end{bmatrix} = (X'X)^{-1} X'E \quad (4)$$

where X is a Jacobean matrix (the construction of which is explained in the next section), and each of the three $\Delta E(Y^i)$ s represents a vector of alterations to the path taken for the corresponding (ith) expectational variable. For example;

$$\Delta E(z^1) = \begin{bmatrix} \Delta E_{1-s}(z_1) \\ \Delta E_{2-s}(z_2) \\ . \\ . \\ \Delta E_{n-s}(z_n) \end{bmatrix}. \quad (5)$$

Having obtained the set of suggested changes to the original values for the expectational variables, the first iteration of the algorithm is complete and the model can be simulated once again treating these variables as exogenous. This process is repeated until the value of the objective function has been reduced to a sufficiently small amount.

CONSTRUCTION OF THE JACOBEOAN MATRIX

The Jacobean is constructed in a fashion that minimises the number of simulations of the model required before the algorithm can be run. The Jacobean must be rebuilt every time the model's parameters are updated. Once this has been done it appears that the one matrix is sufficient to solve the rational expectations problem for any reasonable size shock, (again following from the absence of significantly large non-linearities in the model).

The first step in this process is to run a simulation of the model using any broadly sensible profiles for the expectational variables. For this purpose the original quasi-rational specification in TRYM was a good starting point. The simulation should be conducted over a sample period that is $n+s$ periods long, where n is at least twice the size of s . In this example where the expectations are formed for values ten years ahead, the simulations are run over a thirty year period.

The second step is to calculate the error vectors \mathcal{E} for each of the expectational errors, (as in equation (3) above).

$$(z_t - E_{t-s}(z_t))_{baseline} \quad (6)$$

Next, three more simulations need to be run where each of the expectational variables are altered in the first quarter by a small perturbation (by 0.01 for example). The corresponding error vectors are calculated for each of the expectational variables and numerical differentials are formed for each of the expectational variables;

$$\frac{d\epsilon_t^i}{dE_1^j} = \frac{d(z_t - E_{t-s}(z_t))}{dE_1(z_s)} = \frac{[(z_t - E_{t-s}(z_t))_{baseline} - (z_t - E_{t-s}(z_t))_{shock}]}{0.01} \quad (7)$$

where $t=1,2,\dots,n+s$
 $i=1,2,3$
 $j=1,2,3$.

It is important to note that the calculation of the derivatives includes the effect of changing one expectational variable on the errors associated with the other expectational variables. This means that in the TRYM example a total of nine numerical deviations are calculated from the four simulations conducted.

By making the assumption that the differential of the expectational errors is the same through time regardless of the state of the model eliminates the need to run any more simulations of the model when constructing the Jacobean matrix. This is equivalent to assuming that the model is linear in terms of its explanatory variables and represents a slight approximation of the true nature of the TRYM model. More formally, this assumption can be written as;

$$\frac{d\epsilon_t^i}{dE_1^j} = \frac{d\epsilon_{t+1}^i}{dE_2^j} = \frac{d\epsilon_{t+2}^i}{dE_3^j} = \dots = \frac{d\epsilon_{t+s}^i}{dE_n^j} \quad (8)$$

So far we have simulated and assumed our way to deriving a derivative vector of each expectational error with respect to a variation in each of the expectational variables, at every observation in the simulation period. All that remains is to construct the Jacobean matrix in a fashion that corresponds with the error vector, as described in equation (3). This is probably best described by breaking the matrix up into nine sub-matrices, each representing a smaller Jacobean matrix of each expectational error for a small change in either of the three expectational variables. For example the first sub-matrix would represent the change in the expectational error for the first expectational variable with respect to a change in that variable, ie;

