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Rational Versus Anchored Traders: Exchange Rate Behaviour in Macro Models

By Peter John Marshall

The following alterations to this thesis should be noted:

p. 1 (footnote 1) should read:

See Edey and Romalis (1996) for a summary of the problems in macro models.

p. 11 (footnote 7) should read:

See Froot and Thaler (1990) for an overview of the forward discount bias. For empirical evidence see, for example, Fama (1984) or Taylor (1995).

p. 19 (paragraph 3, sentence 2) should read:

The average bias of market participants' expectations, however, is very small.

p. 106 Lag weighting function should read:

Lag weighting function $\varphi_t = R\, e^{-\rho t}$ $\rho \geq 0$

p. 121 Page duplicated

p. 171 (Figure 8.7.12) omit from legend:

rgl – simulated (TRYM93)

p. 195 Reference (Neale, Northcraftm G.B. and M.A. (1987)). should read:

Northcraft, G.B. and M.A. Neale (1987). "Experts, Amateurs and Real Estate: An Anchoring-and-Adjustment Perspective on Property Pricing Decisions". *Organisational Behaviour and Human Processes* 39:84-97.

pp. 192-196 References should include:

Allen, H.L. and M. P. Taylor (1990). "Charts, Noise and Fundamentals in the Foreign Exchange Market". *Economic Journal* 100(400):49-59.

Powell, A.A.L. (2000). "From Dornbusch to Murphy: Stylized Monetary Dynamics of a Contemporary Macroeconometric Model". *Journal of Policy Modeling* 22(1):99-116.

Taylor, M.P. and H.L. Allen (1992). "Use of Technical Analysis in the Foreign Exchange Market". *Journal of International Money and Finance* 11(3):304-14.

Rational versus Anchored Traders: Exchange Rate Behaviour in Macro Models

A Thesis Submitted for the Degree
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in Economics

by

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Abstract of Thesis
Rational versus Anchored Traders:
Exchange Rate Behaviour in Macro Models

A serious problem in macroeconometric models is the failure to satisfactorily explain the behaviour of exchange rates. The exchange rate is a key variable in the monetary transmission process, as well as an important factor in the implementation of fiscal policy. The failure of exchange rates to follow a prescribed path has serious policy implications for both monetary and fiscal policy.

The role of expectations in the formation of exchange rates is paramount affecting real aspects of the economy. In recent years it has become standard procedure to model the exchange rate using rational expectations. This thesis incorporates a non-fully rational framework for the exchange rate based on work done by Gruen and Gizyki[1] from the Reserve Bank of Australia. Their framework has two types of traders: rational and anchored. An anchored trader makes forecasts about the future exchange rate by using an initial reference point and making adjustments as additional information is assimilated.

From the series of miniature models based on the original Gruen and Gizycki framework that are developed and enhanced, the role of inertia is examined. Inertia in this sense means that the long-run equilibrium is not immediately attained after a shock to the economy. By introducing anchored traders, a form of inertia is added directly to the financial sector. It is found that inertia entering through the financial sector can have the same qualitative effects on the economy as inertia (such as sticky prices) entering through the real side of the economy.

The essence of the anchored traders' framework is incorporated into TRYM[2] by using a scaling factor. It is shown that by varying the proportion of anchored traders' in the economy that the direction of the jump in the exchange rate in response to a monetary or fiscal shock can be reversed. This thesis demonstrates that the presence of anchored traders can - at least in part - explain the seemingly anomalous behaviour of the exchange rate that is sometimes referred to as "market euphoria".

The final part of the thesis involves an historical validation of TRYM where the modified exchange rate formulation is tested to see whether it improves the modelling of the exchange rate. It was shown that it was possible to improve the fit of the exchange rate using the scaling factor, suggesting that a foreign exchange market is better modelled when the presence of anchored traders is taken into account.

[1] Gruen, D. W. R. and M. C. Gizycki (1993), "Explaining Forward Discount Bias: Is It Anchoring?", Reserve bank of Australia Research Discussion Paper no. 9307.

[2] TRYM is the Treasury Macroeconomic Model of the Australian Econonmy. The version used in this thesis is from Taplin, Bruce, Paddy Jilek, Lawrence Antioch, Andrew Johnson, Priya Parawmeswaran and Craig Louis (1993) "Documentation of the Treasury Macroeconomic (TRYM) Model", Australian Treasury, Canberra; paper presented to the June 1993 Treasury Conference on the TRYM Model of the Australian Economy; TRYM Paper No. 2.

Statement of Authorship

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or equivalent institution, and that to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

......[redacted]

(Peter John Marshall)

Date: 15. 05. 01

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Chapter 1

Introduction

One of the major problems in macroeconometric models is the unexplained (or at a minimum, poorly explained) behaviour of the exchange rate[1]. The exchange rate is a key variable in the monetary policy transmission process[2], as well as an important factor in the implementation of fiscal policy.

The standard theoretical assumption that links exchange rates and interest rates is the uncovered interest parity (UIP) condition[3]. UIP establishes a relationship between interest differentials and expected exchange rate movements. However, the empirical evidence regularly dismisses this simple relationship, rejecting the joint hypotheses of rational expectations and uncovered interest parity. Hence there is compelling evidence that, at least in the short run and possibly the medium/long run, the financial markets fail this condition.

The failure of exchange rates to follow a prescribed path has serious policy implications for both monetary and fiscal policy. As demonstrated in simulations of fiscal restraint with the Monash model by Dixon et al. (1996), the dynamics of the exchange rate after a shock have significant short run and long run effects on real variables in the economy. In their simulations, Dixon et al. assume that real public expenditure in Australia is reduced by 0.91 per cent for 8 quarters and then held permanently at 7.3 per cent below control. This corresponds to the $8 billion in expenditure cuts

[1] See Edey (1996) for a summary of the problems in macro models.
[2] See Grenville (1995) for an overview of the monetary policy transmission process.
[3] UIP is discussed further in chapter 2.

planned in 1996-7 and 1997-8 by the Howard government. The authors run two simulations and compare outcomes to a base case forecast.

In the first simulation it is assumed that market participants immediately understand that the nominal and real values of the domestic currency will fall (and that they do so). In the second scenario, it is assumed that participants do not immediately accept that the domestic nominal exchange rate ($ foreign per $ AU) will fall — in fact, the authors assume that the instantaneous reaction is a 2 per cent increase in the nominal value of the domestic currency. Under this scenario the warranted nominal exchange rate devaluation is only recognised after 8 quarters at which time there is an instantaneous devaluation, whereas in the first simulation, rational expectations apply where the fall is immediate.

Due to the delay in recognising the real effect of the budget cut on the exchange rate there will be real effects on the economy in the short to medium term as well as in the long term. For example, due to forcing the two simulations to have the same terminal net foreign debt to GDP ratio, the nominal exchange rate in the second simulation falls lower in the long run. This is because in the short run real aggregate consumption in the second simulation is significantly positive compared to control whereas in the first simulation consumption is marginally negative. The delay in understanding the implications of the fiscal shock means that the eventual improvement in the trade account in the second simulation is larger than is evident in the simulation corresponding to immediate understanding. This reflects the need to compensate for the extra debt accrued in the initial stages of the second simulation.

These simulations, although ad hoc in their descriptions of exchange rate behaviour, illustrate the need to correctly specify and model exchange rates in the short to medium run. The implementation of different intertemporal paths for the expectations of exchange rates affects real variables; hence it is important to attempt to specify marketplace behaviour realistically in order to ensure reliable and consistent policy recommendations.

Expectations play an important role in the formation of exchange rates. Until the 1960s, expectations were assumed to be formed adaptively. The introduction of rational expectations[4] transformed economic modelling, especially of the financial sector. Once rational expectations became the logical starting point for formulating expectations, research either tended to accept rational expectations uncritically or (less frequently) proposed alternative expectation mechanisms that then had to be defended against rational expectations as the default.

This leads into the Gruen and Gizycki (G&G)(1993) framework. This thesis is based on work done by David Gruen and Marianne Gizycki of the Reserve Bank of Australia who developed a model in which heterogeneous agents can coexist indefinitely. Their framework is based on the 1976 rational expectations Dornbusch[5] "overshooting" model.

Using the Dornbusch framework, G&G introduce agents who are not fully rational in the sense that they do not avail themselves of all the available information in forming their expectations. Agents may not be fully rational as they are continuously required to make complex forecasts and to facilitate these forecasts a series of heuristics (rules-of-thumb) are used[6]. One of these heuristics is known as anchoring (or Anchoring and Adjustment).

Anchoring suggests that people form estimates by starting from an initial reference point, from which they make adjustments in the light of additional information. This behaviour has been shown empirically to result in a bias towards the starting point (or anchor). When agents use an anchor, there can either be a resultant systematic error or a situation in which agents eventually fully adjust to the "correct" level. In G&G's world the latter never happens because agents have finite lives.

[4] Muth (1961), Lucas (1976).
[5] Dornbusch (1976).
[6] Tversky and Kahneman (1974) is the seminal work in this area and provides an analysis on behavioural heuristics including "anchoring".

Gruen and Gizycki have developed an operational model that uses the forward discount rate as an anchor for predicting the future exchange rate[7]. The use of the forward discount rate as an anchor for some of the agents in the foreign exchange market leads to a possible explanation of the forward discount bias[8]. The introduction of verified psychological behaviour provides a way to explain the behaviour of the exchange rate in a non-ad-hoc manner.

The ultimate aim of this thesis was to implement the Gruen and Gizycki concept within a large macroeconometric model; namely, the Australian federal Treasury's TRYM[9]. Unfortunately, the G&G framework could be made not entirely compatible with TRYM. Hence the essence of the anchored traders' framework is incorporated into TRYM by using a simple heuristic (a time-varying scaling factor which modifies the behaviour of the exchange rate directly). The latter captures the essence of the G&G story by increasing the inertia of the exchange rate. This allows the exchange rate in the modified TRYM to diverge somewhat from its characteristic jumping behaviour as driven by its Dornbusch underpinnings.

Once the above modification is made to TRYM, the implications of the additional friction on TRYM's behaviour can be assessed when the economy is subjected to a monetary or fiscal shock. Of course, the interpretation that the origin of the changed brehaviour is the existence of anchored traders is not unique — other hypotheses may generate the same or very similar behaviour. The remainder of this chapter lays out the structure of the thesis.

Chapter 2 provides an overview of the current state of exchange rate models as well as providing a brief summary of the main parity conditions utilised in constructing them. The forward discount bias phenomenon and the efficiency of the foreign exchange market are examined. The central role of expectations in the formation of the exchange rate is discussed. In

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[7] The Gruen and Gizycki model is elaborated in Chapter 3.

[8] Discussed in chapter 2.

[9] Taplin et al (1993).

particular, the increasing use of rational expectations in economic modelling over the last 20 years is examined. Finally, recent developments in exchange rate models and expectations theory are briefly discussed.

Chapter 3 further discusses the development of theories of how agents form expectations and how foreign exchange participants use short-cuts to form expectations that sometimes result in systematic errors[10]. The concept of anchoring is explored and the foundations of the G&G model are established. In the latter part of the chapter, the intricacies of the G&G framework are exposited in detail.

In chapter 4 the prototype models that are used later in the thesis are presented and discussed. Two relatively simple models are used: the 1976 Dornbusch overshooting model; and an extended version of the Dornbusch model that is solved numerically, and dubbed the Extended Dornbusch model[11]. This extended Dornbusch model allows for ad-hoc cycles, which are generated to facilitate calibration to a large macroeconometric model.

The anchored model of G&G is specified formally and solved within Excel in chapter 5. The simulation properties of the closed form model are discussed. A numerical algorithm is devised to replicate the behaviour of the exchange rate in the G&G model by combining the extended Dornbusch[12] model and the Anchored model. The properties of this algorithm are discussed.

Chapter 6 extends the Anchored model to include the real exchange rate (RER) in the domestic demand function[13]. This is done to ensure compatibility with the larger macroeconometric models. By combining the Anchored-RER model and the extended Dornbusch model, the integrated Extended Gruen and Gizycki (EGG) model is established.

In chapter 7 the properties of EGG are discussed and compared to the properties of extended Dornbusch. The different types of inertia that exist in

[10] Tversky and Kahneman (1974).
[11] Powell and Murphy (1995).
[12] This represents the scenario where agents form their expectations rationally.
[13] This variable is omitted from G&G's formulation in order to simplify the mathematics and allow for a closed-form solution to be derived.

the EGG model are examined and the inertia variables in EGG are compared to the variables causing inertia in extended Dornbusch.

Chapter 8 starts with a brief outline of the TRYM model. There follows a series of simulations. The introduction of the scaling factor into TRYM is explained and the properties of the exchange rate and other variables are discussed when the economy is subject to a random shock. A permanent monetary shock and a temporary fiscal shock are applied to TRYM. A brief analysis of these shocks is given; then the impact of G&G type behaviour is demonstrated. This is followed by an historical validation of TRYM as a prerequisite to establishing whether adding the G&G ideas to TRYM helps or hinders its historical tracking performance. Here it is assumed that all future values for exogenous variables are known and TRYM produces results for the endogenous variables. This illustrates how accurate the model is in replicating history given the values for all forward exogenous variables. Finally a comparison is made between the within-sample tracking performance of standard TRYM and its modified TRYM counterpart.

Chapter 2

The Determination of Exchange Rates

2.1 Introduction

This chapter provides a synoptic overview of the conceptual basis of exchange rate determination. It also reviews the main models used to determine exchange rates. The first section reviews and discusses the basic parity conditions: purchasing power parity; uncovered interest parity; and covered interest parity. The second section looks at the efficiency of exchange rate markets and discusses the forward rate bias phenomenon. The third section exposits the main models that are used to analyse exchange rates. The final section gives a brief discussion of the way exchange rates are modelled in TRYM.

2.2 Parity Conditions

Three arbitrage conditions enter the thought on exchange rates. These three conditions are: purchasing power parity (PPP); covered interest parity (CIP); and uncovered interest parity (UIP). Each of these parity conditions is considered below in turn.

Purchasing Power Parity

The link between national price levels and exchange rates has been made for centuries, but the concept was formalised by Gustav Cassel in the early part of the twentieth century[1]. He coined the phrase purchasing power parity. The concept of PPP is divided into two areas. The first is absolute purchasing power parity. This implies that the exchange rate is equal to the ratio of the two relevant national price levels:

[1] Cassel (1918).

$$S = P/P^* \tag{2.1}$$

where S is the nominal exchange rate, P is the national price level and P^* is the price level in the foreign country. The relative PPP concept states that the exchange rate should have a constant proportional relationship to the ratio of the two national price levels:

$$S = k\, P/P^*, \tag{2.2}$$

where k is some constant positive parameter. In logarithmic form we have the relationship:

$$s = \alpha + p - p^*, \tag{2.3}$$

where s, p, p^* and α are the logarithms of S, P, P^* and k. When absolute PPP holds, $\alpha = 0$[2]. For relative PPP, α would be non-zero ($\alpha \in (-\infty, \infty)$; $\alpha \neq 0$).

Whilst it is a fact that for either of the above equations a change in the ratio of price levels means an equiproportionate change in the exchange rate:

$$\Delta s = \Delta p - \Delta p^*, \tag{2.4}$$

relative PPP has come to be synonymous with this interpretation. Thus relative PPP states that (in proportional terms) changes in the exchange rate are equal to relative changes in national price levels.

Given estimates of the exchange rate in the form:

$$s = \alpha + \beta p + \beta^* p^* + u \tag{2.5}$$

a test of the restrictions $\beta = 1$ and $\beta^* = -1$ is a test of relative PPP. A test that $\alpha = 0$ as well as the prior two restrictions on β is a test of absolute PPP. A variable closely related to PPP is the real exchange rate stated here in logarithmic form:

$$\tau = s - p + p^* \tag{2.6}$$

where τ is the real exchange rate. From (2.3) it is clear that τ can be interpreted to be a measure of the deviation of the nominal exchange rate from absolute PPP. It is also worth noting that this relationship (2.6) implies

[2] Note that absolute PPP assumes that there is an appropriate set of units in which to measure national outputs and their prices. Note also that from a modern (Armington) perspective this is problematical since even if some common physical unit for measuring domestic and foreign output (tonnes, say) existed, the two goods would not be perfect substitutes, and so absolute parity makes little sense.

that the real exchange rate is time invariant. It is the concept of relative PPP that is considered useful, but even this relationship is considered to have major deficiencies[3].

The first of the major difficulties with PPP is that both traded goods are used in the formation of PPP but countries also produce non-traded goods such as services. A second difficulty exists in that PPP will not hold continuously due to factors such as transportation costs, capital flows, and government intervention. Hence at best PPP will hold in the long-run and is not a reliable indicator of the exchange rate in the short term.

Direct evidence on the validity of the relative PPP in the short-run is unequivocally negative. The PPP is not an indicator of the nominal exchange rate in the short-run. In the long run the evidence is less clear. Tests on equation 2.5 are only one of four main ways PPP has been tested[4]. None of these tests is conclusive in determining the relationship between national prices and the exchange rate in the long-run.

Covered Interest Parity.

Covered interest parity (CIP) is considered to be the least controversial of the three parity conditions considered here. It states that if there are no barriers to arbitrage across borders in international financial markets, then arbitrage should ensure that for similar assets, the interest differential across the two countries should be equal to the difference between the same period forward rate and the spot rate such that[5]:

$$f_t - s_t = i_t - i_t^*, \tag{2.7}$$

where f_t is the one period ahead forward rate, s_t is the spot rate and i_t and i_t^* are the interest rates for the domestic and the foreign countries respectively. In this form, we have the difference of the logarithms of the forward rate and

[3] See for example Froot and Rogoff in Grossman and Rogoff (1995) for a discussion on PPP.
[4] For a summary of the various tests see, MacDonald and Taylor (1990) or Isard (1995).
[5] This relationship is an approximation. $(1+i) = (1+i^*)F/S = (1+i^*)(1+(F-S)/S) = (1+i^*)(1+fd) = (1+i^* + fd + i^*fd)$. As the cross term is very small, we have the relationship $i - i^* = fd = f - s$.

the spot rate (known as the forward discount (or premium if positive)) equal to the inter-country interest differential.

With the major impediments to the empirical truth of CIP consisting of capital immobility, transaction costs and credit risk, we would expect CIP to be more and more likely to hold continuously as capital becomes increasingly mobile and transaction costs fall. This is indeed the case and recent work bears out this result[6]. Hence for all but the most volatile times in the market, CIP holds continuously, implying that there are few direct arbitrage opportunities left unexploited.

Uncovered Interest Parity

Related to CIP is Uncovered Interest Parity (UIP). UIP incorporates the expected value of the future spot exchange rate. The expected capital gains (or losses) from holding one currency rather than the other, in proportional terms is equal to the opportunity cost from holding one set of funds rather than the other set of funds. This opportunity cost is the difference between the interest rates for the two countries' respective assets. We have:

$$E_t s_{t+1} - s_t = i_t - i_t^* \qquad (2.8)$$

$$E_t s_{t+1} - s_t = fd_t \qquad (2.9)$$

$$E_t s_{t+1} = f_t \qquad (2.10)$$

where fd_t is the forward discount and $E_t s_{t+1}$ is the expected value at time t of the spot rate at time t+1. Equation (2.8) is a behavioural assumption that leads into (2.9) through the CIP definition above. Hence the result is that the expected value at time t of the spot rate at time t+1 is the forward rate, f_t.

Hence the expected one period ahead exchange rate is equal to the forward rate. This relationship becomes central when it is predicated on the notion that the expected future spot rate is a predictor of the actual rate.

[6] Taylor (1987, 1989) found that CIP held in all but the most turbulent times. Factors such as credit limits between banks caused short deviations in turbulent times. This is also borne out in that the longer maturity arbitrages were more likely to show a deviation due to the riskier credit rating the longer the maturity of the asset.

This leads into one of the puzzles of the foreign exchange rate market: the Forward Discount Bias.

2.3 Foreign Exchange Market Efficiency – Forward Discount Bias

In the above form of UIP we assume that agents are risk neutral and that if agents hold rational expectations, then UIP will hold. Hence a test of UIP will be a test for risk neutrality and rational expectations jointly.

Because expectations are not directly observable, the most common test for market efficiency has used a regression equation of the form:

$$\Delta_k s_{t+k} = \alpha + \beta(fd_k) + \mu_{t+k} \tag{2.11}$$

where Δs_{t+k} is the change in the spot exchange rate for k periods ahead, α is a constant, fd_k is the forward discount for k periods ahead and μ_{t+k} is an error term.

This regression involves assuming CIP holds – thus the interest differential equals the forward discount. Under rational expectations, the expected change in the exchange rate should vary from the forward discount only by a white noise error term (that is, μ_{t+k} should be white noise).

If agents are risk neutral and have rational expectations, the β parameter should equal 1, and the error term should be uncorrelated to information at time t.

The evidence against this joint hypothesis is overwhelming with β less than 1 in nearly all studies, and frequently $\beta < 0$[7]. The explanations of this anomaly fall into three broad categories. First is the idea that there are time varying risk premia between currencies[8]. The second does not require the rejection of either the UIP hypothesis or the rational expectations hypothesis but relies on explanations that include peso problems and simultaneity

[7] See Froot and Thaler (1990) for an overview of the forward discount bias. For empirical evidence see for example Hodrick (1992), Fama (1984) or Taylor (1995).

[8] This is a failure of the UIP hypothesis with rational expectations still holding.

bias[9]. The third category is a failure of the rational expectations hypothesis with the implication that agents form expectations in some other manner.

If foreign exchange traders are risk averse, UIP may have to be modified to include a time varying risk premium, because traders demand a higher return to compensate for the risk of holding foreign currency. Moreover, to bring the modified UIP into concordance with observed data, the risk-premium needs to vary over time. Hence we have an equation of the form:

$$\Delta_k s^e_{t+k} = fd_k + \xi_t. \qquad (2.12)$$

If the risk premium, ξ_t, is time varying and correlated with the forward discount (or interest differential), the efficiency tests will be distorted[10]. The evidence on this solution to the forward discount bias has been consistently weak and the solution appears to lie in other approaches[11].

The second category includes explanations such as the so-called "Peso problem"[12]. Here the argument is that even if expectations are formed rationally, the restriction of finite data sources means that the forward discount can be a biased predictor of the future spot rate. This occurs where foreign exchange agents attach a small probability to a large deviation in economic conditions that does not eventuate within the finite sample that is under examination[13]. This creates the conditions for a sudden loss of confidence in one of the currencies that may be triggered by extraneous happenings.

Other phenomena within this category include rational bubbles[14], information processing difficulties[15], and the process of rational learning[16].

[9] See for example Taylor (1995) pp 16-17.
[10] See Fama (1984). Distorted here means that although in repeated samples the tests will be unbiased, the tests become sensitive to sampling fluctuations.
[11] See Froot and Frankel (1989), Hansen and Hodrick(1980), Bilson(1981), Hodrick(1987).
[12] The Peso problem refers to the 1976 devaluation of the Mexican Peso.
[13] For a discussion on the Peso problem, see Frankel and Froot (1987). Also Krasker (1980).
[14] Sometimes referred to as self-fulfilling prophecies. See Flood and Hodrick (1990).
[15] Bilson (1981).
[16] Lewis (1988,1989).

In this case agents do not have full knowledge and make repeated mistakes about the new paradigm that is in place after a government policy shift or a structural shift in the economy.

The final category to explain the forward discount bias is a breakdown of rational expectations in the foreign exchange market. To facilitate the discussion on rational expectations, the next section provides a brief overview of rational expectations and expectations in general.

2.4 Expectations

Expectations are ubiquitous in macroeconomics. Agents are continually required to form expectations about future events and economic variables. Until the 1960s, expectations of the future were commonly modelled extrapolatively. The forecasts of an extrapolative forecaster have the property that the forecast at t-1 of Y_t is based on past values of actual Y_t[17]. Hence with the forecast denoted as Y^e_{t-1t}, a commonly used formulation is:

$$Y^e_{t-1t} = a_1Y_{t-1} + a_2Y_{t-2} + a_3Y_{t-3} + ... \tag{2.13}$$

where a_1, a_2, a_3 are weights. A special case of this general form is first order adaptive expectations:

$$Y^e_{t-1t} = (1 - \alpha)(Y_{t-1} + \alpha Y_{t-2} + \alpha^2 Y_{t-3} + ...) \text{ where } \quad 0 \leq \alpha \leq 1. \tag{2.14}$$

Even though this form was commonly used, it was essentially an ad-hoc specification, with little theoretical basis. As well, this extrapolative method is purely backward looking basing all future behaviour on actual past behaviour.

A form of adaptive expectations derived from (2.14) is:

$$(Y^e_{t\,t+1} - Y^e_{t-1\,t}) = (1 - \alpha)(Y_t - Y^e_{t-1\,t}) \qquad 0 \leq \alpha \leq 1 \tag{2.15}$$

This formulation states that agents simply revise their expectations by a fraction $(1 - \alpha)$ of the previous forecast error, $(Y_t - Y^e_{t-1\,t})$. Extreme cases of this behaviour would be where $\alpha = 0$, then $Y^e_{t\,t+1} = Y_t$, and where $\alpha = 1$ where

[17] This section draws heavily on Leslie (1993).

agents do not adjust their expectations. Hence $(1 - \alpha)$ measures the degree to which agents adapt their expectations in light of the actual outcomes.

This approach was very appealing because the expected price level was a weighted average of past levels of the economic variables in question that were observable. Although this framework has some plausible properties, it has certain deficiencies. Most importantly, it may ignore information that is relevant.

Rational Expectations

Rational Expectations[18] is taken to mean the efficient use of all relevant available information. Hence there are no systematic errors and it is not possible for agents to improve their forecasts with the information at hand.

Consider a basic model:

$$Y_t = \alpha + \beta X_t \qquad (2.16)$$

where Y_t is the variable to be explained by the model (the endogenous variable) and X_t's explanation lies outside the model (the exogenous variable). The actual value of Y at time t is realised by adding a constant α to the product of β times X_t. We have an expectation or forecast of Y_t denoted as $E_{t-1}Y_t$ where the forecast is made at t-1. $E_{t-1}Y_t$ is any forecast of Y_t, whereas the rational expectations forecast is derived in a particular manner.

Let $E^R_{t-1} X_t$ be the rational expectations forecast of X_t. Then the rational expectations prediction by the model of Y_t is:

$$E^R_{t-1} Y_t = \alpha + \beta\, E^R_{t-1} X_t\,. \qquad (2.17)$$

[18] Muth (1961) is acknowledged as placing Rational Expectations on the map.

The simplicity and intuitive appeal of rational expectations has caused a minor revolution in macroeconomic modelling. In essence it just states that expectations in the model are consistent in the sense that, provided no new information comes to hand, agents' expectations of future events are fulfilled by the model outcomes. In stochastic models this statement need only be true up to an inherently unpredictable white noise error. Hence rational expectations are sometimes referred to as model consistent expectations.

The forecast error under rational expectations is:

$$Y_t - E^R_{t-1} Y_t = \beta \, (X_t - E^R_{t-1} X_t) \tag{2.18}$$

If this forecast error is zero – that is, the actual outcome equals the forecast – then this is referred to as perfect foresight.

With rational expectations becoming a benchmark or starting point for modelling expectations, there has been widespread debate on whether rational expectations hold or not; and if rational expectations are not valid empirically, on which other formulation should be used.

Rational expectations are appealing in that expectations are usually unobservable and rational expectations provide a coherent and relatively simple way of embedding forward looking behaviour into economic models (although the econometric and computational problems involved can be formidable). Voluminous research has gone into attempts to prove or disprove the empirical relevance of the rational expectations theory.[19]

Rational expectations propose how agents would behave in an ideal world – one in which (a) all agents share the stock of information relevant to the future; (b) in which the investigator's model is known and credible to all agents; and (c) in which the model correctly describes the data generating process that applies in the real world. As well, since information garnering and processing is not costless, satisficing (rather than optimising) behaviour

[19] See Leslie (1993) for discussion on rational expectations. For a related example, see Ericsson and Irons (1995) on the Lucas critique.

may be rational. Empirical failure of rational expectations could be due to any or all of these factors. So empirical testing of rational expectations in many markets indicates that agents seemingly form their expectations in a sub-optimal extrapolative manner. It seems there are elements of forward looking and backward looking expectations in most agents. Rational expectations nevertheless remain a very useful tool in that expectations of many variables in the economy – especially in the financial markets – have a forward looking component. This leads us to consider what is known about agents' actual expectations.

In an article by Frankel and Froot (1987), survey data is used to test investors' expectations. These authors suggest a series of simple models of expectation formation listed below[20]:

Static Expectations: $S^e_{t+1} = S_t$

Distributed Lags: $S^e_{t+1} = (1 - \beta)S_t + \beta S_{t-1}$ $\quad 0 < \beta < 1$

Adaptive Expectations: $\Delta S^e_{t+1} = \gamma(S_t - S^e_t)$ $\quad 0 < \gamma < 1$

Regressive Expectations: $S^e_{t+1} = (1 - \alpha)S_t + \alpha S^n_t$ $\quad 0 < \alpha < 1$

where S^n_t is the normal or long-run equilibrium exchange rate for time t.

Bandwagon Expectations: $\Delta S^e_{t+1} = \theta \Delta S_t$ $\quad \theta > 0$

Adaptive bandwagon: $\Delta S^e_{t+1} = \lambda(S^e_t - S_t) + \alpha \Delta S_t$

Frankel and Froot assessed the goodness of fit of these simple expectation models against actual data. They also tested whether expectations are formed rationally[21]. The general conclusion is that expectations change over time and that none of these models are devoid of systematic expectational errors. They conclude that expectations are not static and are likely to be characterised by heterogeneity.

[20] Maddala (1991).

Heterogeneous Agents

If there are heterogeneous expectations among foreign exchange agents, is there are a way to categorise these different types of agents? One way to differentiate among them was suggested by Frankel and Froot (1990b): that traders can be divided into either fundamentalists or chartists. Chartists (also known as technical traders) tend to forecast by extrapolating recent trends and use charting rules. Frankel and Froot offer evidence from survey data suggesting that foreign exchange agents use technical analysis to forecast short horizons whilst using a long-run equilibrium concept to forecast the long horizon. This dichotomy could reflect the specialisation of different traders in either long- or short-horizon transactions; or the same traders might behave differently according to the horizon of the transaction. With the marketplace consisting of both types of behaviour, the question to be asked is: what percentage of each type exists in the foreign exchange market? Unfortunately, even if these two types of trader/behaviour accurately reflect reality, the proportion would undoubtedly change over time. Frankel and Froot (1990) illustrate this by the fact in that in 1978, 19 out of 23 forecasting firms described themselves as fundamental forecasters whilst in 1988 only 7 out of 31 forecasters said they relied solely on fundamentals to forecast the exchange rate. Frankel and Froot conclude this article with:

> "In short, it may indeed be the case that shifts over time in the weight that is given to different forecasting techniques are a source of changes in the demand for dollars, and that large exchange rate movements may take place with little basis in macroeconomic fundamentals." (pp 184-5.)

[21] This is similar to the literature where expectations are measured by the forward exchange rate but here there is no issue of a risk premium. See Frankel and Froot (1987).

This dual approach to expectations is similar to the approach taken by Gruen and Gizycki, where there exist two types of traders: anchored and rational. As will be explained later in chapter 6, the proportion and characteristics of these two types of traders can change over time.

Survey Data

As mentioned above, survey data of expectations was used to analyse market participants' expectations. This trend to use survey data allows researchers to differentiate between the joint tests for a risk premium and rationality that exists when the forward discount is used as the predictor of the future exchange rate. But survey data sets are not without their problems[22], not the least being that participants have no incentive to be truthful. The majority of literature concerning surveys of expectations aims to ascertain whether the agents' expectations are rational. The two standard tests of rationality ask: Is the expected exchange rate an unbiased predictor of the future exchange rate? and: Does the expected exchange rate fully incorporate all currently available information? In general, most studies[23] reject the proposition that the expectations of the surveyed traders are unbiased and conclude that the expected exchange rate does not incorporate all available information.

The survey data may be used to perform the same regression as in equation (2.11) except that $\Delta_k\, s_{t+k}$ – the change in the log spot price of foreign exchange – is replaced with $\Delta_k\, s^e_{t+k}$ – the average rate of change expected by market participants over the next k periods[24]:

$$\Delta_k\, s^e_{t+k} = \gamma + \delta(fd_k) + \mu_{t+k} \quad . \qquad (2.11.a)$$

[22] Takagi (1991) presents a review on survey studies and discusses the problems inherent in survey data sets.
[23] Dominguez (1986), Ito (1990), Takagi (1991), Frankel and Froot (1990).

The evidence from Froot and Frankel shows that estimates of δ are consistently greater than zero and often insignificantly different from one.

Taking equations (2.11) and (2.11.a) together gives:

$$s_{t+k} - s^e_{t+k} = (\alpha - \gamma) + (\beta - \delta)(fd_k) + \mu_{t+k} - v_t \qquad (2.11.b)$$

The empirical evidence strongly suggests that $(\beta - \delta) \neq 0$. Hence there is unutilised information available at time t, namely the value of fd_k, that helps to forecast the prediction error, $s_{t+k} - s^e_{t+k}$.

The expectations data from surveys[25] and the time series exchange rate data indicate that the average exchange rate expectations are correlated with the forward discount rate. The average bias of market participant's expectations, however, is very small. The fact that there is large volatility and heterogeneous expectations ensures that this persistent bias is not readily discernible. As will we see in chapter 3, Gruen and Gizycki appeal to the psychology literature to explain this small bias.

2.5 Exchange Rate Models

The previous section dealt with how expectations are formed in the foreign exchange market. This section looks at the basic models used to try to explain how exchange rates are formed.

Despite intensive efforts to adequately model the exchange rate, economists have found the task frustratingly elusive. In the early stages of exchange rate modelling, the exchange rate was seen as a result of the interaction of demand and supply for the currency. This reflected the need for foreign exchange to facilitate international trade transactions. This view of the exchange market was in response to the extensive capital controls

[24] See Froot and Frankel (1989).
[25] Smith and Gruen (1989).

that were only gradually relaxed after the collapse of the gold standard in the early 1970s.

This reliance on the demand and supply for foreign exchange to finance international trading transactions is known as the flow approach as developed by Meade (1951)[26]. These ideas were further developed by Mundell (1963) and Fleming (1963). Their model, now known as the Mundell-Fleming model[27], was an example of the flow approach to the formation of exchange rates. With the floating of the exchange rate and the relaxation of capital controls, the flow approach was considered inadequate in that it does not account for stock equilibrium[28]. This led to the stock – or asset – approach to the exchange rate.

The asset approach to the determination of the exchange rate can be divided into 3 categories: the monetary (flexible prices) model; the sticky price monetary model; and the portfolio balance model.

Monetary Models – Flexible Prices

The flexible price monetary model concentrates on only two assets, domestic and foreign money. Implicit in this framework is the perfect substitutability of domestic and foreign bonds.

In the flexible price monetary model, the exchange rate is the relative price of two monies and this framework tries to equilibriate this price (the exchange rate) in terms of the relative supply and demand for the countries' respective currencies[29]. This model is essentially a continuous purchasing power parity model of the exchange rate; it also relies on the quantity theory of money within which money demand functions are stable.

In each country, the demand for real money is modelled as positively related to real income (representing transactions demand) and negatively

[26] For earlier work on exchange rates, see, for example Isard (1995) pp. 90-96 which describes the "elasticities" approach and the "absorption" approach.
[27] See Powell and Murphy (1995) for a succinct description.
[28] Taylor (1995), McDonald and Taylor (1992).
[29] Frenkel (1976), Mussa (1976) for examples of monetary models.

related to the interest rate (representing the opportunity cost of interest foregone on bonds that could otherwise be held). Hence:

$$m_t = p_t + ky_t - \theta i_t \qquad (2.19)$$

$$m_t^* = p_t^* + k^* y_t^* - \theta^* i_t^* \qquad (2.20)$$

where m_t is money demand, p_t the price level, y_t real income and i the interest rate[30]. The * notation reflects the foreign country equivalent of the above variables. As stated before, PPP holds continuously, so

$$s_t = p_t - p_t^* \qquad (2.21)$$

This results in the fundamental equation of the monetary flexible price framework:

$$s_t = m_t - m_t^* - ky_t + k^* y_t^* + \theta i_t - \theta^* i_t^* \qquad (2.22)$$

This equation states that a relative rise in the domestic money supply ($\Delta m_t > \Delta m_t^*$) will result in an increase in s_t; that is, a depreciation in the domestic currency. A relative increase in domestic income ($k\Delta y_t > k^*\Delta y_t^*$) appreciates the currency (s_t falls). In a similar vein, a relative rise in the domestic interest rate ($\theta\Delta i_t - \theta^*\Delta i_t^*$) will result in a depreciation of the home currency.

A significant flaw of the monetary model is the assumption that purchasing power parity holds continuously. This means that the real exchange rate must always be constant[31]. The empirical evidence on real exchange rates is in conflict with the assumption of fixed real exchange

[30] variables in logarithms, except interest rates.
[31] This must hold by definition. The real exchange rate is the nominal exchange rate adjusted for national price levels.

rates in the monetary model, leading to a second generation of monetary models lead by Dornbusch (1976)[32].

Monetary Models – Sticky Prices

Dornbusch's (1976) framework is known as the overshooting model, as exchange rates instantaneously overshoot their new equilibrium levels in response to an unexpected monetary shock. This model is built on three main assumptions: perfect capital mobility (uncovered interest parity), slow domestic goods price adjustment; and perfect certainty. This concept of perfect certainty is very important to the Dornbusch model and is stressed because the overshooting path of the exchange rate is a rational response by the foreign exchange traders to the given scenario. In fact the overshooting path of the exchange rate is the only possible equilibrium path available in the model.

Briefly, the concept behind the overshooting model is simple. Say that the domestic money supply is cut. Sticky goods prices mean an initial fall in the real money supply and a resultant rise in interest rates to clear the money market. Simultaneously and instantaneously the rise in interest rates attracts foreign capital and causes an instantaneous appreciation in the nominal exchange rate (with sticky prices, for a time this means a commensurate rise in the real exchange rate). Foreign exchange traders are aware that they have forced the nominal exchange rate beyond its equilibrium value and that they will probably suffer a loss when converting the domestic currency back to their own currency. But as long as the expected foreign exchange loss (expected rate of depreciation of the domestic dollar) is less than the gain from the interest differential, risk neutral traders will hold the domestic currency.

The currency has instantaneously overshot its long-run (PPP) equilibrium level at the instant that the market learnt of the previously

[32] The Dornbusch "overshooting model" is discussed in further depth in chapter 4 as it provides the framework for the Gruen and Gizycki model.

unexpected cut in the money supply. As domestic prices fall, the real money supply increases and the exchange rate slowly depreciates (at a rate governed by the rate of adjustment of the price level in the goods market) until the nominal exchange rate establishes the long-run PPP level.

The Dornbusch model was a big step forward in the explanation of exchange rate behaviour. It helped explain excess volatility[33] in the foreign exchange market and provided a basis to explain temporary changes in the real exchange rate.

But the overshooting Dornbusch model has been criticised in that it focuses on equilibrium conditions in the market for just one asset: money. Hence it is essentially a monetary model which requires the assumption of perfect substitutability across non-money assets. Relaxing the latter assumption leads into the portfolio balance approach to exchange rate formation.

The Portfolio Balance Approach

At its simplest the portfolio balance approach[34] has two financial assets and two countries. The key feature is the assumed imperfect substitutability between domestic and foreign assets. This means that uncovered interest parity will not hold and must be replaced by an equation such as, $i - i^* - \Delta s^e = \lambda$, where λ is a risk premium. An overview of the portfolio balance approach is given with reference to the following equations[35]:

$$W = M + B + SF \qquad (2.23)$$

$$M = M(i, i^* + \Delta s^e)W \qquad M_1 < 0, M_2 < 0 \qquad (2.24)$$

$$B = B(i, i^* + \Delta s^e)W \qquad B_1 > 0, B_2 < 0 \qquad (2.25)$$

$$SF = F(i, i^* + \Delta s^e)W \qquad F_1 < 0, F_2 > 0 \qquad (2.26)$$

[33] Excess volatility refers to the extra volatility exists beyond the amount explained by standard theories.
[34] For early work see Kouri (1976), and Branson (1977).
[35] Time subscript omitted to ease exposition.

Equation 2.23 is an identity defining wealth, where W is private sector wealth, M is domestic money, B is domestically issued government bonds and F is foreign bonds valued in the foreign currency. As before, S is the spot exchange rate (domestic dollars per foreign dollar). Subscripts on M and B indicate partial derivatives. To achieve equilibrium, the exchange rate adjusts investors' portfolios mix of domestic money and domestic and foreign bonds.

In the short run (in which financial wealth is held constant), the exchange rate is determined by supply and demand for financial assets. However, the exchange rate is also a key determinant of the current account. A current account surplus is reflected by a rise in domestic holdings of foreign assets, which affects wealth that in turn affects the exchange rate. The portfolio balance includes asset accounts, the current account, the price level and the rate of asset accumulation. The attainment of equilibrium can be seen as a dynamic process.

The demand for money, (2.24), is dependent on domestic interest rates and is also related to the foreign interest rate augmented by the expected rate of depreciation of the domestic currency. Similarly, the demands for domestic and foreign bonds, (2.25) and (2.26), reflect their dependence on the domestic and foreign interest rates and the expected rate of depreciation of the domestic currency.

This model provides a relatively basic framework for analysis of the effects of monetary policy on the exchange rate. For example, contractionary monetary policy reduces financial nominal wealth (2.23) and reduces the demand for domestic and foreign bonds. A reduction in the money supply will raise interest rates and as foreign bonds are sold, the domestic currency appreciates.

Summary of Exchange Rate Models

The early models of the exchange rate concentrated on the current account of the balance of payments, emphasising elasticities to determine the exchange rate. The basic tenet of the elasticities approach is that the values of imports and exports are sensitive to real exchange rates in combination with the notion that a country's international trade is linked to national income. This concept is at the centre of current account discussion in the modern era. However this approach, although providing the basis for current work on the current account balance, falls short in helping explain exchange rate behaviour. The ground breaking development of Mundell and Fleming is the recognition that international capital movement and the behaviour of exchange rates should be integrated into open-economy macroeconomics. However their treatment of the asset market equilibrium fell short, paving the way for the development of a series of asset equilibrium models.

Models of asset stock equilibrium can be broadly classified into two camps: the monetary approach where bonds are regarded as perfect substitutes or the portfolio balance approach where bonds are imperfect substitutes leading to a risk premium. These two classes of models provide the basis of new and current work in the explanation of exchange rate models.

2.6 Performance of Exchange Rate Models

The performance of the various exchange rate models has been divided into two approaches: in-sample analysis and out-of-sample performance.

In-sample analysis of an exchange rate model is performed to test whether the relationship between an economic variable and the exchange rate is in line with that predicted by the model. Also, in-sample analyses test how much the variables in aggregate explain the variation in the exchange rate within the sample under analysis. The performance of all the models depends greatly on the particular sample and good and bad results are possible to find for all models. However none of the aforementioned models show any consistency in their in-sample results across different currencies and through different time periods[36].

A stronger test of the performance of exchange rate models is the out-of-sample performance of the model. This is achieved by testing the forecasting performance of the models in comparison to an alternative. The seminal contribution of Meese and Rogoff (1983) compared various exchange rate models to the alternatives of the random walk model, the forward exchange rate, a univariate autoregression of the spot rate and a vector autoregression. The outcome of the Meese and Rogoff experiment was that none of the asset based exchange rate models outperformed a simple random walk model. This was seen as a major setback for work in exchange rate modelling and consequently triggered a large amount of research analysing the implications of this result.

The message seems to be that in times of relative stability – in that the structural characteristics underlying the model are stable – and when the forecasting horizon is relatively long, macroeconomic models of exchange rates utilising historical data may be useful in forecasting exchange rates. But in times of high volatility and structural change, other factors dominate.

2.7 Developments in Exchange Rate Models

The broad conclusion is that asset based exchange rate models have performed erratically in recent years. This may be due to simple misspecification of the models so that more elaborate versions of the abovementioned models may provide the answers to modelling exchange rates. However, despite numerous attempts at extending these models, little improvement has been reported. These developments in exchange rate

[36] For an overview of the performance in-sample see Taylor (1995).

models coincided with an improvement in econometric techniques including error correction mechanisms, cointegration and systems approaches to modelling exchange rates. These developments have improved the knowledge and analysis of the macroeconomic fundamentals underlying the exchange rate. However, the empirical literature demonstrates that there are often large, counterintuitive and persistent movements in exchange rates in contradiction to the economic fundamentals.

This again leads us to the area of heterogeneous expectations as discussed before. This area of the literature is expanding and examples may be found in diverse fields including market microstructure and behavioural finance.

Behavioural finance examines the behaviour of agents in the finance area including the foreign exchange market and there is an increasing trend to examine the particular behavioural characteristics of sections of the finance community. Market microstructure, as the name suggests, is concerned with the marketplace at a more disaggregated level. One driving force behind the development of this field has been the desire to understand the mechanism driving the deviation of exchange rates from their economic fundamentals. Central to much of the market microstructure literature is heterogeneity of expectations. Within this discipline work on the exchange rate is trying to explain the short-run behaviour of the exchange rate using heterogeneous expectations for agents whilst keeping in place the economic fundamentals in regard to the long-run.

This divergence of expectations in the short-run should help us to rationalise past behaviour of exchange rates. However, the ability to predict short-term exchange rate behaviour may prove elusive due to the fact that foreign exchange agents constantly change the way they form expectations in the marketplace. As well the particular mix of agents (i.e. the proportion of chartists or fundamentalists operating in the market at any one time) will be in a constant state of flux.

In the analysis Gruen and Gizycki, "anchoring" provides the heterogeneous expectations. In concordance with previous work in "nonfundamental" analysis[37], Gruen and Gizycki have two types of trader that have different expectations in the short-run, but share the same long-run expectations of the exchange rate.

[37] See Frankel and Froot (1987,1990), Allen and Taylor (1990), De Long et al (1987), Taylor and Allen (1992).

Chapter 3

The Gruen and Gizycki Model

Chapter 3.a

The Foundations of the Gruen and Gizycki Framework

3.a.1 Introduction

As we have seen in the previous chapter, the rise of rational expectations has been followed by discussions on its failure to hold in certain circumstances. This observation is certainly not new but has been formalised in response to the rational expectations revolution. Irrational episodes in history have been common where prices have reached ludicrous and unsustainable levels. The classic example is the 17^{th} century episode in the Netherlands where tulip prices went to astronomical levels. In more recent times, the 1987 October share crash provides another example of irrational pricing. As well, the excess volatility exhibited by these episodes is hard to explain with standard efficient market models.

The analysis of irrational agents has been predicated on anecdotal evidence, not relying on psychological evidence. For example, the chartists and fundamentalists described by Frankel and Froot (1990) are chosen for illustrative purposes rather than for their realism. Gruen and Gizycki have introduced the behavioural heuristic - anchoring – to help explain the behaviour of the exchange rate.

3.a.2 Anchoring

Each day people are required to make numerous decisions. Many of these decisions are based on beliefs concerning uncertain outcomes. Sometimes we have certain numeric odds on which to base our judgement;

however commonly most of our judgements are based on a limited number of behavioural heuristics – or rules-of-thumb – which reduce the complex task of analysing the problem at task. These heuristics simplify the process but they can also lead to systematic and substantial errors[1]. These heuristics include availability, representativeness and anchoring[2]. Anchoring, also referred to as anchoring and adjustment, is where people make estimates by starting from an initial reference value (the anchor) and adjusting from this reference point as information is processed. Thousands of examples of anchoring have been presented in the literature. A simple example is shown by asking the questions[3]:

Is the population of Turkey greater than 35 million?

What's your best estimate of Turkey's population?

The first question is asked to half the sample respondents, but the other half is asked the same question with 100 million substituted for 35 million. Both parts of the sample are asked the second question. Invariably the half given the 100 million anchor estimate the population of Turkey to be higher.

This bias extends to experts in their field as demonstrated by Northcraft and Neale (1987) in an experiment involving real estate agents. Examples of anchors can be found in most academic fields. In economic forecasting, Lawrence and O'Connor (1992) have discovered examples of anchoring.

The dangers of the anchoring and adjustment heuristic depends primarily on the way the anchor is chosen. This is illustrated in our example above where the anchors for the population of Turkey were chosen

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[1] The seminal work in this area is Tversky and Kahneman (1974). Another early work is Slovic and Lichtenstein (1971).
[2] Representativeness is used when people need to assess the probability that an event or an object belongs to a particular process or class. Availability is used when people need to assess the frequency of a class or the plausibility of a particular development. See Tversky and Kahneman (1974) for detailed descriptions of these heuristics.
[3] Hammond, Keeney and Raffia (1998).

arbitrarily. The anchor is a judgemental strategy that is made on the available cues and information.

The forward exchange rate qualifies as an anchor as to how foreign exchange participants form their view of the future exchange rate. The forward exchange rate is the price paid now in local currency for foreign currency to be delivered at a set future date. Thus the forward exchange rate is an obvious reference point for agents who need to forecast the future value of the spot exchange rate.

3.a.3 Assumptions of the Gruen and Gizycki model[4]

There are two open economies that have an exchange rate that is market driven. Analysis focuses on the smaller of the two countries. Foreign prices and interest rates are constant and the small country assumption is used so that the foreign interest rate is given. Locally, supply is fixed and there is no long-run growth in prices or money supply. Covered interest parity holds at all times.

To help understand the process that occurs in this model, the following is an intuitive description of the market reaction to an unanticipated expansion in the domestic money supply for both types of traders: anchored and rational. Immediately before the shock, the economy is in long-run equilibrium and with risk-neutral agents, the domestic and foreign interest rates are equal.