$$X^{11} = \begin{bmatrix} \frac{d\epsilon_1^1}{dE_1^1} & \frac{d\epsilon_1^1}{dE_2^1} & \frac{d\epsilon_1^1}{dE_3^1} & \dots & \frac{d\epsilon_1^1}{dE_n^1} \\ \frac{d\epsilon_2^1}{dE_1^1} & \frac{d\epsilon_2^1}{dE_2^1} & \dots & \dots & \frac{d\epsilon_2^1}{dE_n^1} \\ \frac{d\epsilon_3^1}{dE_1^1} & \frac{d\epsilon_3^1}{dE_2^1} & \dots & \dots & \frac{d\epsilon_3^1}{dE_n^1} \\ \dots & \dots & \dots & \dots & \dots \\ \frac{d\epsilon_n^1}{dE_1^1} & \frac{d\epsilon_n^1}{dE_2^1} & \frac{d\epsilon_n^1}{dE_3^1} & \dots & \frac{d\epsilon_n^1}{dE_n^1} \end{bmatrix} \quad (9)$$

So that the first column of this sub-matrix represents the effect of changing the first expectational variable (E_1^1) in the first observation of the sample on the expectational error from that variable (ε_t^1) through the sample period.

To use an example from the TRYM context, the first number in the first column may be the impact of altering the expected future exchange rate in the first quarter, on the exchange rates' expectational error in the first quarter. The second observation in this column would then be the subsequent effect on this expectational error in the second quarter occurring from the same variation in the expected exchange rate in the first quarter.

The second column in the above example represents the sequence of effects on the expectational errors for the exchange rate through out the simulation period of altering the expected future exchange rate in the second quarter.

The next sub-matrix to the right represents the effect of a variation in the second expectational variable on the errors arising from the first. Continuing the above example, each column of this matrix would represent the effect on the exchange rates expectational errors of changing the expected future price level in each particular quarter.

$$X^{12} = \begin{bmatrix} \frac{d\varepsilon_1^1}{dE_1^2} & \frac{d\varepsilon_1^1}{dE_2^2} & \frac{d\varepsilon_1^1}{dE_3^2} & \cdot & \frac{d\varepsilon_1^1}{dE_n^2} \\ \frac{d\varepsilon_2^1}{dE_1^2} & \frac{d\varepsilon_2^1}{dE_2^2} & \cdot & \cdot & \frac{d\varepsilon_2^1}{dE_n^2} \\ \frac{d\varepsilon_3^1}{dE_1^2} & \frac{d\varepsilon_3^1}{dE_2^2} & \cdot & \cdot & \frac{d\varepsilon_3^1}{dE_n^2} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \frac{d\varepsilon_n^1}{dE_1^2} & \frac{d\varepsilon_n^1}{dE_2^2} & \cdot & \cdot & \frac{d\varepsilon_n^1}{dE_n^2} \end{bmatrix} \quad (10)$$

The overall Jacobean matrix can now be constructed by placing each of the nine sub-matrices in the positions that correspond to the elements in the error vector, as represented in equations (3) and (4).

$$X = \begin{bmatrix} X^{11} & X^{12} & X^{13} \\ X^{21} & X^{22} & X^{23} \\ X^{31} & X^{32} & X^{33} \end{bmatrix} \quad (11)$$

This matrix will be of dimension $(n \times 3) \times (n \times 3)$, which in the case of the TRYM example where the simulation period has been chosen to be twenty years long at a quarterly frequency, this matrix is quite large (240×240). The choice of sample period is crucially dependant on the distance forward through time that the expectations are looking and the treatment of the models terminal conditions.

THE TERMINAL CONDITIONS

The reader who is either very observant or familiar with rational expectations solution problems may have noticed the omission, so far, of any mention of the terminal conditions. The treatment of the terminal conditions is an interesting facet of any rational expectations solution method as it

represents a classic “chicken or the egg” problem that must be overcome for the solution method to be operational.

The problem arises because the modeller is trying to eliminate the difference between the expected future value of a variable and the actual value that the variable takes right throughout a finite simulation period. The problem is : What happens when the simulation period is almost over and the expectational variables are looking past the end of the simulation?