To help exposition, we can think of the monetary expansion occurring in two stages.[5] In the first stage, the monetary expansion occurs through government intervention, the domestic interest rate falls instantaneously to clear the domestic money market and the forward rate changes to satisfy

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[4] Gruen and Gizycki (1993) pp 9-13.

[5] In recent years, central banks have adopted the short-term interest rate as their main policy instrument, and an activity variable such as nominal GNE as their target, rather than following a monetary rule. These two approaches are closely related. The difference between them can involve no more than the addition of one extra equation (a policy reaction function) that is used to substitute out the stock of money. For example see the discussion of Murphy's New Zealand Model (NZM) by Powell (2000).

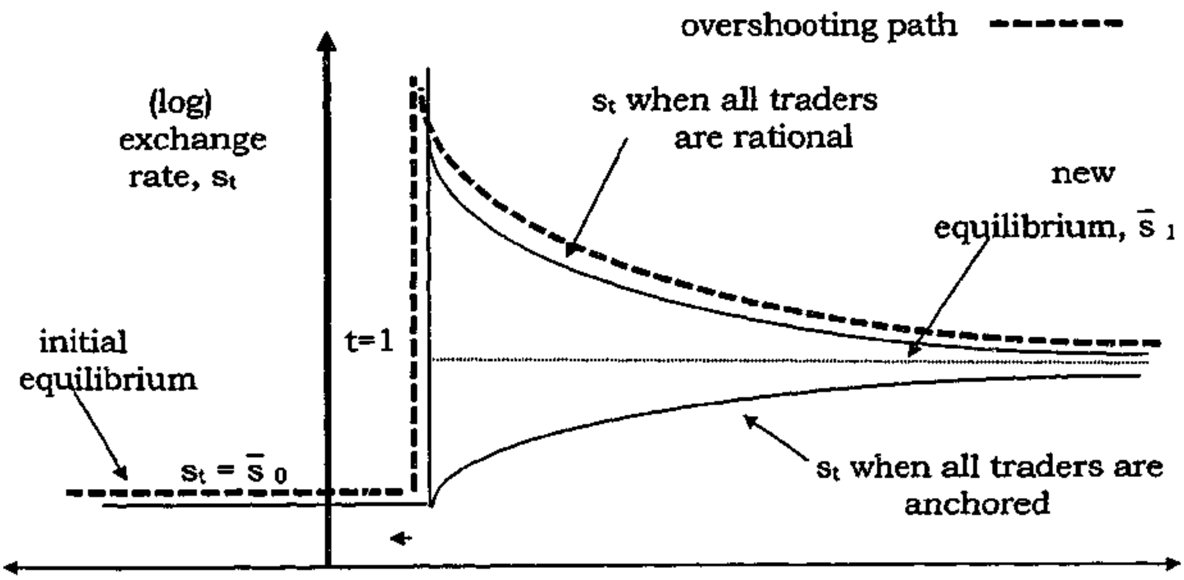
covered interest parity. However the spot exchange rate is unmoved. The second stage involves the spot exchange rate, forward rate and the domestic interest rate moving to equilibriate the market.

In the Gruen and Gizyki world, the first stage is identical for both types of traders, but the second stage differs. In the Dornbusch model, where we have all rational traders, the exchange rate overshoots its new equilibrium position due to the stickiness of goods prices.

In contrast when the foreign exchange market consists of anchored traders only, the exchange rate does not follow the overshooting path. This is because these traders' expectation of the one-period-ahead spot rate is equal to the current corresponding one-period forward rate. These traders do have a target level for the equilibrium exchange rate that is the same long-run equilibrium level as for the rational traders. Hence after a monetary shock, there is no jump in the spot exchange rate which follows a monotonic adjustment path to the new long-run equilibrium.

Figure 3.a.1

Exchange rate response to an unanticipated domestic monetary expansion



In diagram 3.a.1, both paths for the exchange rate are illustrated. In either case, the initial and new equilibrium level of the exchange rate is the same. The dashed line shows the path the exchange rate takes in Dornbusch's rational traders world. The exchange rate representing the anchored traders does not jump when the monetary shock occurs but follows a monotonic path to the new equilibrium level. The anchored traders are unaware of the excess return that is available and follow the simple path to the new equilibrium.

Obviously, if traders lived long enough to extract all of the available signal from a notoriously noisy market, the market could not contain anchored traders as they would learn from their mistakes over time and would capture all available profits by turning themselves into rational traders. However, given that there is large volatility in the foreign exchange market and the nominal exchange rate is subjected to continual shocks, it is believable that a persistent, albeit small, bias in expectations could exist permanently. This is the view taken by Gruen and Gizycki and demonstrated numerically in their simulations of a mixed foreign exchange market, in which both types of traders, rational and anchored, persist indefinitely.

3.(b.) Mechanics of Gruen and Gizycki Model

3.b.1 Reduced form of the G&G model.

The model of G&G is initially based on the seminal paper of Dornbusch (1976). G&G make several simplifying assumptions whilst retaining key elements of the Dornbusch model. These elements are that the model retains exchange rate overshooting and no forward rate discount bias when there exists a completely rational and risk neutral market. The simplifying assumptions are introduced to facilitate exposition. Further to the assumptions discussed in the previous chapter, an LM curve is assumed of the form,

$$m_t - p_t = \phi \bar{y} - \lambda i_t. \qquad (3.b.1)$$

This LM curve includes the assumption of fixed domestic supply $\bar{y}$, leaving only the interest rate and prices to adjust to shocks to the money supply. As well, it is assumed that the shocks to the money supply are independent across periods. The demand function takes a simplified form of the corresponding Dornbusch model equation:

$$\ln(D_t) = \xi + \delta \bar{y} - \sigma i_t. \qquad (3.b.2)$$

Excluded from this demand function is the real exchange rate. (The complete relative price expression is simplified by normalising the foreign price level to one ($P^*=1$, $\ln P^*=p^*=0$)). In line with the initial model of Dornbusch, domestic supply is considered constant. The Phillips curve gives the result:

$$\Delta p_{t+1} = \pi \ln(D_t/Y_t) = \pi(\xi + (\delta-1)\bar{y} - \sigma i_t). \qquad (3.b.3)$$

This reflects one of the cornerstones of the Dornbusch overshooting model: the assumption that goods prices do not adjust instantaneously to excess demand.

Under special assumptions[1], the domestic interest rate, i, will equal the foreign interest rate, i^*. In long run equilibrium, $p_t = \bar{p}_t$, and the long run LM curve is;

$$\bar{p}_t = m_t + \lambda i^* - \phi\bar{y} . \qquad (3.b.4)$$

When the long run LM curve is subtracted from its short-run counterpart (3.b.1), the result is

$$p_t - \bar{p}_t = \lambda\ (i_t - i^*). \qquad (3.b.5)$$

In the long run $\Delta p = 0$; hence substitution of this result into (3.b.3) results in:

$$\xi + (\delta - 1)\ \bar{y}\ = \sigma i^*. \qquad (3.b.6)$$

This is a constraint between $\bar{y}$ and i^*, two variables exogenous to the model. This constraint is required due to the dropping of the dependence of demand on the real exchange rate. This leads to the equation

$$\Delta p_{t+1}\ = -\ \lambda\ (i_t - i^*)/\theta\ , \qquad \text{where } \theta = \lambda/(\pi\sigma) > 0. \qquad (3.b.7)$$

In terms of the dynamics of the model, the result for θ is important. Theta (θ) is dependent on lambda (λ), which is the semi-elasticity of demand for money with respect to the interest rate; on sigma (σ), the semi-elasticity of aggregate demand (reflecting investment's sensitivity to the interest rate) and on pi (π), the rate at which prices adjust to excess demand. From equation (3.b.7) it can be seen that $1/\theta$ is the rate at which goods prices adjust to money shocks.

In the long run, money neutrality leads to:

$$\bar{p}_{t+1} = \bar{p}_t + v_{t+1}, \qquad (3.b.8)$$

where v_{t+1} is the (permanent) monetary shock. In the analysis below it is assumed that there is just one such shock which impinges at the

[1] These assumptions will be clarified later in the chapter.

beginning of t+1. Equation (3.b.8) means that in the long run, the price level will change by the shock applied to the money supply. The interest differential equation is derived from the core equations (which are repeated below for convenience):

$$p_t - \bar{p}_t = \lambda\,(i_t - i^*) \tag{3.b.5}$$

$$p_{t+1} - \bar{p}_{t+1} = \lambda\,(i_{t+1} - i^*)\,, \tag{3.b.5a}$$

$$\Delta p_{t+1} = p_{t+1} - p_t = -\lambda\,(i_t - i^*)/\theta\,, \tag{3.b.7}$$

$$\bar{p}_{t+1} = \bar{p}_t + v_{t+1}\,, \tag{3.b.8}$$

Substitute (3.b.7) and (3.b.8) into (3.b.5.a) to obtain:

$$p_t - \bar{p}_t - \lambda\,(i_t - i^*)/\theta - v_{t+1} = \lambda\,(i_{t+1} - i). \tag{3.b.9}$$

Now use (3.b.5) in the preceding equation, and solve for $(i_{t+1} - i^*)$:

$$(i_{t+1} - i^*) = (i_t - i^*)(1 - 1/\theta) - v_{t+1}/\lambda. \tag{3.b.10}$$

Equation (3.b.9) illustrates both the initial reaction (jump) of interest rates to a monetary shock as well as the path back to equilibrium. The initial jump can be easily seen in that before the shock there is equilibrium, hence $i_t = i^*$ and the jump is $- v_{t+1}/\lambda$. After the initial jump, the path of the interest differential is determined by the rate at which prices adjust, $1/\theta$. The interest rate path is independent of whether there are rational or anchored traders in the market. As can be seen by equation (3.b.10), the interest rate path is only dependent on θ, v_{t+1} and λ. This is because we have assumed that, at all times, the economy is on the IS, LM and Phillips curves. These equations are assumed to always prevail in the economy, hence the interest rate can only follow the path that these equations determine.

The interest rate path has the general form:

$$(i_{t+j} - i^*) = (i_t - i^*)(1 - 1/\theta)^j - v_{t+1}/\lambda(1 - 1/\theta)^{j-1} \tag{3.b.11}$$

where $j = 0,1,2.....T$.

From this one can see that where there is initial equilibrium, the first term of the right hand side will equal zero as $i_t = i^*$. At the instant at which the shock v_{t+1} impinges, j=1; thus the second part of the RHS equals - v_{t+1}/λ (the interest differential jump). As $j \to \infty$, the effect of the shock on the interest rate decays to zero, illustrating that the long run interest rate remains equal to i*.

Having established the behaviour of prices and of interest rates, we can now proceed to develop the behaviour of the nominal exchange rate. First, we can define $\bar{s}_t$ as the equilibrium value of the nominal spot rate s_t (foreign currency per local dollar). The equilibrium real exchange rate is defined as $\bar{s}_t - \bar{p}_t$. It is assumed that the exchange rate follows a random walk with shocks e_{t+1};

$$(\bar{s}_{t+1} - \bar{p}_{t+1}) = (\bar{s}_t - \bar{p}_t) + e_{t+1} \quad e_{t+1} \sim iid(0, \sigma_e^2) \qquad (3.b.12)$$

The standard deviation of the long run real exchange shocks, σ_e, is calibrated using observed data and it is assumed that both rational and anchored traders understand the properties of real exchange rate shocks. The equations (3.b.7,8,9 & 12) account for the stochastic properties of the foreign exchange market.

In this model, there exist the two types of traders, anchored and rational. Rational traders are assumed to have full knowledge of the market and behave accordingly. On the other hand, anchored traders' expectations are adaptive:

$$E_t^a(s_{t+1}) = f_t - \beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)], \qquad \beta > 0 \quad (3.b.13)$$

These expectations involve two important behavioural assumptions. The first assumption is that the forward rate, f_t acts as an anchor for the one-period-ahead spot rate. The second assumption is that anchored traders understand that the long-run real exchange rate has changed and they know its value. The anchored traders use this value as the target level for the real exchange rate. If the real exchange rate is not at the target level, anchored traders' expectations follow an adaptive path, adjusting at the rate β from the anchor (the forward rate, f_t) towards their target level of the real exchange rate.

3.b.2 Traders' asset demand function

All investors must entrust their financial wealth to one of the types of traders, rational or anchored. The traders then choose the proportion of domestic to foreign assets to be held. In this they act as honest and well-informed agents for their clients, fully internalising the utility function of the investors. Thus they use the same coefficient of relative risk aversion, γ, and the same consumption bundle proportions as those of the investors when making decisions about portfolio management. As all investors have the same coefficient of relative risk aversion and the same consumption bundle, then in this respect there is no difference between the two types of traders.

The consumption bundle consists of a constant share g of foreign goods and (1-g) of domestic goods. Each period, the traders optimise portfolios, trading mean against variance in accord with their clients' preferences.

W_t is the real wealth a trader holds in period t and x_t is the proportion of W_t that is held in the foreign asset. The real rates of return to the domestic and foreign assets are r^d_{t+1} and r^f_{t+1} with $z_{t+1} = r^f_{t+1} - r^d_{t+1}$ as the difference between the rates return on the two assets. Real wealth in period t+1, W_{t+1} is accumulated from its previous value according to:

$$W_{t+1} = W_t + r^d_{t+1}(1-x_t)W_t + r^f_{t+1} x_t W_t,$$

$$W_{t+1} = W_t(1+x_t z_{t+1} + r^d_{t+1}).$$

Thus wealth in period W_{t+1} can be seen as composed of initial wealth, the excess return of foreign interest bearing assets held by the trader and the initial wealth W_t multiplied by the domestic rate of return.

As stated, traders maximise a function of expected value and variance of the end of period real wealth, $F(E_t(W_{t+1}),V_t(W_{t+1}))$. We want to maximise the function, $F(\bullet,\bullet)$ with respect to x_t conditional on the available information set. This results in:

$$x^k_t = -(V^k_t z_{t+1})^{-1} Cov^k_t (z_{t+1} r^d_{t+1}) + (\gamma V^k_t z_{t+1})^{-1} E^k_t z_{t+1}.$$
$$k = a,r \qquad (3.b.13a)$$

This solution is derived as follows:

First we need to evaluate the first order conditions:

$$\frac{\partial F}{\partial x_t} = F_1 \frac{\partial E_t(W_{t+1})}{\partial x_t} + F_2 \frac{\partial V_t(W_{t+1})}{\partial x_t} = 0,$$

where F_1 and F_2 respectively are the derivatives of F with respect to expected wealth and variance. Below we use the idea that from the viewpoint of the operators $E_t(\bullet)$ and $V_t(\bullet)$, wealth in t, W_t, is given and non-stochastic.

Consider $\quad E_t(W_{t+1}) = E_t(W_t) + W_t x_t E_t(z_{t+1}) + W_t E_t(r^d_{t+1});$

$$\Rightarrow \quad \frac{\partial E_t(W_{t+1})}{\partial x_t} = 0 + W_t E_t(z_{t+1}) + 0.$$

Consider $\quad V_t(W_{t+1}) = V_t(W_t + W_t x_t z_{t+1} + W_t r^d_{t+1}),$

$$= V_t(W_t x_t z_{t+1} + W_t r^d_{t+1}),$$

$$= W_t^2 x_t^2 V_t(z_{t+1}) + W_t^2 V_t(r^d_{t+1}) + 2W_t^2 x_t Cov_t(z_{t+1}, r^d_{t+1}).$$

$$\Rightarrow \frac{\partial V_t(W_{t+1})}{\partial x_t} = 2W_t^2 (x_t Vt(z_{t+1}) + Cov_t(z_{t+1}, r^d_{t+1})),$$

$$\Rightarrow F_1 W_t Et(z_{t+1}) = -2F_2 W_t^2 x_t V_t(z_{t+1}) - 2F_2 W_t Cov_t(z_{t+1}, r^d_{t+1}).$$

Solving for x_t:

$$x_t = (F_1 Et(z_{t+1}) + 2F_2 W_t Cov_t(z_{t+1}, r^d_{t+1}))/ (-2F_2 W_t V_t(z_{t+1})).$$

Substituting in the coefficient of relative risk aversion $\gamma = -2 \frac{F_2}{F_1} W_t$ gives:

$$x_t^k = -(V_t^k z_{t+1})^{-1} Cov_t^k (z_{t+1}, r^d_{t+1}) + (\gamma V_t^k z_{t+1})^{-1} E_t^k z_{t+1}, \quad k = a,r \quad (3.b.14)$$

where k is notation for either anchored (a) or rational (r) traders.

The next step is to simplify (3.b.14) by obtaining operationally useful approximations for the moments appearing on its right. The real domestic rate of return is given by:

$$r^d_{t+1} = (1+i_t) P_t^C / P^C_{t+1} - 1. \quad (3.b.15)$$

P_t^C is a consumer price index for domestic residents based on the investors' consumption basket. To understand this equation we can start by expressing the real rate of return on the domestic asset, r^d_{t+1} as the nominal rate of return less the rate of inflation for the relevant price index:

$$r^d_{t+1} = i_t - \frac{d}{dt} \ln P_t^C,$$

$$\approx (1+i_t)(1-\Delta P^C_{t+1}/P^C_t) - 1,$$

$$= (1+i_t)(P^C_{t+1}/P^C_t) - 1. \qquad (3.b.16)$$

The excess real foreign return, z_{t+1} is given by:

$$z_{t+1} = [(1+i^*)(S_{t+1}/S_t) - (1+i_t)]\,(P^C_{t+1}/P^C_t). \qquad (3.b.17)$$

Investors spend a constant fraction g of their consumption on foreign goods; hence P^C_t is represented by a Cobb-Douglas price index;

$$P^C_t = (P^*_t\ S_t)^g(P_t)^{1-g}, \qquad (3.b.18)$$

in which $P^*_t S_t$ represents the price of foreign goods in domestic dollars. A first-order Taylor's approximation is then used to obtain an expression for the rate of inflation of consumer prices in terms of inflation of the price of the domestic good and of the rate of exchange rate appreciation;

$$P^C_t/P^C_{t+1} \approx 1 - g\Delta s_{t+1} - (1-g)\Delta p_{t+1} \qquad (3.b.19)$$

This is an approximation and is derived as:

$$P^C_t/P^C_{t+1} \approx P^C_t / \{P^C_t(1+\Delta \ln P^C_t)\}$$

$$= 1/(1+\Delta \ln P^C_t)$$

$$\approx 1-\Delta \ln P^C_t \qquad (3.b.20)$$

Using (3.b.18) and substituting into (3.b.20);

$$P^C_t/P^C_{t+1} = 1-g\Delta \ln P^*_t - g\Delta \ln S_t - (1-g)\,\Delta \ln P_t$$

$$= 1- g\Delta s_{t+1} - (1-g)\,\Delta p_{t+1} \qquad (3.b.21)$$

The small country assumption that P* is a constant exogenous variable has been used to infer that $g\Delta \ln P_t^* = 0$. By substituting (3.b.21) into (3.b.16), the result is:

$$r_{t+1}^d \approx i_t - g\Delta s_{t+1} - (1-g)\,\Delta p_{t+1}$$

(3.b.22)

Assuming that $\Delta p_{t+1} << \Delta s_{t+1}$, we can approximate (3.b.17) by:

$$z_{t+1} \approx i^* - i_t + \Delta s_{t+1} \qquad (3.b.23)$$

where we have neglected the term $i^*\Delta s_{t+1}$ because it is of smaller order of magnitude than the other terms. The right hand side of equation (3.b.23) is composed of two components; the first, $i^* - i_t$, is the interest rate differential, whilst the second component Δs_{t+1} can be interpreted as capital gains due to exchange rate movements. Thus the excess return, z_{t+1} is a combination of these two components. From these two approximations ((3.b.22) and (3.b.23)), it is possible to derive the covariance of z_{t+1} with r_{t+1}^d.

$$\begin{aligned}
Cov_t(z_{t+1}, r_{t+1}^d) \approx\ & E_t(i^* - i_t + \Delta s_{t+1} - E_t(i^*) + E_t(i_t) - E_t(\Delta s_{t+1}))\times \\
& E_t(i_t - g\Delta s_{t+1} - (1-g)\,\Delta p_{t+1} - E_t(i_t) + gE_t(\Delta s_{t+1}) + (1-g)E_t\,\Delta(p_{t+1})) \\
=\ & E_t\,(\Delta s_{t+1} - E_t(\Delta s_{t+1}))\times \\
& E_t((-g)(\,\Delta s_{t+1} - E_t(\Delta s_{t+1})) - (1-g)(\Delta p_{t+1} - E_t\,\Delta(p_{t+1})) \\
=\ & -gV_t(\Delta s_{t+1}) - (1-g)Cov_t(\Delta s_{t+1}, \Delta p_{t+1}).
\end{aligned}$$

For $\Delta p_{t+1} << \Delta s_{t+1}$, $|Cov_t(\Delta s_{t+1}, \Delta p_{t+1})| << V_t(\Delta s_{t+1})$, so that the covariance between the excess real foreign rate of return and the corresponding domestic rate may be approximated by:

$$Cov_t(z_{t+1}, r_{t+1}^d) \approx -gV_t(\Delta s_{t+1}) \qquad (3.b.24)$$

Note that from the viewpoint of the operator V_t^k, all t-subscripted variables are non-stochastic, so that $V_t^k(\Delta s_{t+1}) \equiv V_t^k(s_{t+1} - s_t) \equiv V_t^k(s_{t+1})$

Also recall that whilst the nominal exchange rate, s, is a jumping variable in this Dornbusch style framework, the domestic price is not. However the nominal exchange rate is much more volatile than the price level, and the variance of the nominal exchange rate is closely approximated by that of the real exchange rate, σ_e^2, for both rational and anchored traders; thus $V_t^k(\Delta s_{t+1}) \approx \sigma_e^2$. Hence

$$Cov_t(z_{t+1}, r_{t+1}^d) \approx -g\,\sigma_e^2 . \qquad (3.b.25)$$

Now recall equation (3.b.14):

$$x_t^k = -(V_t^k z_{t+1})^{-1} Cov_t^k(z_{t+1} r_{t+1}^d) + (\gamma V_t^k z_{t+1})^{-1} E_t^k(z_{t+1}) .$$

and substitute in the approximations, (3.b.25) and (3.b.23). In light of the fact that $V_t^k(z_{t+1}) \approx V_t^k(s_{t+1})$ (which is implied by equation (3.b.23)). We now make the following substitutions into (3.b.14):

- for the covariance term, we use (3.b.25);
- for the variance term, we substitute the last line of:

$$\begin{aligned} V_t^k(z_{t+1}) &= V_t^k(\Delta s_{t+1}) \\ &= V_t^k(s_{t+1}) \\ &\approx \sigma_e^2 ; \end{aligned}$$

- for z_{t+1} in the part of (3.b.14) involving $E_t^k(z_{t+1})$ we use (3.b.23).

We get:

$$\begin{aligned} x_t^k &\approx (i^* - i_t + E_t^k(\Delta s_{t+1}))(\gamma V_t^k(z_{t+1}))^{-1} - (-g\sigma_e^2 / \sigma_e^2) \\ &\approx g + ((i^* - i_t + E_t^k(\Delta s_{t+1}))(\gamma\,\sigma_e^2)^{-1} . \qquad (k=a,r) \qquad (3.b.26) \end{aligned}$$

These are the traders' asset demand functions, where x_t^k is the proportion of period-t wealth that trader of type k holds in the nominal foreign asset. This expression consists of two terms, of which the first is g, which is the minimum variance portfolio. This portfolio represents the assets the trader would hold if his/her clientele were infinitely risk-averse ($\gamma = \infty$). The second part of the expression represents the speculative part of the portfolio. For example if there is a higher than expected excess return on the foreign asset, then the trader is induced to hold more of that asset than is represented in the minimum-variance portfolio.

In this simplified exposition, we make the assumption that the supply of domestic and foreign interest-bearing assets available exactly matches the minimum-variance portfolio; hence a constant proportion, g, of total wealth managed by the traders is in foreign assets. This scenario would occur if the agent is infinitely risk-averse ($\gamma = \infty$). In this case the agent would want to hold assets in exactly the same proportion as held in their consumption bundle. Under these conditions the foreign interest rate and the domestic interest rate will be equal in the long run. That is, there will not be any risk premium. This is the assumption for the special case that is referred to in section 3.b.1.

3.b.3 Spot Exchange Rate

Given that anchored traders manage a proportion α of the total market wealth, by equating supply (g) with demand (x), we get;

$$g = \alpha x_t^a + (1-\alpha)x_t^r . \qquad (3.b.27)$$

We can now derive the spot exchange rate path using equations (3.b.13),(3.b.26) and (3.b.27). But first we need the expectations for both anchored and rational traders. As a matter of definition,

$$E_t^a(\Delta s_{t+1}) = E_t^a(s_{t+1}) - s_t, \qquad (3.b.28)$$

$$E_t^r(\Delta s_{t+1}) = E_t^r(s_{t+1}) - s_t. \qquad (3.b.29)$$

Substituting (3.b.28) into (3.b.13) gives;

$$E_t^a(\Delta s_{t+1}) = f_t - \beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)] - s_t.$$
(3.b.30)

Then for k = a, substituting (3.b.30) into (3.b.26) leads to;

$$x_t^a = g + (i^* - i_t + f_t - \beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)] - s_t)(\gamma\, \sigma_e^2)^{-1}. \qquad (3.b.31)$$

Putting k=r in (3.b.26) gives:

$$x_t^r = g + (i^* - i_t + E_t^r(s_{t+1}) - s_t)(\gamma\, \sigma_e^2)^{-1}. \qquad (3.b.32)$$

Then substitute (3.b.32) and (3.b.31) into (3.b.27), obtaining:

$$g = g + [(i^* - i_t + \alpha f_t - \alpha\beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)] - \alpha s_t + (1-\alpha)E_t^r(\Delta s_{t+1})](\gamma\, \sigma_e^2)^{-1}.$$

Hence it follows that

$$[(i^* - i_t + \alpha f_t - \alpha\beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)] - \alpha s_t + (1-\alpha)E_t^r(\Delta s_{t+1})] = 0,$$

which can be solved for $E_t^r(\Delta s_{t+1})$:

$$E_t^r(\Delta s_{t+1}) = ((i_t - i^*) - \alpha f_t + \alpha\beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)] + \alpha s_t)/(1-\alpha). \qquad (3.b.33)$$

As covered interest parity is deemed to hold at all times, then:

$$fd_t = (f_t - s_t) = (i_t - i^*) \Rightarrow f_t = s_t + (i_t - i^*),$$

and (3.b.33) becomes

$$E_t^r(\Delta s_{t+1}) = (i_t - i^*) + [(s_t - p_t) - (\bar{s}_t - \bar{p}_t)](\alpha\beta)/(1-\alpha). \qquad (3.b.34)$$

Now $E_t^r(\bar{s}_{t+1}) = E_t^r(\bar{s}_{t+1} - \bar{p}_{t+1}) + E_t^r(\bar{p}_{t+1})$.

From equations (3.b.8) and (3.b.12) we get:

$$E_t^r(\bar{s}_{t+1}) = \bar{s}_t - \bar{p}_t + E_t^r(e_{t+1}) + \bar{p}_t + E_t^r(v_{t+1}).$$

But under rational expectations, $E_t^r(e_{t+1}) = 0 = E_t^r(v_{t+1})$, since both of these stochastic elements are classically well behaved.

Therefore $E_t^r(\bar{s}_{t+1}) = \bar{s}_t$ and by the same logic

$$E_t^r(\bar{s}_{t+j}) = \bar{s}_t \quad \forall\ j \geq 0. \tag{3.b.35}$$

Let $d_{t,j} = E_t^r(s_{t+j} - \bar{s}_{t+j}) \quad \forall\ j \geq 0;$ (3.b.36)

then $d_{t,j} = E_t^r(s_{t+j}) - \bar{s}_t$ and $d_{t,j+1} = E_t^r(s_{t+j+1}) - \bar{s}_t$.

Hence $\Delta d_{t,j+1} = d_{t,j+1} - d_{t,j} = \Delta E_t^r(s_{t+j+1}) = E_t^r(\Delta s_{t+j+1})$. (3.b.37)

From (3.b.34) $E_t^r(\Delta s_{t+1}) = (i_t - i^*) - [(s_t - p_t) - (\bar{s}_t - \bar{p}_t)](\alpha\beta)/(1-\alpha);$

this implies $E_t^r(\Delta s_{t+j+1}) = (i_{t+j} - i^*) - [(s_{t+j} - p_{t+j}) - (\bar{s}_t - \bar{p}_t)](\alpha\beta)/(1-\alpha).$

Substituting the last equation into (3.b.37),

$$d_{t,j+1} - d_{t,j} = (i_{t+j} - i^*) - [(s_{t+j} - p_{t+j}) - (\bar{s}_t - \bar{p}_t)](\alpha\beta)/(1-\alpha),$$

$$= (i_{t+j} - i^*) - [(s_{t+j} - \bar{s}_t) - (p_{t+j} - \bar{p}_t)](\alpha\beta)/(1-\alpha).$$

Under rational expectations, given that information is conditional on time t and that there are no further shocks, (3.b.36) can be re-expressed as: $d_{t,j} = (s_{t+j} - \bar{s}_{t+j}) = (s_{t+j}) - \bar{s}_t$. The equality of $E_t^r(s_{t+j})$ with the actual outcome s_{t+j} results from the assumption that the rational traders can foresee perfectly the (non-stochastic) time path of future exchange rates in the absence of further shocks. Since any further shocks cannot, by construction, be anticipated, the best that rational traders can do is to ignore them. Substituting in this form of (3.b.36) as well as (3.b.5) into the above equation realises:

$$d_{t,j+1} - d_{t,j} = (i_{t+j} - i^*) - (d_{t,j} - \lambda\,(i_{t+j} - i^*))(\alpha\beta)/(1-\alpha)$$

$$d_{t,j+1} - (1+(\alpha\beta)/(1-\alpha))d_{t,j} = (i_{t+j} - i^*))(1-\lambda\alpha\beta)/(1-\alpha)$$

From (3.b.11), interest rate formation is $(i_{t+j} - i^*) = (i_t - i^*)(1-1/\theta)^j$; hence:

$$d_{t,j+1} - (1+(\alpha\beta)/(1-\alpha))d_{t,j} = (i_t - i^*))(1-\lambda\alpha\beta)/(1-\alpha)(1-1/\theta)^j.$$

The general solution is derived by solving the first order difference equation of the form $y_{t+1} + ay_t = c$.

$$\Rightarrow d_{t,j} = A(1+(\alpha\beta)/(1-\alpha))^j + \frac{(1-(\lambda\alpha\beta)/(1-\alpha)}{1-(1+\alpha\beta/(1-\alpha)-1/\theta}(i_t - i^*)(1-1/\theta)^j$$

$$= A(1+(\alpha\beta)/(1-\alpha))^j + \frac{(1-(\lambda\alpha\beta)/(1-\alpha)}{-\alpha\beta/(1-\alpha)-1/\theta}(i_t - i^*)(1-1/\theta)^j$$

$$= A(1+(\alpha\beta)/(1-\alpha))^j + \frac{\alpha\beta-(1-\alpha)/\lambda}{\alpha\beta+(1-\alpha)/\theta}(i_t - i^*)(1-1/\theta)^j$$

$$= A(1+(\alpha\beta)/(1-\alpha))^j + \frac{\alpha\beta\lambda-(1-\alpha)}{\alpha\beta+(1-\alpha)/\theta}(i_t - i^*)(1-1/\theta)^j$$

$$= A(1+(\alpha\beta)/(1-\alpha))^j + \lambda\mu(i_t - i^*)(1-1/\theta)^j \qquad (3.b.38)$$

where $\mu = \dfrac{\alpha\beta-(1-\alpha)/\lambda}{\alpha\beta+(1-\alpha)/\theta}$ and A is an arbitrary constant. By ruling out explosive bubbles and imposing the transversality condition of $\lim_{j\to\infty} d_{t,j}=0$, it follows that A=0, and hence:

$$d_{t,0} = s_t - \bar{s}_t = \lambda\mu(i_t - i^*), \qquad (3.b.39)$$

$$\Rightarrow \quad s_{t+1} - \bar{s}_{t+1} = \lambda\mu(i_{t+1} - i^*).$$

$$= \lambda\mu(i_t - i^*) - (\lambda\mu)/\theta\,(i_t - i^*) - \mu v_{t+1}; \tag{3.b.40}$$

hence:

$$\Delta s_{t+1} = \bar{s}_{t+1} - \bar{s}_t - \frac{\lambda\mu}{\theta} fd_t - \mu v_{t+1}. \tag{3.b.41}$$

Re-expressing the terms in (3.b.41):

$$-\frac{\lambda\mu}{\theta} = \frac{\alpha\beta - (1-\alpha)/\lambda}{\alpha\beta + (1-\alpha)/\theta}\left(-\frac{\lambda}{\theta}\right)$$

$$= 1 - \frac{\alpha\beta(\lambda+\theta)}{1+\alpha(\beta\theta-1)} \quad = \quad \eta(\alpha), \text{ (say)} \tag{3.b.42}$$

Hence $$-\frac{\lambda\mu}{\theta} = \eta \Rightarrow -\mu = \frac{\theta\eta}{\lambda}. \tag{3.b.43}$$

We note that $\bar{s}_{t+1} - \bar{s}_t = (\bar{s}_{t+1} - \bar{p}_{t+1}) - (\bar{s}_t - \bar{p}_t) + \bar{p}_{t+1} - \bar{p}_t$ (3.b.44)

From equations (3.b.8) and (3.b.12), (3.b.44) becomes

$$\bar{s}_{t+1} - \bar{s}_t = e_{t+1} + v_{t+1} \tag{3.b.45}$$

Now substitute (3.b.45),(3.b.43),(3.b.42) into (3.b.41) to get;

$$\Delta s_{t+1} = e_{t+1} + v_{t+1} + \eta fd_t + \frac{\theta\eta}{\lambda} v_{t+1};$$

$$\Delta s_{t+1} = \eta fd_t + (1 + \frac{\theta\eta}{\lambda}) v_{t+1} + e_{t+1}. \tag{3.b.46}$$

The above equation gives the exchange rate change from t to t+1.

Using equations (3.b.46) and (3.b.10), we can derive the time evolution of the exchange rate:

$$s_{t+\tau} = s_t + v_{t+1}(1 + \frac{\theta\eta}{\lambda}(1-1/\theta)^{\tau-1}). \tag{3.b.47}$$

3.b.4 Implications of the Time Evolution of the Spot Exchange Rate

Having derived the path of the exchange rate, we can now illustrate the effect of the presence of anchored or rational traders in the marketplace. When the market is made up solely of anchored traders, then $\alpha = 1$ and therefore

$$\eta(1) = 1 - \frac{\alpha\beta(\lambda+\theta)}{1+\alpha(\beta\theta-1)} = -\lambda/\theta \,. \tag{3.b.48}$$

The time evolution of the spot rate (3.b.47) then becomes:

$$s_{t+\tau} = s_t + v_{t+1}(1 - (1-1/\theta)^{\tau-1}) \,. \tag{3.b.49}$$

When all traders in the market are rational, $\alpha = 0$ and $\eta(0) = 1$ results in:

$$s_{t+\tau} = s_t + v_{t+1}(1 + \frac{\theta}{\lambda}(1-1/\theta)^{\tau-1}) \,. \tag{3.b.50}$$

The initial change in the spot rate in reaction to a change in the money supply is illustrated by equation (3.b.46). This shows the initial jump in the nominal spot exchange rate for all combinations of traders. The jump in the exchange rate is generated by innovations, v_{t+1} in the money supply and e_{t+1} in the real exchange rate. But below we concentrate on just the former.

At time t, which is prior to the shock impinging at t+1, asset markets are in long-run equilibrium, and $i_t = i^*$ if γ is large so that traders hold the minimum variance portfolio. Interest parity then implies that fd_t is always zero. As well, it is assumed that the effect of a money supply shock on the real exchange rate is well understood by both types of market participants. Given the neutrality of money, the effect of the monetary shock on the *real* exchange rate in the long run is zero. Moreover by assumption e_{t+1} is zero (because we are analysing only the effects of the monetary shock). This leaves us with just the middle term of (3.b.46) to deduce the behaviour of the respective agents in response to a money supply shock:

$$\Delta s_{t+1} = \qquad (1 + \frac{\theta\eta}{\lambda})v_{t+1} .$$

This equation gives the initial jump of the nominal spot rate. When all traders are anchored, $\alpha = 1$ and therefore $\eta(1) = -\lambda/\theta$. Hence:

$$\Delta s_{t+1} = \qquad (1 + -\frac{\theta\lambda}{\lambda\theta})v_{t+1} = (1 - 1)v_{t+1} = 0 .$$

This failure of the exchange rate to react instantaneously to the monetary shock is in sharp contrast with the jumping exchange rate of the standard Dornbusch model. From this point the anchored traders follow a path towards the long run change in the nominal spot rate, v_{t+1}. This is shown by equation (3.b.49). By expanding this equation the process can be illustrated better:

$$s_{t+\tau} = s_t + v_{t+1} - v_{t+1}(1-1/\theta)^{\tau-1} \qquad (3.b.51)$$

The shock to money supply, v_{t+1} occurs at the end of time period t, which is the beginning of time t+1. Initially the anchored traders do not react and $\Delta s_{t+1} = 0$. But as time progresses, the spot rate follows a path up to $s_t + v_{t+1}$ with the rate of approach determined by the value of θ. This is the path as demonstrated in diagram 3.a.1.

When the market is composed entirely of rational traders, the initial jump is given by $v_{t+1}(1+\frac{\theta}{\lambda})$. As both θ and λ are positive numbers, this is the Dornbusch overshooting behaviour of the spot rate. Again, the spot rate returns to its long run value as determined by the parameter, θ, albeit from the opposite direction as for anchored traders. This overshooting behaviour by the rational traders is triggered by the excess returns available. The fact that anchored traders are unaware of these excess returns accounts for their failure to exploit them.

The average market participants' exchange rate expectations are derived from equations (3.b.13) and (3.b.46):

$$\alpha E_t^a(\Delta s_{t+1}) + (1-\alpha)E_t^r(\Delta s_{t+1})$$
$$= \alpha(fd_t - \beta[(s_t - p_t) - (\bar{s}_t - \bar{p}_t)]) + (1-\alpha)\eta fd_t,$$

With no external shocks v_{t+1} equals zero and $E_t^r(\Delta s_{t+1})$ equals ηfd_t. In equilibrium $\bar{s}_t = s_t$ and $p_t = \bar{p}_t$, hence:

$$= \alpha fd_t + (1-\alpha)fd_t$$
$$= fd_t$$

The mean expectations of the agents, irrespective of the ratio of anchored traders to rational traders (i.e. regardless of the value of α), is always the forward discount.

3.b.5 Asset Supplies not equal to Minimum Variance Portfolio

In this case the proportion of total wealth in the form of foreign interest bearing assets managed by the traders is $g + k$, $0 \leq g+k \leq 1$. As before, g is the proportion of foreign assets in the trader's minimum variance portfolio and k is an arbitrary constant. The arbitrage condition, (3.b.27) becomes;

$$g + k = g + ((i^* - i_t + \alpha E_t^a(\Delta s_{t+1}) + (1-\alpha)E_t^r(\Delta s_{t+1})/(\gamma \sigma_e^2)^{-1}). \quad (3.b.52)$$

In the absence of money shocks, the model is in equilibrium and $p_t = \bar{p}_t$ and $s_t = \bar{s}_t$. By equation (3.b.13), $E_t^a(\Delta s_{t+1}) = i_t - i^*$, while $E_t^r(\Delta s_{t+1}) = 0$. Substituting this into (3.b.52);

$$g + k = g + ((i^* - i_t + \alpha(i_t - i^*))/(\gamma \sigma_e^2)^{-1}). \quad (3.b.53)$$

For this equation to hold,

$$k = ((i^* - i_t + \alpha(i_t - i^*))/(\gamma \sigma_e^2)^{-1}),$$

which can be re-expressed in terms of i*:

$$i^* = i_t + x, \qquad \text{where } x = k\gamma \sigma_e^2 /(1-\alpha)\,. \tag{3.b.54}$$

The excess return on the foreign asset, x can be seen as a risk premium required for traders to lift their holdings in the foreign asset from g to g + k. Equations (3.b.7) and (3.b.9) are replaced with;

$$\Delta p_{t+1} = -\lambda\,(i_t - i^* + x)/\theta\,; \tag{3.b.55}$$

$$(i_{t+1} - i^* + x) = (i_t - i^* + x)(1 - 1/\theta) - v_{t+1}/\lambda. \tag{3.b.56}$$

The spot equation is solved in the same manner as before resulting in:

$$\Delta s_{t+1} = \qquad \eta x + \eta fd_t + (1 + \frac{\theta\eta}{\lambda})v_{t+1} + e_{t+1}\,. \tag{3.b.57}$$

This modification has just added a constant, ηx to the right hand side. The effect on the market participants' exchange rate expectations is similar to just adding a constant to the right hand side (using the same logic as described on page 50):

$$\alpha E_t^a(\Delta s_{t+1}) + (1-\alpha)E_t^r(\Delta s_{t+1}) = (1-\alpha)x + fd_t\,. \tag{3.b.58}$$

In this case, the average market expectation for the exchange rate exceeds the forward discount wherever there are any anchored traders. This somewhat unexpected result is due to the fact that anchored traders expectations do not include the risk premium, x.

3.b.6 Conclusion

This chapter has presented an exhaustive treatment of the Gruen and Gizycki model. We have shown that the G&G framework possesses some desirable properties. The model formally includes traders whose expectations are anchored to the on-period ahead forward rate. However, the market participant's mean expectations is the forward discount no matter what the proportion of anchored traders present in the market at any one time. The essential features of the Dornbusch model have been preserved: in a fully rational and risk-neutral market, the G&G model displays overshooting of the exchange rate and no forward discount bias.

This elegant closed form framework provides us with a benchmark to formulate numerical models that are required to incorporate cycles into the model. To achieve this end we first outline two prototype models, the Dornbusch model and the Extended Dornbusch model in chapter 4.

Chapter 4

Prototypes for Generalising Gruen and Gizycki

4.1 Introduction

In the G&G framework, the real exchange rate is excluded from the demand function to allow an analytical solution to be derived relatively straightforwardly. This simplification preserves the essence of the Dornbusch model, namely that the model exhibits exchange rate overshooting and is free from forward discount bias. But in order to integrate the G&G framework into a large macroeconometric model, the demand function requires the real exchange rate to be reintroduced into the aggregate demand function. This precludes the possibility of a closed form solution, suggesting the need for a numerical solution.

In attempting to create a numerical framework for G&G where the real exchange rate is operational in the demand function, I have taken Dornbusch's 1976[1] overshooting exchange rate model (hereafter DBM) and the Extended Dornbusch model (EDBM) as presented by Powell and Murphy[2] as the initial template for the model. The DBM is itself a closed form continuous time model. EDBM is a numerically solved discrete-time version of DBM with the introduction of inertia into the IS curve.[3]

Inertia in the IS curve is required to reconcile the Murphy[4] model and the basic Dornbusch model. With the introduction of inertia, an analytical solution is not possible, hence the need to solve the model numerically. The two models DBM and EDBM have been constructed in Excel solely due to this program's simplicity of use. The first task was to ensure consistency between DBM and EDBM; that is to verify that removing inertia from EDBM causes that model to reproduce numerically

[1] Dornbusch (1976).
[2] Powell and Murphy (1995) ch. 3 & 26.
[3] See Powell and Murphy pp.317-326 for an explanation of the Extended Dornbusch model and a method for its solution.
[4] The Murphy Model is a macroeconometric model of Australia and was developed by Chris Murphy. A detailed analysis of the model is available in Powell and Murphy (1995).

the solutions attained analytically from DBM. To help understand this process, a brief synopsis of DBM and EDBM follows.[5]

4.2 Dornbusch's 1976 overshooting model

The Dornbusch model (DBM) is an extension of the perfect capital mobility version of the Mundell-Fleming model.[6] DBM extends Mundell-Fleming by incorporating exchange rate expectations whilst retaining the Keynesian assumption that goods prices are relatively sticky. In concordance with Dornbusch's original 1976 paper, supply of aggregate output is taken as given, meaning the length of run is relatively short. DBM was constructed so that the effects of a monetary shock (either expansionary or contractionary) on aggregate demand and the exchange and interest rates could be demonstrated under a regime that includes a floating exchange rate and perfect asset market mobility.

Basic Assumptions

The following key assumptions underpin DBM:

(1) In the very short run the price of DBM's sole commodity is fixed, whilst in the medium run the price of the domestic good adjusts gradually towards an equilibrium in which the goods market clears.

(3) The domestic economy is assumed to be small relative to world trade, hence world prices and interest rates are deemed exogenous.

(4) Aggregate potential supply is exogenous.

(5) Expectations formed in financial markets are assumed to be rational.

(6) Uncovered interest parity holds at all times.

(7) The exchange rate and the domestic interest rate are fully flexible.

(8) The supply of money is exogenously controlled by the government.

(9) The long-run exchange rate is determined by purchasing power parity.

[5] This synopsis is an abbreviated version of the explanation found in Powell and Murphy (1995) chs.3 and 26.

Underlying Structural Model

DBM starts with the basic IS/LM framework. Aggregate demand is defined by

$$A = C + G + I + T,$$

where A is aggregate demand, C is private consumption, G is government spending, I is investment and T is net exports. The IS curve in DBM shows the relationship between aggregate demand, A, and the nominal interest rate r at given values G of government spending, P* of the price level in the rest of the world, S of the nominal exchange rate ($ foreign per local dollar), P of the domestic price level, Y* of income in the rest of the world and Y of aggregate supply at home.

In this context, aggregate demand, A is equal to current real GDP: whereas real aggregate supply, Y can be loosely interpreted as the concept of real GDP at normal rates of utilisation of factors. Using this setup, A can vary from Y in either direction depending whether there is 'excess' demand or 'excess' supply in the system. In DBM, real government spending is exogenous:

$$G = \bar{G},$$

whilst the behavioural functions F–(•) characterising the other components, C, I and T, follow standard assumptions.[7]

$$C = F^{C}(Y), \qquad \frac{dC}{dY} > 0;$$

$$I = F^{I}(r), \qquad \frac{dI}{dr} < 0;$$

$$T = F^{T}\left(Y, Y^{*}, \frac{P^{*}/E}{P}\right), \ \frac{\partial T}{\partial Y} < 0, \ \frac{\partial T}{\partial Y^{*}} > 0, \ \frac{\partial T}{\partial\left[\frac{P^{*}/E}{P}\right]} > 0.$$

From these assumptions, it follows that aggregate demand A has positive derivatives with respect to each of the following variables:

[6] Mundell (1962), Fleming (1962). For a brief overview see Powell and Murphy (1995) pp.15-21.

real government spending, G,

the overseas price level, P*,

real domestic permanent income (or 'supply'), Y, and

real foreign income Y*;

and has negative derivatives with respect to:

the nominal exchange rate, E (foreign $ per local $),

the local price level, P, and

the nominal interest rate r.

The LM curve shows the relationship between the stock of (nominal) money M that the public would be willing to hold as a function of the nominal interest rate r at given levels Y of permanent income and P of the price level:

$$M = F^M(Y,P,r) .$$

It is assumed that its use as a medium of exchange and as a store of value motivates the public to hold money, and that at any given nominal interest rate r, the stock of 'real money' that the public wishes to hold, M/P, is proportional to real permanent income, Y. Because holding money means missing out on earning interest, the demand for money is inversely related to the interest rate. These considerations lead to the following restrictions on the LM curve:

$$\frac{\partial M}{\partial Y} > 0 ; \qquad \frac{\partial M}{\partial P} > 0 ; \qquad \frac{\partial M}{\partial r} < 0 .$$

Additionally, it is common to assume that the demand for money has unitary elasticity with respect to Y. The structural form equations lead to the partially reduced form displayed below in Table 4.1.

[7] See Powell and Murphy (1995) p.24 for a brief rationale for these assumptions.

Table 4.1
Equations of the Dornbusch Model*

Description	Equation	
SHORT-RUN EQUATIONS OF THE DORNBUSCH MODEL		
IS curve	$a = \mu g + \delta(p^* - s - p) - \sigma i + \gamma y + \tau y^*$	(4.1)
LM curve	$m - p = \phi y - \lambda i$	(4.2)
Uncovered interest parity	$i = i^* + x$	(4.3)
Expected rate of depreciation of the exchange rate	$x = \theta(s - \bar{s})$	(4.4)
Phillips curve	$\dot{p} = \pi (a - y)$	(4.5)
LONG-RUN EQUATIONS FOR THE PRICE LEVEL AND NOMINAL EXCHANGE RATE		
Long-run neutrality of money	$\bar{p} = m - y$	(4.6)
Purchasing Power Parity	$\bar{p} = p^* - \bar{s}$	(4.7)

*(After Powell and Murphy, (1995), p.27.

Partially reduced form

For simplicity it is assumed that the IS and LM curves have constant elasticities; thus the equations of the DBM are linear in the logarithms[8]. The assumption of constant elasticities for the IS curve can only be a local approximation in that the structural form of A is globally linear in the levels values of its components; hence the IS curve cannot be globally log-linear in the variables determining its components. Notation for the equations of the model is given in Table 4.1, and for its variables in Table 4.2.

The logarithms of the variables are denoted by the corresponding lower-case letters, while elasticities are denoted by lower-case Greek letters. The plus and minus signs in the equations of Table 4.1 have

[8] There is one exceptional variable, namely, the interest rate, which is expressed as a proportion per unit time interval.

been chosen to ensure that each of the parameters represented by a Greek lower-case letter is a positive magnitude.