The treatment of the terminal conditions in the Fair Taylor Extended Path methodology is to extend the simulation path beyond the end of the desired (or original) simulation period by at least twice the length of time that the expectational variables look ahead. At the end of this simulation period it is usual practice to assume that the expectational variables and the corresponding expectations of these variables jump to their steady state values. This period at the end of the simulation period can be thought of as representing the rest of eternity as far as the simulation is concerned and must be far enough beyond the first part of the simulation to not effect the results in the original desired sample period.

In the TRYM context, this approach would imply simulating the model repetitively over a sample period that is at least thirty years long and would expand the Jacobean matrix’s dimensions to greater than (360×360) , which is beyond the limits of the TSP software used. Thus following the Extended Path approach would severely reduce the practicality of employing rational expectations in the TRYM model.

The solution adopted here is to extend the sample period by the length of time that the expectational variables look forward, ten years, and replace the following ten years worth of values for the expectational variables and their associated expectations with that suggested by reduced form expressions that replicates the model’s normal correction back to it’s steady state values after a shock. Initial trials using error correction models explaining the three expectational variables in terms of lagged dependant variables and their steady state values have proved to be quite proficient at replicating the model’s dynamics.

The three reduced form expressions for the values taken by the exchange rate, the 90 day bank bill yield and the GNEA deflator past the end of the twenty year simulation period are as follows;

$$ER_t = 1.92 \times ER_{t-1} - .92 \times ER_{t-2} + .008 \times \{ERSS_{t-1} - ER_{t-1}\} \quad (12)$$

$$RI90_t = 1.94 \times RI90_{t-1} - .94 \times RI90_{t-2} + .011 \times \{RI90SS_{t-1} - RI90_{t-1}\} \quad (13)$$

$$(\Delta \ln P_t - \text{inf}) = 1.79 \times (\Delta \ln P_{t-1} - \text{inf}) - .817 \times (\Delta \ln P_{t-2} - \text{inf}) + .0005 \times \{PSS_{t-1} - P_{t-1}\} \quad (14)$$

where ER is the exchange rate
 RI90 is the ninety day bank bill
 P is the GNEA price deflator
 inf is the steady state inflation rate
 the tag of SS represents a steady state value for that variable

These estimated parameters are from a version of the TRYM model estimated using the September quarter 1995 TRYM model data base and reflect the typically slow adjustment of the TRYM model towards its steady state growth path.

In the first run of the model with rational expectations values for the reduced form parameters reported above can be estimated from a standard deterministic simulation of the model using the quasi-rational expectations (alternatively any semi sensible numbers can be put in their place). It is then simply a matter of updating these estimated parameters using the first ten years from the first rational expectations solution. If desired, these estimates can be further refined by repeating this process until the parameter values cease to change.

Different lag structures may be required to accurately replicate a different models convergence to it's steady state growth path. The quality of this replication should be tested by dynamically simulating the reduced form equations and comparing the results with those from the full model..

CONCLUSION

Given the desire to specify rational expectations in the TRYM model as a standard option a practical method of solving the model with rational expectations has been suggested in the TSP operating environment.

This approach greatly reduces the number of simulations needed to construct the numerical Jacobean matrix used by the algorithm. This matrix only needs to be rebuilt when the models parameters or specification are altered. The method also reduces the size of the simulation period required to insulate the sample period of interest from the effects of eventually jumping to the models terminal conditions.

Whilst the computational costs of constructing and running the algorithm have been reduced to a minimum, initial trials on the TRYM model using several different parameter and data sets suggest the convergence properties of the algorithm are quite respectable, with convergence typically being achieved within four to ten iterations.

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The only practical difference is that a price level target yields a greater penalty on variation in inflation. For example a given deviation on the inflation rate maintained over a number of quarters will yield a far greater deviation on the price level. There are parallels here with the Hodrick Prescott (HP) filter. In the case of a HP filter if a sufficiently high weight/penalty (λ) is put on the acceleration term (in this case variation in inflation) then the estimated trend will collapse to the OLS line (in this case the implied price level target). That is, the higher the penalty on variation in inflation from the average inflation target the smaller the deviation from the implied price level target.