The equations of Table 4.1 split naturally into a set of five short-run equations plus a pair of long-run equations. The role of the latter is to determine the price level and nominal exchange rate in the steady state. Note that the particular assumptions used for this pair below — long-run money neutrality and Purchasing Power Parity (PPP) — could be replaced by some other long-run relationships without the necessity to change the short-run equations.

The partially reduced form of the IS curve is equation 4.1. The first term on the right, g, represents government expenditure. The second represents the effect of the real exchange rate on net exports. The third term, $-\sigma r$, represents the investment schedule, with the minus sign indicating that the elasticity of investment with respect to the interest rate is negative. The term γy represents the net effect of income via the consumption function and through the net exports function. The net effect of income is positive due to the assumption that the stimulatory effect of income on aggregate demand via consumption, $\frac{\partial C}{\partial Y}$ exceeds the contractionary impact via net exports, $-\frac{\partial T}{\partial Y}$. The last term τy^* has a positive elasticity representing the foreign-income-sensitive component of aggregate demand acting via net exports.

The domestic economy is assumed to be small in comparison to the world economy, hence the foreign price level is assumed to be fixed and is normalised at $P^*=1$, $p^*=0$. As there is no formal supply side in this model, the level of permanent income is considered fixed. Equation 4.2 is a log linear version of the standard demand for money function. There is no money growth in DBM and when the authorities alter the money supply, there is an instantaneous jump in the level of money which then remains constant at the new level.

Table 4.2.
Notation for variables in the Dornbusch Model

Variable	Description
a	real aggregate demand in the home country
g	real aggregate spending by government in the home country (exogenous)
s	current spot exchange rate, defined as the foreign currency price of a unit of domestic currency[b]
$\bar{s}$	long-run exchange rate
m	nominal quantity of money (exogenous)
p	domestic price level (initial value exogenous; endogenous thereafter)
$\bar{p}$	domestic price level in the long run
p^*	foreign price level (exogenous, and normalised so that $p^* = 0$)
$\dot{p}$	rate of domestic price inflation
i	domestic nominal interest rate
i^*	foreign nominal interest rate (exogenous)
x	expected rate of depreciation of the local currency
y	real aggregate supply at 'normal' rates of utilisation of capital and labour in the local economy (exogenous) — also interpreted as permanent income
y^*	real income in the rest of the world (exogenous)

The standard closure has the shaded variables set exogenously. As there are 14 variables and 7 equations, one further exogenous setting is required. This is achieved by setting an initial value for p.

(After Powell and Murphy, (1995), p.28.)

The uncovered interest parity condition states that arbitrage by risk-neutral traders in foreign exchange ensures that the domestic interest rate equals the foreign interest rate plus the time rate of accrual of any capital gain to be made by holding securities denominated in the foreign currency. This condition is given by equation 4.3. As the domestic economy is assumed to be a negligible part of the world capital market, the foreign rate of interest (with value denoted by i*) is treated as being exogenously determined.

Equation 4.4 is the expectations generation equation. It states that the expected time rate of depreciation of the spot exchange rate is proportional to the difference between the current spot rate and the long-run rate. The latter can easily be worked out: in the version of DBM exposited here, money is neutral in the long run. With aggregate supply, y, exogenously held fixed, a (permanent) monetary expansion therefore leads to an equiproportional increase in the price level in the long run (see equation (4.6)). Given an exogenous foreign price level p^* (which is common to both short and long runs in our exposition), the long-run value of the nominal exchange rate is then known from PPP (equation (4.7)). Hence (4.4) provides an operational basis for expectations concerning the time rate of nominal exchange rate changes.

The final equation of DBM, (4.5), is a standard Phillips curve in which the rate of inflation responds positively to excess demand in the goods market.

The above provides a brief outline of the structure of DBM. For a discussion on the equilibrium exchange rate and a proof that expectations are model consistent under a suitable choice of the parameter θ, refer to Powell and Murphy (1995).[9]

The effects of a monetary expansion under rational expectations

A permanent increase in the money supply, increasing money stocks to a new constant level, would cause disequilibrium in both the asset and goods markets. To avoid disequilibrium occurring in the asset market, either prices or the interest rate must change, as y is fixed. Remember the LM curve is of the form,

$$m - p = \phi y - \lambda i.$$

If $dm \neq dp$ then there will be a change, $-\lambda di$ in the interest rate. In DBM, prices are assumed to be absolutely sticky (there is no initial jump in p at the time of the shock), hence all the initial change must be absorbed by the interest rate. The foreign interest rate, i^* is also exogenous and hence $di^* = 0$, leading to the result (see equation (4.3)) that the change in the interest rate is equal to the change in the expected rate of depreciation of the domestic currency. This is required for uncovered interest parity to hold at all times. Under rational expectations $x \equiv - \dot{s}$ [10] thus (with $dy = 0$),

$$dm - dp = \lambda d\dot{s} \ .$$

This means that an increase in the money supply, with prices initially fixed, leads to a *rise* of (dm/λ) in the rate of exchange rate appreciation, $\dot{s}$. The effects of an increase in the money supply are illustrated in figure 4.1.

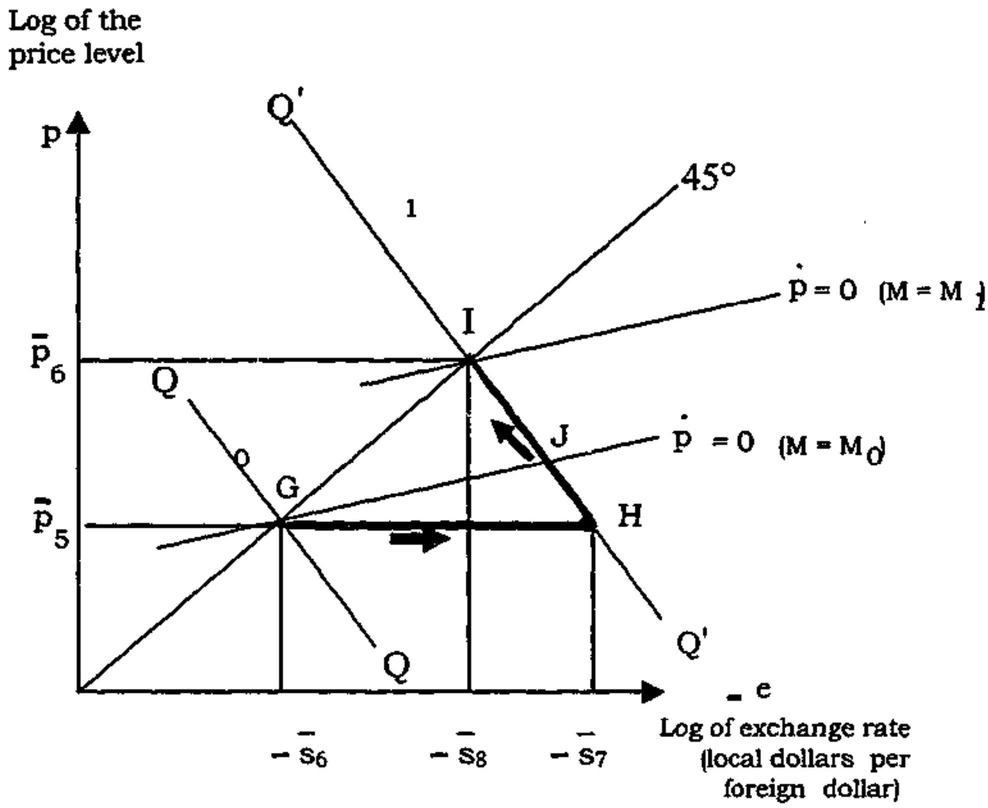
The monetary shock (an increase in nominal money from M_0 to M_1) causes the asset market equilibrium schedule QQ to shift outwards to Q'Q', a shift that is proportional to the increase in the money supply. The monetary expansion also causes the non-inflationary goods and money market equilibrium curve to shift from the locus shown as $\dot{p} = 0$ (with $M = M_0$) to that shown as $\dot{p} = 0$ (with $M = M_1$). The economy's long-run equilibrium position hence moves from G to I where the changes in the long-run price level and exchange rate exactly offset the effects of each other caused by the increase in the nominal quantity of money, in line with the assumption made above that money is neutral in the long run.

Because of the differential adjustment speeds of the asset and goods markets, however, the economy does not move directly to I. The exact adjustment path depends on the extent to which prices are able to adjust. As it is assumed for the purpose of this exposition that prices are absolutely rigid in the very short-run, then, following the monetary

[9] See Powell and Murphy (1995) pp. 32-36.
[10] ibid. p.38

expansion, the economy instantaneously moves to point H, only reaching point I in the long-run after moving along the Q'Q' schedule.

Figure 4.1.
Effects of a monetary expansion in DBM

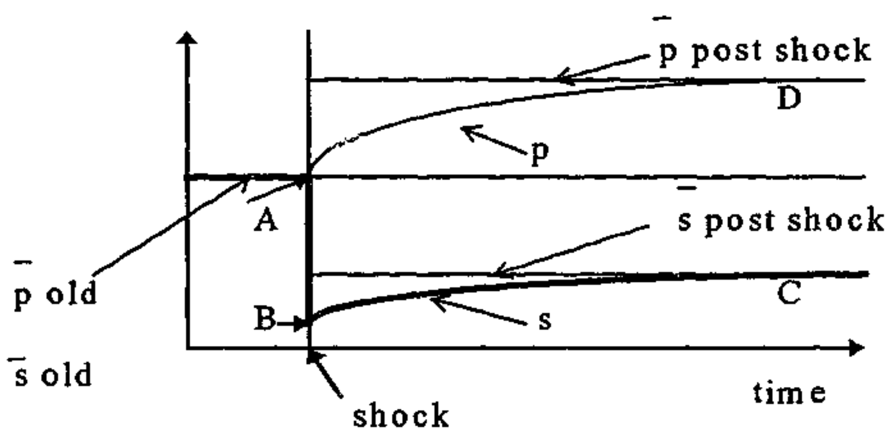


After Powell and Murphy, (1995), p.40.

The movement from G to H implies an instantaneous fall in the interest rate. With prices rigid in the short-run, the instantaneous increase in the nominal quantity of money causes real balances (M/P) held by the public to jump to a new (higher) level; for the public to be persuaded to hold the extra money, the interest rate must fall instantaneously to a new level consistent with the LM curve.

The extent of the jump is analytically computable in DBM[11], however here I will illustrate the behaviour of the endogenous variables in a purely heuristic manner.

Figure 4.2
Paths of the domestic price level and the nominal exchange rate
in DBM after an unanticipated, permanent expansion of the money stock at t = 0

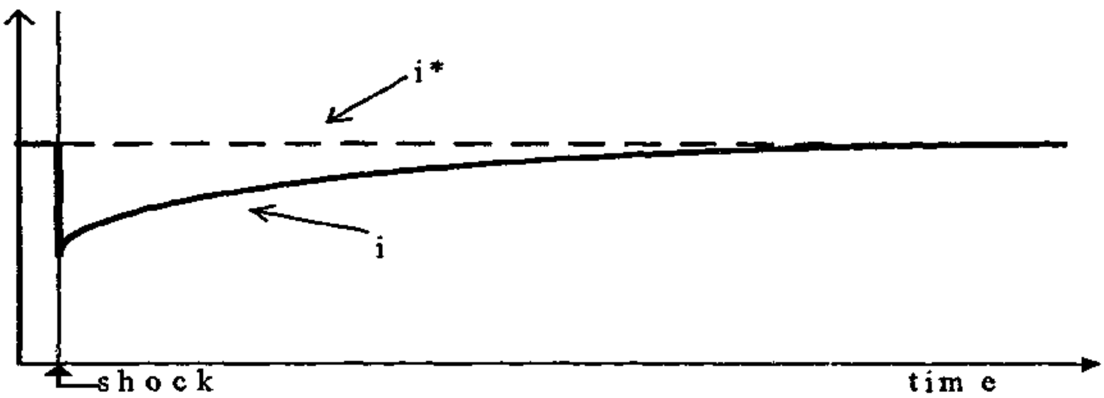


In figure 4.2, the effects of a monetary shock on the exchange rate and the price level are illustrated. The path of the domestic interest rate is shown in figure 4.3. The exchange rate is subjected to a instantaneous change in its value at time = 0. The old equilibrium exchange rate is at point A. In the case of a monetary expansion, the exchange rate overshoots its new long run equilibrium to point B, and then follows a monotonic path towards the new long equilibrium at point C. The general price level is at first absolutely sticky, hence at t = 0 there is no reaction from the price level. As time proceeds, price follows a monotonic increase to the new long run price level at point D.

[11] ibid. See p 40-42 for an example of calculating the magnitude of the jump in the exchange rate.

Figure 4.3

Trajectory of the domestic nominal interest rate.



The interest rate in figure 4.3, like the exchange rate, is subjected to an instantaneous jump. In the case of a monetary expansion the interest rate falls at t = 0, and then follows a monotonic rise to reclaim its original value. This jump is a direct consequence of requiring uncovered interest parity to hold at all times. The DBM provides the basis for all subsequent models in this thesis. The first extension requiring exploration is the Extended DBM.

4.3 The Extended Dornbusch Model (EDBM)

As stated, DBM is solved analytically and in continuous time. EDBM is solved numerically in discrete time. The EDBM was initially developed by Powell and Murphy to reconcile the Murphy Model with the Dornbusch model. This involved the addition of inertia into the IS curve. The different treatment of time in the two models requires care to be used. The equations used for the extended Dornbusch model are depicted in table 4.3[12]. The variable listing is comparable to that for the DBM in table 4.2.

[12] Powell and Murphy (1995) Table 26.4.1

Table 4.3

Equations of the Extended Dornbusch Model

SHORT-RUN DISEQUILIBRIUM EQUATION

Actual aggregate demand

$$a_t = \psi\, \alpha_t + \varphi_t\,(1-\psi)\, \alpha_{t-1} + (1-\varphi_t)\,(1-\psi)\, \alpha_{t-2} \qquad (4.8)$$

Lag weighting function $\varphi_t = R\, e^{-\rho t}$ $\rho \geq 0$ (4.9)

SHORT-RUN EQUILIBRIUM EQUATIONS

Equilibrium IS curve

$$\alpha = \mu g + \delta\,(p^* - s - p) - \sigma i + \gamma y + \tau y^* \qquad (4.10)$$

LM curve	$m - p = \phi y - \lambda i$	(4.11)
Uncovered interest parity	$i = i^* + x$	(4.12)
Expected rate of depreciation of the domestic currency	$x = -\dot{s}$	(4.13)
Phillips curve	$\dot{p} = \pi\,(a - y)$	(4.14)

LONG-RUN EQUILIBRIUM EQUATIONS FOR THE PRICE LEVEL AND EXCHANGE RATE

Long-run neutrality of money	$\bar{p} = m - y$	(4.15)
Purchasing Power Parity	$\bar{p} = p^* - \bar{s}$	(4.16)

After Powell and Murphy, (1995), p.319

The equations vary from DBM in four ways:

- The addition of two variables, α and φ. These two variables form part of the short-run disequilibrium equation.

- There are two additional equations, 4.8 and 4.9, while the interpretation of 4.10 differs from that of the almost identical equation in Dornbusch.
- Rational expectations is always enforced, so that actual and expected depreciation of .. exchange rate are equal.
- Time is discrete rather than continuous.

The lag structure in equation 4.8 involves placing a weight a (ψ) between zero and one on the current short-run equilibrium value α_t of aggregate demand and distributing the remaining weight on the previous two periods of actual demand. The lag weighting function, φ_t (equation 4.9), is chosen to allow the possibility that $\varphi_t(1-\psi)$ exceeds one initially ($t=0$) and for a certain time afterwards. Such a weighting scheme is chosen as the simplest representation of the damped cyclical time paths typical of variables in the Murphy model.[13]

With the parameter $\rho > 0$ in 4.9, the variable φ_t decays towards zero over time, so that

$$a_t \to \psi\, \alpha_t + (1-\psi)\, \alpha_{t-2}\,.$$

The damping of cycles in the endogenous variables s, p and i ensures that 4.10 implies that

$$\alpha_{t-2} \to \alpha_t$$

as $t \to \infty$, so that $a_t \to \alpha_t$ as $t \to \infty$; that is, eventually, actual aggregate demand is effectively determined by an algebraic expression agreeing with the one that would have determined its value immediately after the shock in the unmodified Dornbusch model. But at such a distance in time after the shock, PPP will have ensured that $\Delta s = -\Delta p$, while the interest rate will have converged back to its initial (externally set) value ($\Delta i = 0$). Equation 4.10 then tells us that aggregate demand must have returned to the initial equilibrium.

For a given value of ψ, the parameters R and ρ jointly determine the size of the initial exchange rate jump, the average amplitude of the

[13] A more detailed explanation is available in Powell and Murphy (1995), pp. 319-20.

cycles early in the trajectory of the exchange rate, and the rate at which the cycles decay.

Without closed form solutions for p_t and e_t, the model must be solved numerically. For my purposes, the short-run disequilibrium equations have been neutralised by setting psi (ψ) equal to 1. This results in EDBM collapsing back into the basic Dornbusch model - DBM. When the coefficient on the real exchange rate (δ) is set to zero, a model of rational expectations currency trading in the G&G style is created. That is, under a monetary shock the demand equation is dependent solely on variation in the domestic interest rate and the model exhibits overshooting behaviour of the exchange rate.[14] [15]

4.4 Comparison of DBM and EDBM

The requirement for a numerically solved model such as EDBM stems from the fact that to solve DBM analytically is only possible in rare circumstances; one of these special cases is where traders assume rational expectations. With the need to introduce traders with non-rational expectations — that is anchored traders — the analytical framework of DBM will become unsolvable. Furthermore, when combining both anchored and rational traders, analytical solutions, if at all possible, would be unique to each particular combination of traders and would prove extremely cumbersome to manage.

Therefore we need to verify the validity and consistency of using a numerical version of DBM and consequently ensure the numerical

[14] A small country scenario is utilised; hence y^* is taken as given and for the purposes of this model government (g) is assumed to be an exogenous variable.

[15] Two main problems occurred in gaining the numerical solution. The first was that the initial time frame that was allowed for in Excel was too short for there to be a convergence of the exchange rate in EDBM to the long run. This also meant that the initial jump was inconsistent with DBM. The time frame was extended by using an exponential time scale beyond 100 periods. Using this method it was possible to closely replicate, with EDBM, the path of the analytically solved DBM once the second problem was solved.

The second problem is that it is difficult to get Excel to come to an adequate solution. This seems to stem from the algorithm used by the Solver add-in in Excel, which is unable to handle the non-linearity well (especially with δ set to zero). Hence to successfully get convergence for the exchange rate in EDBM is often a laborious task.

model's relevance to the G&G framework. This process involves two steps; the first is to ensure that when the real exchange rate is turned off in DBM (i.e. $\delta = 0$), a model consistent with the rational expectations version of G&G ensues; the second step is to confirm that with $\delta = 0$, the analytical solution of DBM coincides with its numerical counterpart in EDBM. It then follows that the numerical solution obtained from EDBM concurs with the rational expectation version of the G&G model when the parameter δ is set to zero.

The solution for the exchange rate obtained by Gruen and Gizycki is represented by equation (3.b.47):

$$s_{t+\tau} = s_t + v_{t+1}(1+\frac{\theta\eta}{\lambda}(1-1/\theta)^{\tau-1}).$$

Noting that when the market comprises solely rational expectation traders, $\alpha = 0$ and $\eta = 1$[16], we see that (3.b.47) becomes;

$$s_{t+\tau} = s_t + v_{t+1}(1+\frac{\theta}{\lambda}(1-1/\theta)^{\tau-1}). \tag{4.15}$$

Equation 4.15 provides the rational expectation path in the G&G model. This can be easily compared to the path of the exchange rate for DBM when $\delta = 0$. In comparison to each other, these two series agree to the fourth decimal place across a wide range of parameters.[17] Thus it can be concluded that the rational expectation version of the G&G model and the modified DBM ($\delta = 0$) are for all practical purposes, identical.

Again by linking spreadsheets for DBM and EDBM, it is easily verifiable that across a large range of parameter settings, DBM and EDBM are almost equivalent in their solutions for the path of the exchange rate.

The closed form DBM model provides the benchmark for comparison. With the coefficients set at the following values:

$\sigma = 0.45 \qquad \pi = 0.3 \qquad \lambda = 30,$

---

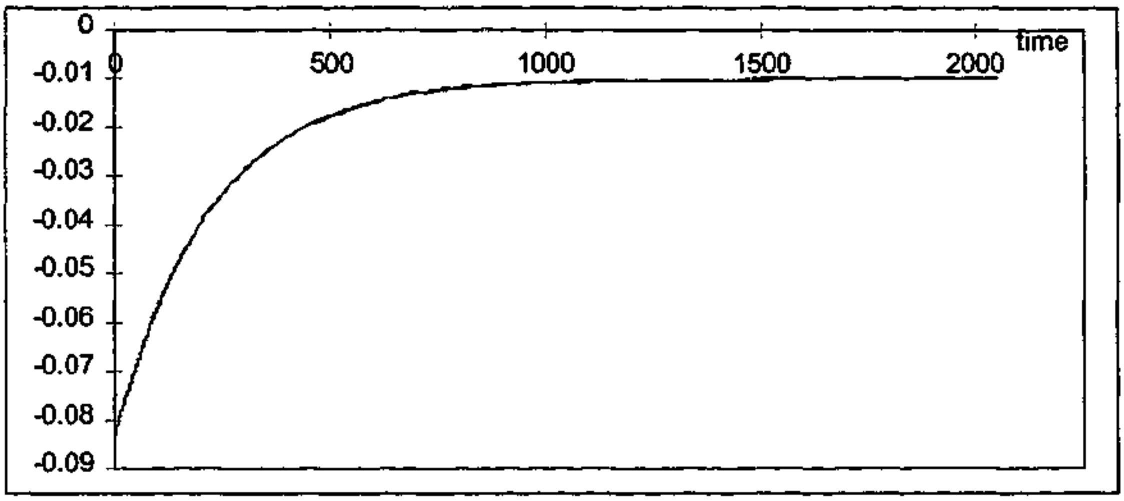
[16] $\eta = 1 - \dfrac{\alpha\beta(\lambda+\theta)}{1+\alpha(\beta\theta-1)}$

[17] The comparison has been completed numerically and by charting in Excel. The differences occur due to solving a differential equation as a finite time recursion.

DBM and EDBM were compared at varying values of δ. When $\delta = 0$, in DBM the initial jump of the exchange rate is -0.083656485 whilst the equivalent jump in EDBM is -0.083651901. The path to the long run is illustrated in figure 4.6. There is an initial jump from control at zero to -0.0837 and a monotonic retracement to the new long run equilibrium value of -0.00995. The paths of the two models overlap each other and as illustrated by the graph (figure 4.6), are indistinguishable at ordinary levels of resolution.

Figure 4.6.

The path of the exchange rate after a monetary shock of 1% for both EDBM and DBM when the real exchange rate is non-operational ($\delta = 0$)



The experiment is easily extended for non-zero values of delta, where the real exchange rate in the IS curve becomes operational. Using an arbitrary value for δ of 0.5, results in the analytical solution (DBM) for the initial (post-shock) value of the exchange rate of -0.011772975. This compares with the numerical solution (with φ still set to 1) of -0.011768402 in EDBM. This is accurate to 4 significant digits and the paths are again indistinguishable.

This exercise shows that the analytical model and the numerical model are consistent at relevant values of δ. The considerations above make a strong case for the use of the EDBM as a generalisation of behaviour in G&G under rational expectations when real exchange rates are allowed to play the role originally assigned them by Dornbusch.

Chapter 5

A Numerical Algorithm for the G&G Model

5.1 Introduction

In chapter 3.b, I established the mechanics of the Gruen and Gizycki model. In chapter 4, I have described a prototype framework from which a numerically solved miniature model can be produced. Using this framework, chapters 5 and 6 are dedicated to formulating a working model that is both consistent with the G & G framework and the mechanisms of a large macroeconometric model.

5.2 Equations and variables of the Anchored Model

The next step was to construct a working computer model of the G&G framework, including both rational and anchored traders. Initially, I began with the simplest case and elaborated as necessary. This initial model (in which all traders are anchored to the forward exchange rate) — the Anchored model — uses the equations listed in Table 5.1.

Table 5.1
Equations of the Anchored Model[(a)]

EQUATIONS OF MOTION IN THE ANCHORED MODEL		
IS Curve (reduced form)	$\Delta p_\tau = -\lambda\ (i_{\tau-1} - i^*)/\theta$	(5.1)
Anchored Traders' Expectations	$E^a_{s_\tau} = f_{\tau-1} - \beta[(s_{\tau-1} + p_{\tau-1}) - (\bar{s}_{\tau-1} + \bar{p}_{\tau-1})$	(5.2)
Interest Rate Dynamics	$(i_\tau - i^*) = (i_{\tau-1} - i^*)(1 - 1/\theta) - v_\tau/\lambda$	(5.3)
Covered Interest Parity	$f_{\tau-1} = i_{\tau-1} - i^* + s_{\tau-1}$	(5.4)
Exchange rate	$s_{\tau-1} = (i_{\tau-1} - i^*) + E^a_{s_\tau}$	(5.5)
LONG-RUN EQUATIONS		
Long-run neutrality of money	$\bar{p}_\tau\ =\ m_\tau - y_\tau$	(5.6)
Purchasing Power Parity	$\bar{p}_\tau\ =\ p^* - \bar{s}_\tau$	(5.7)

note: $\theta = \lambda/\pi\sigma$, see p 34.
note that the range of τ is from t+1 to infinity where the monetary shock impinges in τ=t+1
(a) The first four equations are explicit in G&G (1993); the fifth appears to be implicit.

In table 5.1 there are 7 equations extracted from the Gruen and Gizycki paper. Equation 5.1 is the reduced form of the IS curve that follows from the assumptions used in the G&G paper.[1] This form of the IS curve describes the change in the log price of domestic goods, Δp_{t+1} in terms of λ, the semi-elasticity of money demand with respect to the interest rate, the domestic and foreign interest rates (i and i*

Table 5.2

Notation for variables in the Anchored Model*

Variable	Description
i_t	domestic nominal interest rate
i^*_t	foreign nominal interest rate (exogenous)
p^*	foreign price level[2]
Δp_{t+1}	rate of domestic price inflation
s_t	current spot exchange rate, defined as the foreign currency price of a unit of domestic currency (initial value exogenous; endogenous thereafter)
$\bar{s}_t$	long-run exchange rate
p_t	domestic price level (initial value exogenous; endogenous thereafter)
$\bar{p}_t$	domestic price level in the long run
f_t	1 - period ahead forward rate of exchange rate
$E^a_{s_t}$	Anchored Traders' Expectations of the future exchange rate
y_t	real aggregate supply
m_t	nominal quantity of money
v_{t+1}	a shock to the domestic money supply

* All variables except i and i*, the interest rates are natural logarithms – interest rates are expressed as a proportion per annum. Variables in shaded rows have completely exogenous time paths.

[1] See Gruen and Gizycki (1993) Appendix A.

[2] The foreign price level, p*, is set at one in the levels, P* = 1, hence lnP* = p* = 0.

respectively) and $1/\theta$, the rate at which goods prices respond to a monetary shock. Equation 5.2 (see equation 3.b.13) is the expectations equation for anchored traders as explained in chapter 3.[3]

Equation 5.3 describes the initial jump and subsequent path of the domestic interest rate. This equation subsumes the LM curve. The assumptions that the real exchange rate has no influence on aggregate demand and that the supply of domestic and foreign interest-bearing assets made available to be managed by the traders exactly matches their minimum-variance portfolios, leads to equation 5.3.[4] With the economy in initial equilibrium at $t = 0$, then $i = i^*$ and any monetary shock, v_{t+1} will cause a jump in i at $t = 1$ of $-v_{t+1}/\lambda$. After this initial jump the domestic interest rate will follow a monotonic retracement back towards the world interest rate, i^*, at a rate governed by the parameter, θ.

Equation 5.4 determines the forward rate, f_{t-1}, given world and domestic interest rates as well as the current spot rate. This condition is known as covered interest parity and in this model is assumed to hold at all times as the forward foreign exchange market is assumed devoid of transaction costs and default risk. The final equation of the system making up the Anchored model is equation 5.5, exchange rate determination. The exchange rate equation contains the expected exchange rate for anchored traders $E^a_{s_t}$.

The two long-run equations (5.6 and 5.7) comprise a subsystem where $\bar{p}$ and $\bar{s}$ are determined endogenously by virtue of the exogeneity of y, m and p*. Thus any instantaneous jump in any of the three exogenous variables, in our scenario specifically the money supply, m, results in equiproportionate positive and negative jumps in $\bar{p}$ and $\bar{s}$ respectively.

[3] See p.36

[4] The exact derivation has been covered in chapter 3.b.2.

5.3 Closure of the Anchored Model

In this system there are 13 variables as listed in table 5.2. There are five clearly exogenous variables, the foreign nominal interest rate, i^*, aggregate supply, y, foreign price level, p^*, the initial level of money, m, and the monetary shock, v_{t+1}.

The evolution of the variables in the Anchored model naturally divides into two stages. The first stage is the interval of time when the monetary shock impinges. The second stage is the evolution of all the endogenous variables in subsequent periods, until a new long-run equilibrium is reached.

The anchored traders' expectations are tied to the forward exchange rate. As demonstrated analytically in chapter 3[5], when the market comprises anchored traders alone, the spot exchange rate is unmoved when the economy is subjected to a monetary shock. Appealing to this result, we can state that, as with the domestic price level, the spot exchange rate is also absolutely sticky at the time when the shock impinges. Therefore the spot exchange rate is also tied to its previous value. This means that both p and s are predetermined in t+1, the interval in which the shock impinges. In this we follow Gruen and Gizycki's notation.

We are assuming that the economy is in an initial long-run equilibrium and therefore that $i_t = i^*$; as well we normalise the initial exchange rate and price level to unity, so that $p_t = s_t = 0$. There are 7 equations in 13 variables of which five have fully exogenous trajectories. In addition, two endogenous variables, s_t and p_t, have exogenous initial values. Thus for the period at which the shock impinges there are nine conditions to determine eight endogeneities. Consequently, one equation becomes redundant at the time of the shock. This is equation 5.5. As s_{t+1} is tied to its previous value, equation 5.5 is not required to determine the exchange rate's initial value, but after the shock has impacted, the exchange rate becomes endogenous. Therefore immediately after the

[5] see p.48.

monetary shock (v_{t+1}) has impinged, equation 5.5 becomes operative, being required to determine the spot exchange rate endogenously in periods t+2, t+3, etc.. This allows the variables, i_τ, $\Delta p_{\tau+1}$, f_τ, $E^a_{s_{\tau+1}}$, $s_{\tau+1}$, $\bar{p}_\tau$, and $\bar{s}_\tau$ to be endogenously determined after the monetary shock has occurred at t+1 (i.e. for all $\tau \geq t+1$). Of course, with the time changes in p now endogenous, and with an exogenous starting value for its level, the path of p across t+2, t+3, etc., now is endogenised.

5.4 Simulation Properties of the Anchored Model

In this simulation $s_t = 0$. With the parameters taking the values:

$$\beta = 0.2 \qquad \lambda = 12 \qquad \theta = 40,$$

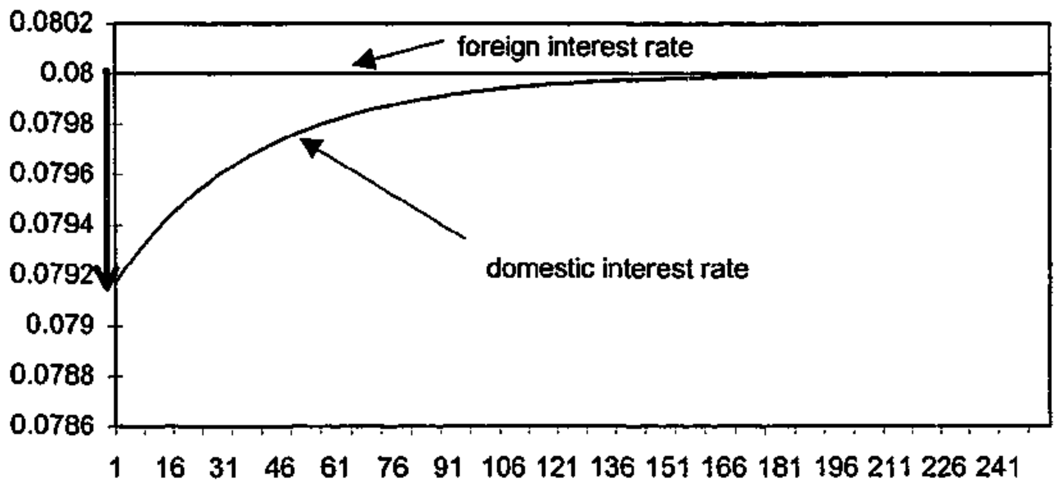
and the system subject to a 1% monetary shock, the anchored model behaved in a predictable manner. The paths of the endogenous variables are illustrated in figures 5.1 - 5.5.

Figure 5.1 shows the path of the two interest rate variables, i and i*. i* is fixed exogenously at 8% per annum as indicated by the straight line. Preceding the shock the domestic economy is in equilibrium and with the absence of a risk premium, $i = i^*$; that is, both the domestic and world interest rates are set at 8%. Immediately after the shock the domestic interest rate deviates from the world interest rate. As noted above, the magnitude of the instantaneous (i.e. within period t+1) fall in the interest rate due to a monetary shock is - v_{t+1}/λ, a consequence of the assumption that agents are continually on the money demand schedule, (eqn. 3.b.1). In reaction to the 1% monetary expansion, the value of the domestic interest rate falls instantaneously (at period t+1) to 0.0791708. Then (as in DBM) the interest rate follows a monotonic path back towards the world interest rate of 8%, converging after about 200 periods. The rate of convergence is dictated by the value taken by θ according to equation 5.3.

With the magnitude of the fall in the interest rate known, the values of f_t and $E^a_{s_{t+1}}$ can be determined. Taking the first difference of equation 5.4 (CIP) we obtain $\Delta f_{t+1} = \Delta i_{t+1}$ as i^* is fixed and Δs_{t+1} has been predetermined to equal 0. Referring to equation 5.2, we know that $s_{t+1} = p_{t+1} = 0$ (sticky prices à la Dornbusch and sticky exchange rate under anchoring) and from equations 5.6 and 5.7 we know that $\bar{p}_{t+1} = -\bar{s}_{t+1}$. Hence Δf_{t+1} is equal to $E^a_{s_{t+2}}$ But in equation 5.5 $E^a_{s_{t+1}} = 0$ because s_t is at its pre-shock normalised value (zero), while $(i_t - i^*)$ is also zero because the initial equilibrium has not yet been disturbed. Hence $E^a_{s_{t+1}} = 0 + \Delta E^a_{s_{t+2}} = \Delta f_{t+1}$.

Figure 5.1

The paths of the domestic and foreign interest rates



The three variables depicted in figure 5.2, are $E^a_{s_t}$, s_τ and f_τ. They have similar paths in that they all approach the long run value of 0.00995[6] and initially take the value 0. The spot exchange rate, $s_{\tau-1}$ does not move in t+1 as it is anchored; however both $E^a_{s_{t+1}}$ and f_t[7] react immediately to the monetary shock, their values falling to -0.0008292 (= v_{t+1}/λ = 0.00995/12) and from there follow a monotonic path to their new long run values. This behaviour can be clearly seen in figures 5.2 and5.3.

[6] A 1% monetary shock converts to a value of 0.00995 according to ln(1+1/100).

[7] Via equation 5.4 with s_t predetermined and i* exogenous $\Delta f_t = \Delta i_t$.

Figure 5.2

The paths of $E^a_{s_\tau}$, $s_{\tau-1}$ and $f_{\tau-1}$, after a 1% monetary shock

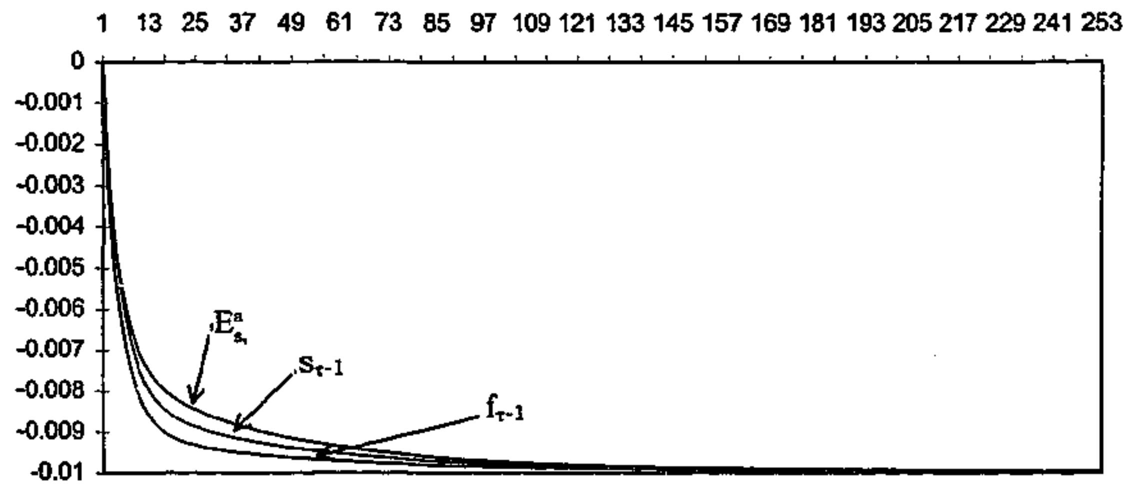
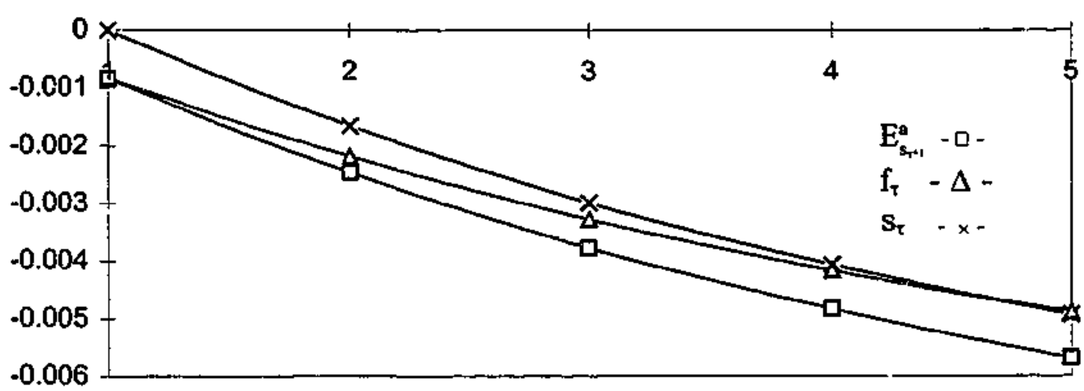


Figure 5.3

Initial stages of $E^a_{s_{\tau+1}}$, s_t and f_τ in the Anchored model.



After its initial stickiness in t+1, price (p) follows the path shown in figure 5.4, which is determined by Δp_{t+1}, whose path is depicted in figure 5.5. Here the rate of inflation jumps to a value of 0.00025 then monotonically falls, so that there is virtually no inflation by period 200.

Figure 5.4.

The path of p, the price level, after a 1% monetary shock in the Anchored model.

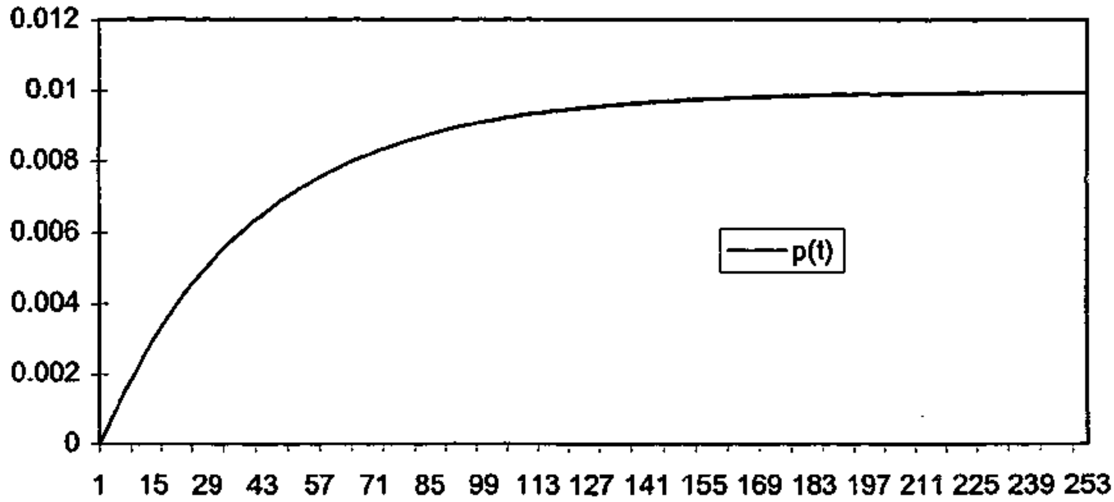
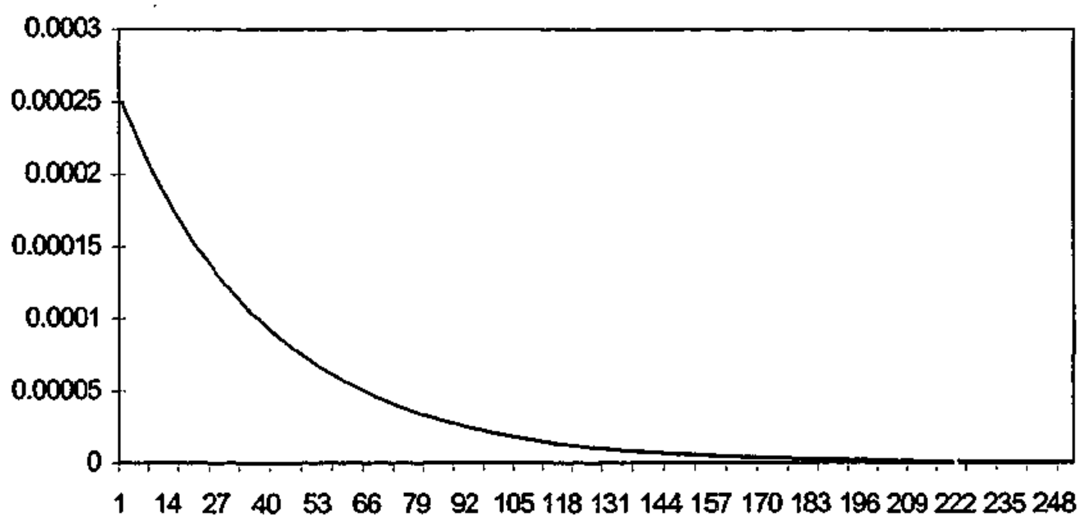


Figure 5.5

The path of Δp, the rate of inflation, after a 1% monetary shock in the Anchored model.



All of the endogenous variables follow the prescribed paths required in the G&G framework, allowing us to proceed to the next stage of the process. This is to expand the model to allow for the combination of anchored and rational traders in a numerically solved model.

5.5 Exchange rate behaviour in G&G under different calibrations

We now have numerical solutions for the rational expectations model, EDBM, and for the Anchored model. We also have a closed form solution for the G&G model under their scenario in which the real exchange rate is expunged from the IS curve. The equation for the exchange rate is 3.b.47:

$$s_{t+\tau} = s_t + v_{t+1}\left(1+\frac{\theta\eta}{\lambda}(1-1/\theta)^{\tau-1}\right). \qquad (5.8)$$

This equation provides the base to which a numerical solution can be calibrated. At this stage the coefficient on the real exchange rate (δ) is still held to zero. The aim is to reintroduce the real exchange rate after a numerical solution has been estabiished under the restrictive set of conditions for which we have a closed form solution (namely, (5.8)).

The closed form solution of the G&G framework as represented by equation 5.8 will have different instantaneous jumps, in response to a permanent monetary shock, depending on the values that α and β take. α represents the proportion of anchored traders in the market, varying from 0 (when all traders are rational) to 1 (when all are anchored). β is the coefficient determining the rate at which anchored traders' expectations adjust from the anchor (the forward rate, f_t) towards their current target level for the real exchange rate.

G&G have calibrated β in terms of weakly anchored and strongly anchored traders.[8] With the domestic goods market in long-run equilibrium, the initial jump in the exchange rate is zero ($\Delta s_{t+1} = 0$) when only anchored traders are present. Conversely when all traders are rational the instantaneous jump of the exchange rate is $\Delta s_{t+1} = v_{t+1}(1+\theta/\lambda)$, where v_{t+1} is the magnitude of the monetary shock. G&G have derived values for β when $\alpha = 0.5$. If the spot exchange rate

[8] Gruen and Gizycki (1993) p.21.

were to jump half way as compared to a fully rational market, G & G characterise the situation as the *weakly anchored case*. Then:

$$\Delta s_{t+1} = v_{t+1}(1+\theta/\lambda)/2. \tag{5.9}$$

Recalling equation 3.b.46:

$$\Delta s_{t+1} = \eta fd_t + (1 + \frac{\theta\eta}{\lambda})v_{t+1} + e_{t+1},$$

we see that as there is an initial long run equilibrium $i_t = i^*$ at t, hence $fd_t = 0$[9]. Since there are no other shocks besides the single monetary shock occurring at t+1, then $e_{t+1} = 0$. This leads to:

$$\Delta s_{t+1} = (1 + \frac{\theta\eta}{\lambda})v_{t+1}. \tag{5.10}$$

Equating equation (5.9) to equation (5.10) gives us:

$$v_{t+1}(1+\theta/\lambda)/2 = (1 + \frac{\theta\eta}{\lambda})v_{t+1}.$$

Substituting for η from equation 3.b.48 leads to:

$$v_{t+1}(1+\theta/\lambda)/2 = (1 - (\frac{\alpha\beta(\lambda+\theta)}{1+\alpha(\beta\theta-1)})\frac{\theta}{\lambda})v_{t+1}.$$

This simplifies to:

$$\beta = 1/\theta.$$

When the exchange rate jumps only one-tenth of the way — the *strongly anchored case* — $\Delta s_{t+1} = v_{t+1}(1+\theta/\lambda)/10$ and it follows that $\beta = 9/\theta$.

Often it is more convenient to parametise the model given θ and λ in terms of the relative size of the jump, rather than in terms of β. Thus the scenario described above can be extended combining any value of α (between 0 and 1) and any assumption on the effect anchored traders have on the jump in the exchange rate. The resultant formula for β is given by:[10]

$$\beta = \frac{(\frac{1}{\kappa}-1)}{\theta}, \tag{5.11}$$

[9] See equation 3.b.33.

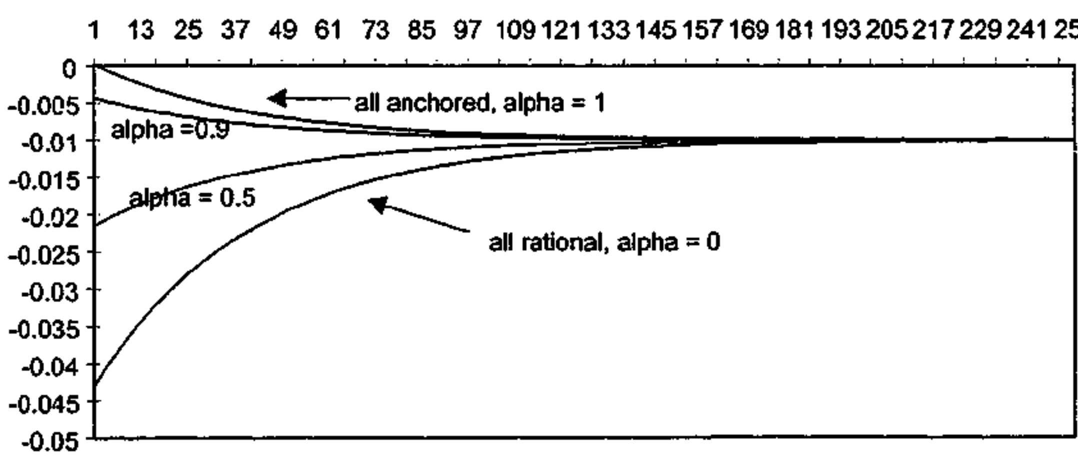
[10] The derivation is shown in Appendix A.

where κ is equal to the assumed proportional jump in the exchange rate[11] in the G&G model when the anchored and rational traders are evenly divided ($\alpha = 0.5$), θ is the speed of adjustment in the Anchored model, and λ is the value of the semi-elasticity of demand for money. For any given values of α, θ, and λ, values of β that correspond to values of κ can be calculated via (5.11). Given that $\alpha = 0.5$, when $\kappa = ½$, we have weak anchoring, and when $\kappa = 1/10$, we have strong anchoring.

Notice that in the definitions above, weak and strong anchoring have been defined (by G&G) relative to a market equilibrium in which anchored and rational traders have equal shares (α=0.5). Here the concept is extended to refer to the *behaviour* of the anchored traders irrespective of their market share. If the parameters of the anchored traders (θ, λ, β) are such that $\kappa \leq 0.5$ when $\alpha = 0.5$, we say that these traders are weakly anchored; if on the other hand the values of these two behavioural parameters imply $\kappa \leq 0.1$ when $\alpha = 0.5$, we regard them as strongly anchored, irrespective of what prevailing actual value of α is in the market.

Figure 5.6

The path and initial jump of the exchange rate in G&G when κ is fixed at ½ (weakly anchored) and α allowed to vary when the market is subjected to a 1% monetary shock.



[11] That is, the proportion of the corresponding Dornbusch jump.

The path of the exchange rate after the initial jump is dependent on α, β, θ and λ. In figure 5.6, the anchored traders are assumed to be weakly anchored.[12] Thus when $\alpha = 0.5$, the resultant jump is exactly half that of the rational traders' jump. When $\alpha = 0.9$, the resultant jump is one-tenth that of the rational traders' jump. With κ set at ½, β is equal to 0.025.

As in EDBM, after a monetary shock, a full instantaneous adjustment to the new long-run equilibrium in the Anchored Model is possible. With the current parameter settings, α needs to be set at approximately 0.77 for full instantaneous adjustment.[13] The analogous adjustment is possible in EDBM by the appropriate calibration of the parameter ψ in equation 4.1. Anchoring of the exchange rate provides an alternative mechanism to those described in Powell and Murphy for changing the qualitative and quantitative properties of the initial jump in the exchange rate.[14]

In figure 5.7, α is fixed at 0.5. By varying the assumption about the degree of anchoring (i.e. κ), we can see the resultant differences. When we have strongly anchored traders ($\kappa \leq 1/10$), the jump is at least one-tenth of the rational jump. If we have weakly anchored traders ($\kappa \leq$ ½), the resultant jump is half of the rational traders' jump.

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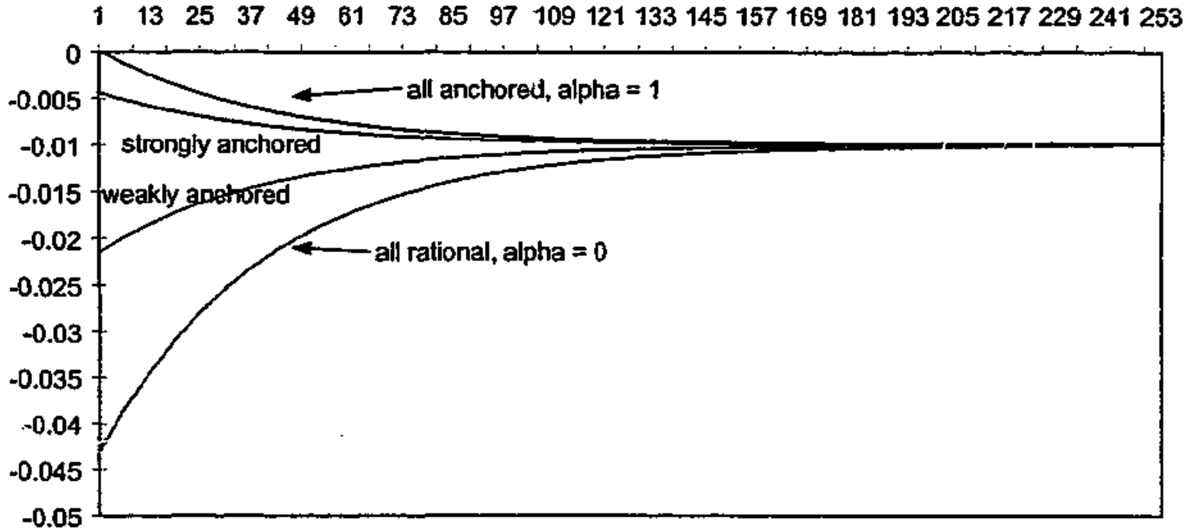
[12] The values of $\theta = 40$ and $\lambda = 12$ are unchanged for figures 5.6 and 5.7. Altering these values changes the path to the long-run equilibrium but not the initial jump.

[13] Clearly, the value for α required to attain instantaneous long-run equilibrium, varies with different parameter settings.

[14] Powell and Murphy (1995), p.322.

Figure 5.7
The path and initial jump of the exchange rate in G&G with α=0.5 and varying κ, as well as the extreme cases (α=1, α=0), when the market is subjected to a 1% monetary shock.



5.6 Numerical algorithm for G&G

The properties of the closed form are well known, so the next step is to create a combination of the two numerical models, the Anchored model and EDBM, to replicate the closed form behaviour of the exchange rate in the Gruen and Gizycki model (at least to a good approximation). This procedure is strictly heuristic: the G&G model builds on rational and anchored behaviour: although by no means certain, it might be expected that the exchange rate in G&G would be approximated by a linear combination of the values that it would take in the two component models. The approach adopted below for verifying this surmise is purely empirical.

Finding a suitable heuristic algorithm is logically divided into two steps. The first is to determine the actual jump in the exchange rate and the second is to characterise the subsequent path to the long-run equilibrium.

Unlike the combination determining its subsequent path, the jump in the exchange rate can be found analytically. It is[15]:

$$\text{jump} = \left(\frac{1}{1+(\frac{\alpha}{1-\alpha})(\frac{1}{\kappa}-1)} \right)\left\{ v_{t+1}(1+\frac{\theta}{\lambda}) \right\}, \tag{5.12}$$

where α is the proportion of anchored traders, v_{t+1} is the once off monetary shock, and therefore $(v_{t+1})(1+\theta/\lambda)$ is the jump in the exchange rate that would occur when the market comprises only rational traders. For example, if α = 0.9 and κ = 0.1, then the exchange rate will jump 1/82 of the way as compared to a fully rational market.[16]

As stated previously the initial jump when expressed as a fraction of the jump in a fully rational market is independent of the other parameters — λ, σ, π and β — but the numerical algorithm constructed for the exchange rate's subsequent path involves the parameters β and λ as well.[17] The process for devising this algorithm was essentially by trial and error. The resulting algorithm is reasonably accurate across a wide range of parameter settings. The algorithm determining the market exchange rate is:

$$s^m_\tau = Y_\tau . s^a_\tau + (1 - Y_\tau).s^d_\tau ; \qquad (\tau \geq t+1) \tag{5.13}$$

in which τ is a positive integer, and

$$\text{where} \qquad Y_\tau = .(1-(\frac{1}{1+(\frac{\alpha}{1-\alpha}).(\frac{1}{\kappa}-1)})). \qquad (\tau = t+1) \tag{5.14}$$

$$Y_\tau = \sum_{n=1}^{\tau} \frac{0.4}{\lambda}.(1-(\frac{1}{1+(\frac{\alpha}{1-\alpha}).(\frac{1}{\kappa}-1)})).(1-0.75.\beta)^n \qquad (\tau \geq t+2) \tag{5.15}$$

s^a_τ is the exchange rate as determined in the Anchored model,

[15] See Appendix A for a derivation of the jump in the exchange rate.

[16] (1/(1+(0.9/(1-0.9))9) = 1/82. If on the other hand, α = 0.5 and κ = 0.1, then by definition of the latter, the exchange rate will jump 1/10 of the rational jump.

s_τ^m is the exchange rate as determined by the numerical algorithm

s_τ^d is the exchange rate as determined in the Extended Dornbusch model,

λ is the semi-elasticity of demand for money with respect to the interest rate,

α is proportion of anchored traders in the market,

β is the rate at which anchored traders adjust to long-run equilibrium and,

κ is the proportion of a fully rational jump that the exchange rate would take when $\alpha = 0.5$.

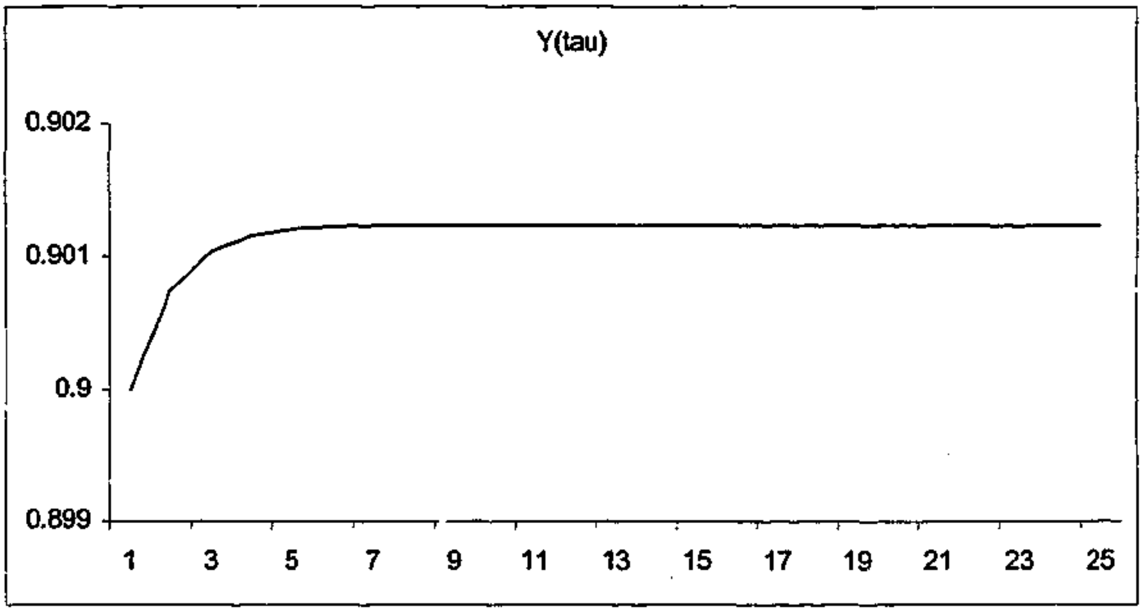
Equation 5.13 is a linear combination of the two numerical models, but the weights vary according to the parameters listed above, as well as across time. The functional form of the weighting function 5.15, as well as the parameter values 0.4 and 0.75 in 5.15, were found by experimentation. While other choices might also work satisfactorily, the above choice works well over a reasonably wide range of the parameters of the underlying models (as will be seen below).

Figure 5.8 illustrates the behaviour of the algorithm for a given set of parameters. As shown the jump is 0.9 of the initial jump that would occur if there were solely rational traders. Hence the exchange rate would in the period after the shock jump by $0.9^*(v_{t+1})(1+\theta/\lambda)$. After this initial jump there is a monotonic path to a long run constant that determines the ultimate mix of anchored and rational traders.

[17] The non-appearance of σ and π in the algorithm implies that the algorithm will be accurate across a restricted range of these parameters. In practice the algorithm works well provided $\pi\sigma > 0.25$.

Figure 5.8[18]

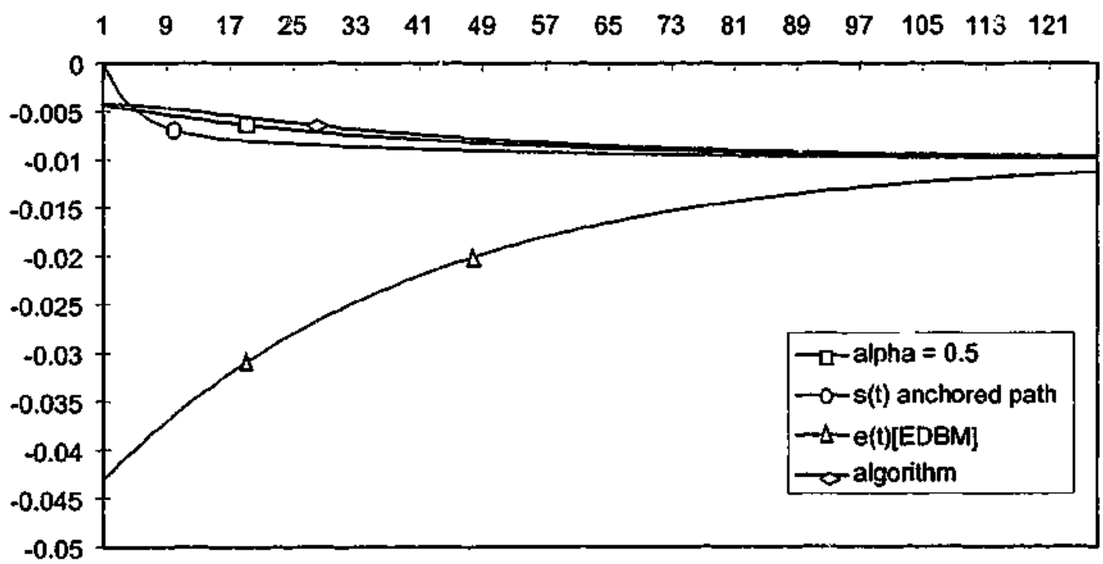
The path of the algorithm when $\alpha = 0.5$ and $\kappa = 0.1$.



Figures 5.9 to 5.16 illustrate the accuracy of the numerical algorithm.

Figure 5.9

The path of the exchange rate for the closed form solution of Gruen and Gizycki as compared to the algorithm when $\alpha = 0.5$ and traders are strongly anchored. (As well, the paths of all anchored and all rational traders are illustrated).[19]



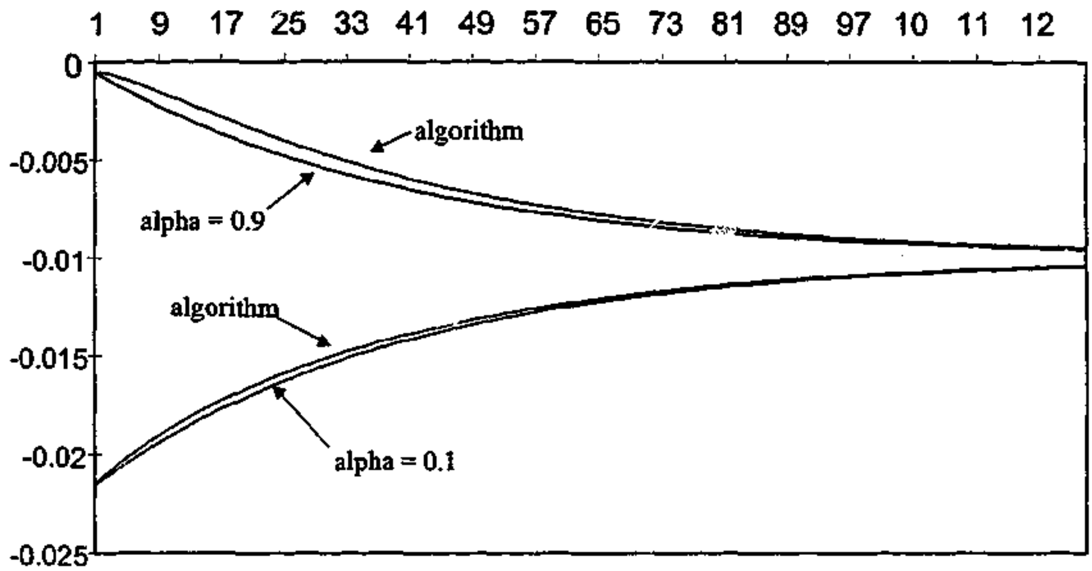
[18] $\lambda = 12, \theta = 40$.

[19] $\lambda = 12, \theta = 40$. The economy has been subjected to a 1% monetary expansion.

The parameters are set at the values as above[20], but now β is determined endogenously according to equation 5.11. With strongly anchored traders (κ = 1/10), figure 5.9 illustrates the accuracy of the algorithm when α = 0.5. As is evident the correlation is reasonably accurate. When α = 0.1 and 0.9, with all the settings as above, the comparison can be seen in figure 5.10.

Figure 5.10

Comparison of algorithm and closed form solution when α = 0.1 and α = 0.9.



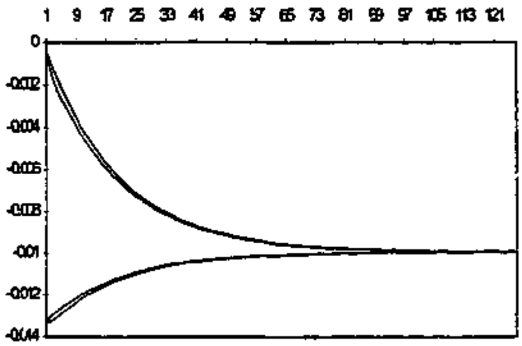
The values of θ (= $\pi\sigma/\lambda$), λ, α and κ can all be varied. Across realistic values of these parameters, the numerical algorithm behaves well.

Figures 5.11 - 5.16 further demonstrate the accuracy of the algorithm across a range of parameters. Each figure contains two sets of paths of the exchange rate. Each set is composed of the closed form solution and the corresponding solution of the algorithm. As is evident, the algorithm is sufficiently accurate across this range of parameters. But figures 5.15 and 5.16 portend some limitations with the algorithm. These two figures in comparison with the previous four figures have a lower κ. Depending on the other parameters, a sufficiently low κ will send the algorithm haywire.

[20] See footnote 14.

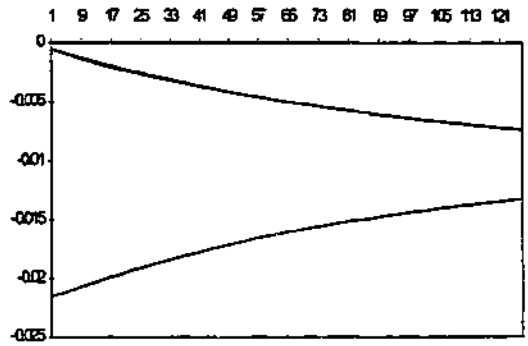
An example is given in figure 5.17 where κ is set to 1 and the remaining parameters are σ = 0.45, λ = 6, π = 0.6667 and α = 0.5. This figure displays exchange rate paths for the Anchored model, the closed form and for the algorithm.

Figure 5.11



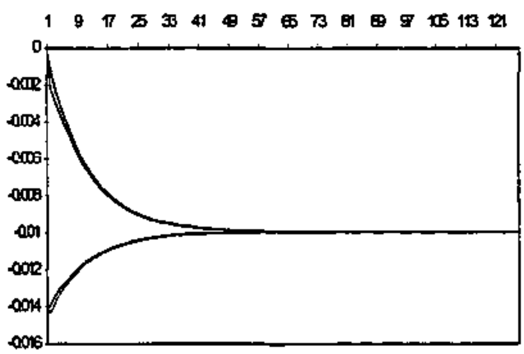
$\sigma = 0.9$ $\kappa = 9$ $\lambda = 12$ $\pi = 0.6667$ $\alpha = 0.1, 0.9$

Figure 5.12



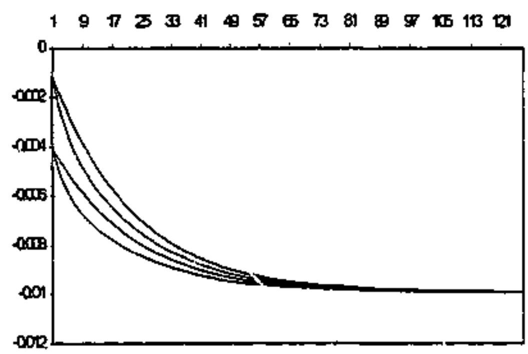
$\sigma = 0.9$ $\kappa = 9$ $\lambda = 30$ $\pi = 0.6667$ $\alpha = 0.1, 0.9$

Figure 5.13



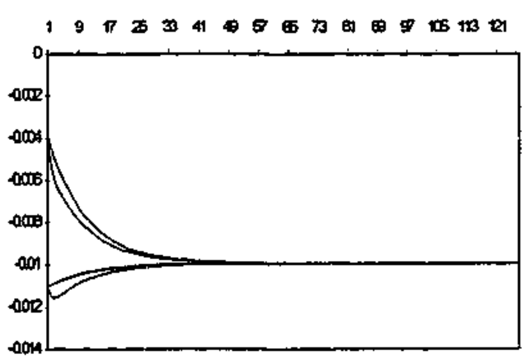
$\sigma = 0.6$ $\kappa = 9$ $\lambda = 6$ $\pi = 0.9$ $\alpha = 0.1, 0.9$

Figure 5.14



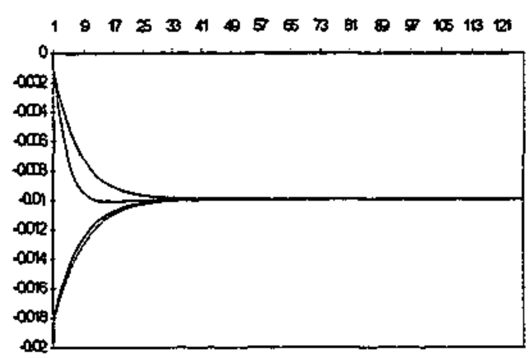
$\sigma = 0.6$ $\kappa = 9$ $\lambda = 12$ $\pi = 0.9$ $\alpha = 0.5, 0.8$

Figure 5 15



$\sigma = 0.9$ $\kappa = 5$ $\lambda = 6$ $\pi = 0.75$ $\alpha = 0.5, 0.2$

Figure 5.16

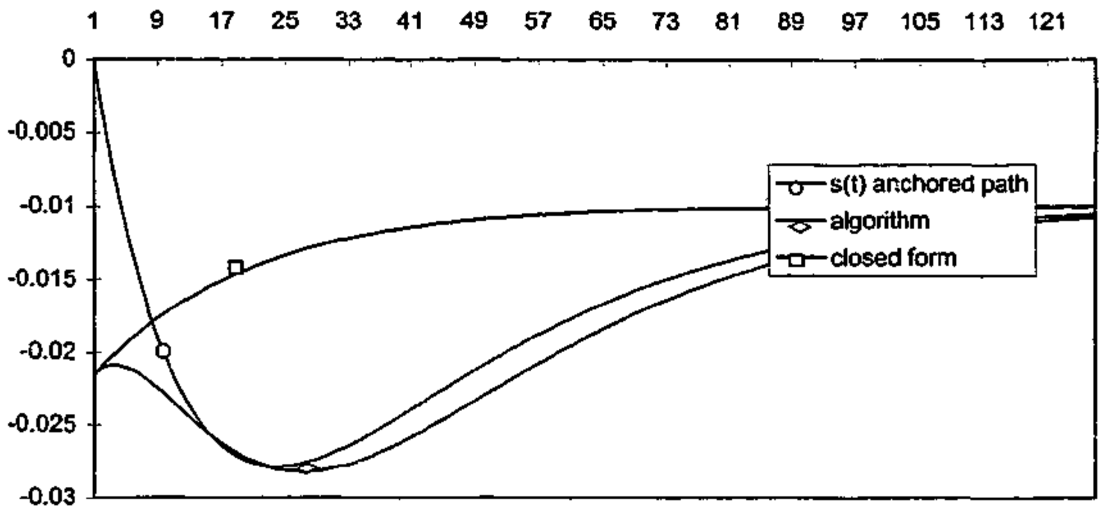


$\sigma = 0.9$ $\kappa = 2$ $\lambda = 6$ $\pi = 0.9$ $\alpha = 0.1, 0.9$

Note that the algorithm is the lower path for each of the pairs of exchange rate paths.

Figure 5.17

Example of the non-monotonic properties of the Anchored model and the subsequent effect of this non-monoticity on the algorithm.



The Anchored model as represented in table 5.1, has non-monotonic properties. In figure 5.17, this is the path signified by the circle. Although the exchange rate converges to its long-run value, the path is not monotonic. This particular behaviour of the exchange rate occurs when β in the expectations equation is significantly small. Also evident is that after the initial jump, the algorithm tends to follow the exchange rate from the Anchored model rather than the closed form exchange rate.

The expectations equation (eq. 5.2):

$$E^{a}_{s_{t+1}} = f_t - \beta[(s_t + p_t) - (\tilde{s}_t + \bar{p}_t)],$$

is devised in the levels not in first differences. This means that β is not constrained to the usual [0,1] space; in fact β can take all values greater than zero.

When β is sufficiently small, the Anchored model's exchange rate exhibits non-monotonic behaviour as seen in figure 5.17. For example, in the above diagram, given the parameters, β needs to be above $0.33\dot{3}$ for the exchange rate in the Anchored model to be non-monotonic. If θ is doubled, β needs to be above $0.166\dot{6}$ to ensure a monotonic retracement of the exchange rate. Another minor problem exists with the algorithm in that it does not behave well for very low values of π and σ.

Hence to ensure that we follow the intention of the Gruen and Gizycki paper[21], we will restrict the permitted parameter space so that the exchange rate in the Anchored model exhibits monotonic behaviour at all times.

[21] — that the exchange rate in response to a shock jumps instantaneously and then follows a monotonic path to the long-run equilibrium.

Chapter 6

Putting the Real Exchange Rate Back into G&G – the EGG Model

6.1 Introduction

In chapter 5, a numerical algorithm was developed that replicated the framework developed by Gruen and Gizycki. Using this numerical algorithm, the G&G framework is now extended to include a more realistic domestic demand function that includes the real exchange rate. It is assumed that when the real exchange rate is included, the general properties of the numerical algorithm are unchanged.

6.2 Derivation of the Anchored-RER Model

An analytical solution of the G&G model is quite difficult as reported by G&G in their paper. They couldn't find such a solution when the real exchange rate appeared in the IS curve. This is not surprising since we know that only a negligible proportion of difference and differential equations possess an explicit closed form solution. However G & G were committed to working with an analytically closed form. So for reasons of tractability, they dropped the real exchange rate from the domestic demand function[1].

The formulation of the numerical algorithm for the spot exchange rate in Chapters 4 and 5 omits any reliance on the real exchange rate embedded in the demand function (i.e., $\delta = 0$ in 4.3). To ensure the compatibility of the algorithm for the integrated model with larger, more realistic, macroeconometric models, the re-introduction of the real exchange rate is necessary. By simply redefining the demand function as presented by Gruen and Gizycki to again reflect the original Dornbusch model, we can follow the same assumptions and procedures as outlined in chapter 3.b.

[1] Their problem involves the solution of a difference equation but as we have a numerically solved model, the re-introduction of the real exchange rate will not cause any additional problems.

The LM curve is assumed to be the same as before,

$$m_t - p_t = \phi \bar{y} - \lambda i_t. \tag{6.1}$$

Domestic supply is again fixed at $\bar{y}$, leaving interest rates and prices to adjust to shocks to money supply. The demand function follows the original Dornbusch model and differs from the G&G formulation via the re-introduction of the real exchange rate term:

$$\ln(D_t) = \xi + \delta \bar{y} + \chi(p^* - s - p) - \sigma i_t. \tag{6.2}$$

The real exchange rate, $p^* - s - p$, is simplified by normalising the foreign price level to one ($P^*=1$, $\ln P^*=p^*=0$). Hence the Phillips curve may be written as:

$$\Delta p_{t+1} = \pi \ln(D_t/Y_t) = \pi(\xi + (\delta-1)\bar{y} + \chi(- s - p) - \sigma i_t). \tag{6.3}$$

As in the simplified version, goods prices do not instantaneously adjust to excess demand. Using the same set of assumptions as discussed in chapter 3.b, in long run equilibrium we have $i = i^*$ and, $p_t = \bar{p}_t$, resulting in the long run LM curve:

$$\bar{p}_t = m_t + \lambda i^* - \phi \bar{y}. \tag{6.4}$$

When the long run LM curve is subtracted from its short-run counterpart, the result is:

$$p_t - \bar{p}_t = \lambda (i_t - i^*). \tag{6.5}$$

In the long run $\Delta p = 0$; hence the long-run version of (6.3) is:

$$0 = \xi + (\delta-1)\bar{y} + \chi(- \bar{s} - \bar{p}) - \sigma i^*. \tag{6.6}$$

Subtracting (6.6) from (6.3) and substituting for $(p_t - \bar{p}_t)$ from (6.5), leads to:

$$\Delta p_{t+1} = - \lambda (i_t - i^*)/\theta - \pi\chi((s + p) - (\bar{s} + \bar{p})), \qquad \text{where } \theta = \lambda/(\pi\sigma) > 0. \tag{6.7}$$

This result contains an extra term in comparison to the original G&G formulation: $-\pi\chi((s + p) - (\bar{s} + \bar{p}))$. This equation will certainly alter the dynamics of the model as $1/\theta$ is no longer the sole parameter influencing the rate at which goods prices adjust to monetary shocks.

Following the same procedure as used in chapter 3.b, leads to the equation:

$$(i_{t+1} - i^*) = (i_t - i^*)(1 - 1/\theta) - \pi\chi/\lambda((s + p) - (\bar{s} + \bar{p})) - v_{t+1}/\lambda, \qquad (6.8)$$

which is analogous to equation (3.b.10):

$$(i_{t+1} - i^*) = (i_t - i^*)(1 - 1/\theta) - v_{t+1}/\lambda. \qquad (3.b.10)$$

Equation (6.8) again illustrates the initial jump of the interest rate in response to a monetary shock, $-v_{t+1}/\lambda$, which is unchanged from equation (3.b.10). But after the initial instantaneous reaction to the monetary shock the path to long run equilibrium is different.

6.3 Equations and variables of the Anchored-RER Model

The above formulation for the interest rate dynamics leads to a new set of equations for the Anchored-RER model as shown in Table 6.1.

Table 6.1

Equations of the Anchored-RER Model

EQUATIONS OF MOTION IN THE ANCHORED-RER MODEL		
Price Dynamics	$\Delta p_\tau = -\lambda\ (i_{\tau-1} - i^*)/\theta - \pi\chi((s_{\tau-1}+ p_{\tau-1}) - (\bar{s}_{\tau-1}+ \bar{p}_{\tau-1})$	(6.9)
Anchored Traders' Expectations	$E^a_{s_\tau} = f\tau\text{-}1 - \beta[(s\tau\text{-}1 + p\tau\text{-}1) - (\bar{s}\tau\text{-}1+ \bar{p}\tau\text{-}1)$	(6.10)
Interest Rate Dynamics		
	$(i_\tau - i^*) = (i_{\tau-1} - i^*)(1 - 1/\theta) - \pi\chi/\lambda((s_{\tau-1}+ p_{\tau-1})-(\bar{s}_{\tau-1}+ \bar{p}_{\tau-1})) - v_\tau/\lambda$	(6.11)
Covered Interest Parity	$f_{\tau-1} = i_{\tau-1} - i^* + s_{\tau-1}$	(6.12)
Exchange Rate	$s_{\tau-1} = (i_{\tau-1} - i^*) + E^a_{s_\tau}$	(6.13)
LONG-RUN EQUATIONS		
Long-run neutrality of money	$\bar{p}_\tau = m_\tau - \bar{y}_\tau$	(6.14)
Purchasing Power Parity	$\bar{p}_\tau = p^* - \bar{s}_\tau$	(6.15)

Note: $\theta = \lambda/\pi\sigma$, see p.34.

Note that the range of τ is from t+1 to infinity where the monetary shock impinges in τ=t+1.

The Anchored-RER model is identical to the Anchored model, as represented in table 5.1, for five of the seven equations. The price dynamics equation curve has an added term $(-\pi\chi((s_{\tau-1}+ p_{\tau-1}) - (\bar{s}_{\tau-1}+ \bar{p}_{\tau-1})))$ (cf. equations 6.9 and 5.1) as does the interest rate dynamics equation $(-\pi\chi/\lambda((s_{\tau-1}+ p_{\tau-1})-(\bar{s}_{\tau-1}+ \bar{p}_{\tau-1})))$ (cf. equations 6.11 and 5.3). The notation of the model is identical and is repeated below for convenience:

Table 6.2

Notation for variables in the Anchored-RER Model*

Variable	Description
i_t	domestic nominal interest rate
i_t^*	foreign nominal interest rate (exogenous)
p^*	foreign price level[2]
Δp_{t+1}	rate of domestic price inflation
s_t	current spot exchange rate, defined as the foreign currency price of a unit of domestic currency (initial value exogenous; endogenous thereafter)
$\bar{s}_t$	long-run exchange rate
p_t	domestic price level (initial value exogenous; endogenous thereafter)
$\bar{P}_t$	domestic price level in the long run
f_t	1 - period ahead forward rate of exchange rate
$E^a_{s_{t+1}}$	Anchored Traders' Expectations of the future exchange rate
$\bar{y}_t$	real aggregate supply
m_t	nominal quantity of money
v_{t+1}	a shock to the domestic money supply

* All variables except i and i*, the interest rates are natural logarithms – interest rates are expressed as a proportion per annum.

The closure of the model remains unchanged with 13 variables as listed in table 6.2. There are still five clearly exogenous variables, the foreign nominal interest rate, i^*, aggregate supply, $\bar{y}$, foreign price level, p^*, the initial level of money, m, and the monetary shock, v_{t+1}. As in the Anchored model, the evolution of the variables in the Anchored-RER model divide into two stages; the first stage is the interval when the shock impinges and the second stage is the subsequent evolution of the endogenous variables until a new equilibrium is attained. The sequence for determining the evolution of the endogenous variables is as described for the Anchored model.

[2] The foreign price level, p^*, is set at one in the levels, $P^* = 1$, hence $\ln P^* = p^* = 0$.

6.4 Simulation Properties of the Anchored-RER Model

This initial simulation follows the scenario set out in chapter 5, with the parameters taking the following values:

$\beta = 0.2 \qquad \lambda = 12 \qquad \theta = 40 \qquad \pi = 0.666667 \qquad \sigma = 0.45$

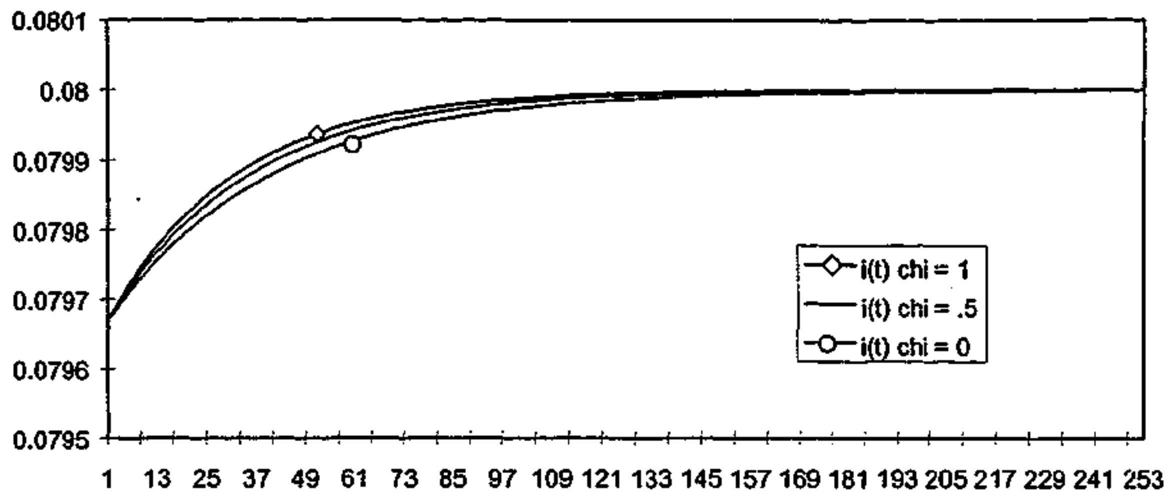
and the system subjected to a 1% monetary shock. The path of the interest rate is shown for varying values of χ. When $\chi = 0$, the path is identical to the path of i in the Anchored model. This is self-evident in that when $\chi = 0$, the second terms in equations 6.9 and 6.11 vanish and the equations collapse to equations 5.1 and 5.3 respectively in the Anchored model — the two models are then identical.

In figure 6.1, the path of the interest rate is shown for three different scenarios, where χ takes on different values. There is still an instantaneous jump in the interest rate that occurs when the monetary shock is introduced. It is evident that the introduction of the real exchange rate term in the domestic demand schedule has not affected this initial jump. As in the scenario used for the Anchored model, i^* is fixed exogenously at 8%. With a 1% monetary shock the value of the domestic interest rate falls instantaneously to 0.0791708 irrespective of the value of χ.

However, in the periods after the jump the path of the domestic interest rate, i, is dependent on the value of χ. But the reintroduction of the real exchange rate term into the demand function has only a minimal effect on the rate of adjustment of the domestic interest rate. Using the parameters as shown above, in figure 6.1, χ is set successfully at 0, 0.5 and 1. When $\chi = 0$, the Anchored-RER model collapses back into the Anchored model; hence the path for the interest rate is the same as shown in figure 5.1. The path of the interest rate when $\chi > 0$ indicates a quicker

Figure 6.1

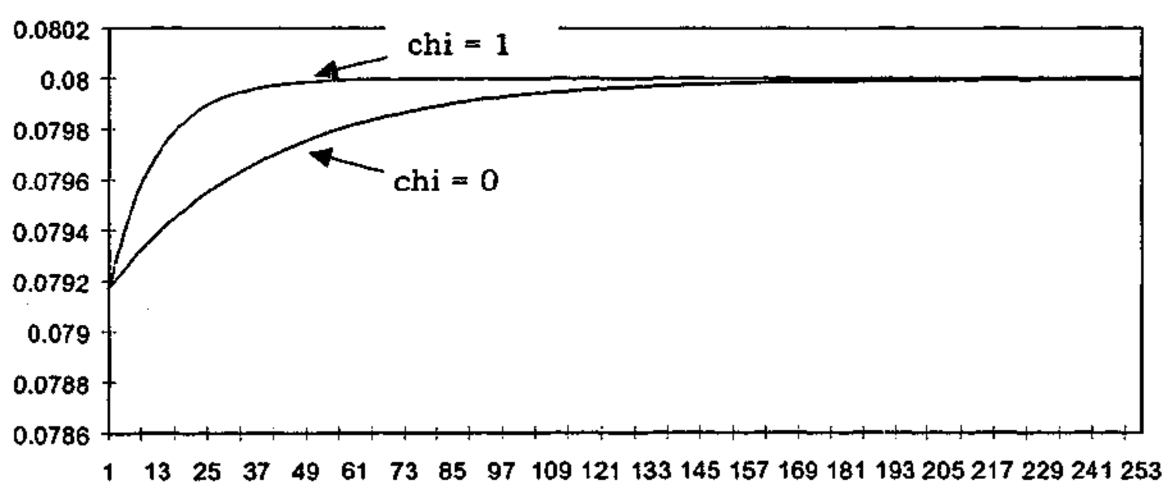
The paths of the domestic interest rate in the Anchored-RER model, when the value of χ is varied, in response to a permanent monetary shock.



rate of adjustment to the long-run equilibrium, although the rate is not significantly greater. The difference in the rate of convergence is dependent on the parameter settings. In figure 6.2 a different set of parameters has been used and the rate of convergence is significantly greater. For all values of $\chi > 0$, the interest rate converges at a faster rate than if χ is set to zero.

Figure 6.2

Paths of the domestic interest rate for the Anchored-RER model subject to alternative parameter settings[(a)].

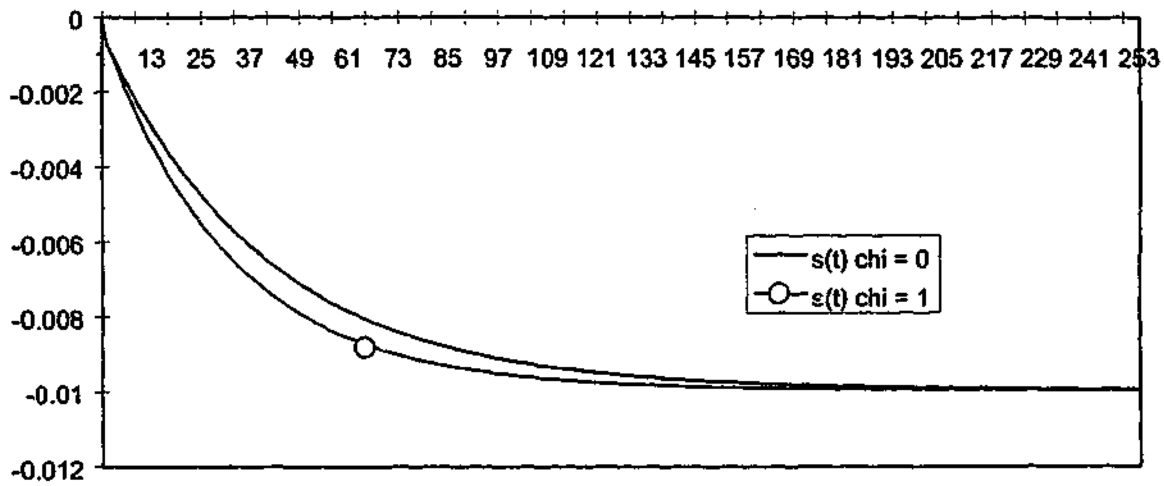


(a) Parameter settings: $\beta = 0.5$, $\lambda = 12$, $\theta = 40$, $\sigma = 0.9$, $\pi = 0.333$

The result for all the other endogenous variables is similar. $E^a_{s_t}$, s_t and f_t. all increase their rate of convergence as χ is increased. In figure 6.3 the path of the exchange rate is shown when $\chi = 0$ and $\chi = 1$ with the model subject to the original parameter settings[3]

Figure 6.3

Path of the exchange rate in the Anchored-RER model for $\chi = 0$ and $\chi = 1$.



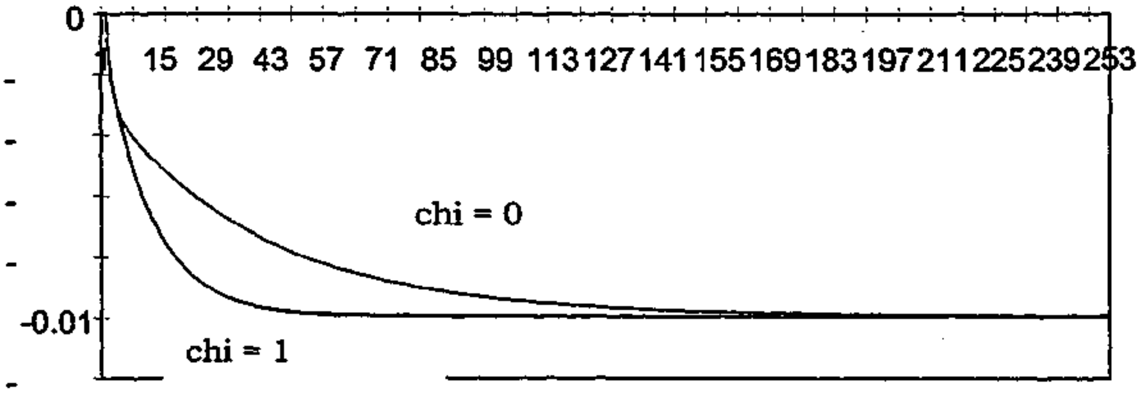
The relative paths of the exchange rate, like the interest rate, can be affected by the selection of the parameter values. Figure 6.4 illustrates that differing parameters values can force the two models' exchange rates to vary considerably for an extended period. As with the domestic interest rate, whatever parameter settings are used, the Anchored-RER model's exchange will converge to the long run equilibrium at a faster rate than the exchange rate from the Anchored model ($\chi = 0$).

The problem inherent in the Anchored model also appears in the Anchored-RER model. This relates to the non-monotonic behaviour of the exchange rate for very low values of β. This is again a result

[3] $\beta = 0.2, \lambda = 12, \theta = 40$ $\pi = 0.666667$ $\sigma = 0.45$

Figure 6.4

Path of the exchange rate in the Anchored-RER model for $\chi = 0$ and $\chi = 1$[(a)]



(a) Parameter settings: $\beta = 0.5$, $\lambda = 12$, $\theta = 40$, $\sigma = 0.9$, $\pi = 0.333$

of the anchored traders' expectations equation being formed in the levels rather than in first differences. As stated previously, the parameter space will be restricted so as to ensure that the intention of Gruen and Gizycki for monotonic behaviour is followed.

6.5 Simulation Properties of EDBM for different values of the real exchange rate elasticity of the IS curve.

The inclusion (assigning the relevant parameter a non-zero value[4]) of the real exchange rate term in the domestic demand schedule has a significant effect on EDBM, for both the jump and the subsequent path towards the new long-run equilibrium in response to an unanticipated monetary shock. This comparison is demonstrated in figures 6.5 and 6.6. In figure 6.5, $\chi = 0$ with the rest of the parameters set to:

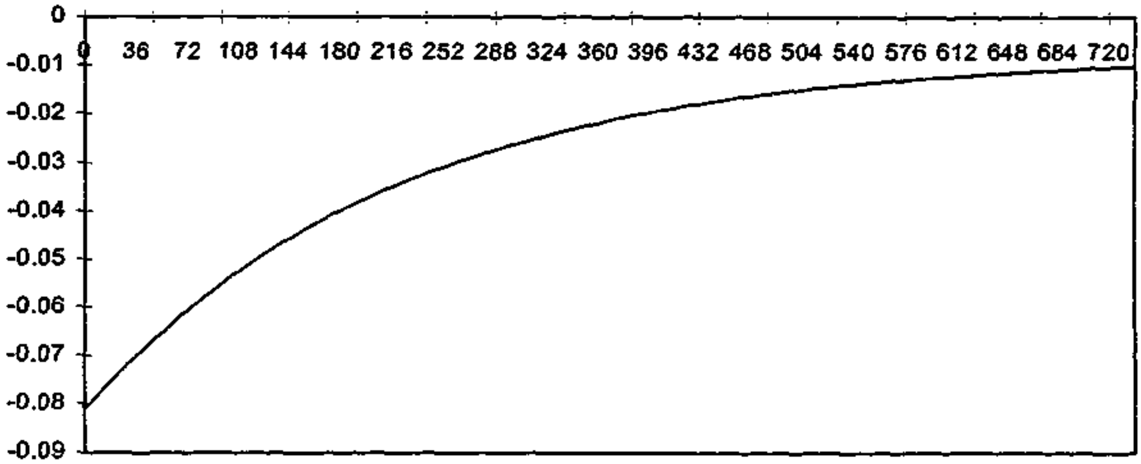
$\pi = 0.3$, $\sigma = 0.45$, $\lambda = 30$,

the result is a large jump in the exchange rate to –0.08365. This compares to a jump of –0.01177 when $\chi = 0.5$ as shown in figure 6.6[5]. Any non-zero value for χ has a significant effect on the initial jump of the exchange rate.

[4] In the Anchored-RER model the relevant parameter is χ; in EDBM it is δ.

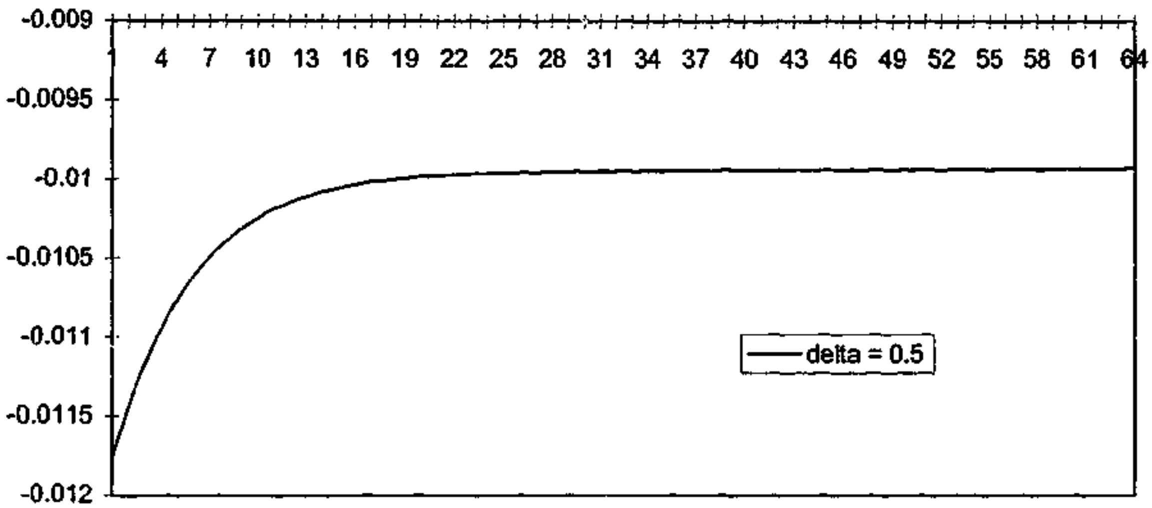
[5] The value of the parameters, other than χ are the same as above.

Figure 6.5
The path of the exchange rate, s, in EDBM when $\chi = 0$, in response to a 1% monetary shock. The initial value for s_t is zero[6].



As well the exchange rate approaches the new equilibrium significantly faster when χ assumes a non-zero value. When $\chi = 0$ (figure 6.5), it takes

Figure 6.6
The path of the exchange rate, s, in EDBM when $\chi = 0.5$, in response to a 1% monetary shock. The initial value for s_t is zero and the new equilibrium value of s is –0.00995.



[6] There is a kink in the curve making the path non-monotonic. To ensure convergence in Excel, when $\chi = 0$, the timeframe needs to be extended. This was done by creating a logarithmic timescale after the 100^{th} period; hence there appears to be a kink in the curve at this point. However the path is actually monotonic.

around 700 periods for the exchange rate to reach the new equilibrium[7]. This is in stark contrast to the 30 periods required when $\chi = 0.5$. Again for any non-zero values of δ, the rate of adjustment is greater than for a zero value of δ.

6.6 Integrated EGG Model – Algorithm

We have discussed the properties of the Anchored model (Anchored-RER) and EDBM when the real exchange rate term is reintroduced to the domestic demand schedule. We now have a numerical model for the Gruen and Gizycki framework that includes a more realistically formed domestic demand function. This model, the Anchored-RER can be combined with the EDBM to form the Extended Gruen and Gizycki (EGG) model by using the algorithm developed in chapter 5. The algorithm is repeated here:

$$s_\tau^m = Y_\tau . s_\tau^a + (1 - Y_\tau). s_\tau^d; \qquad (\tau \geq t+1) \qquad (6.15)$$

in which τ is a positive integer, and

$$\text{where} \qquad Y_\tau = .(1-(\frac{1}{1+(\frac{\alpha}{1-\alpha}).(\frac{1}{\kappa}-1)})). \qquad (\tau = t+1) \qquad (6.16)$$

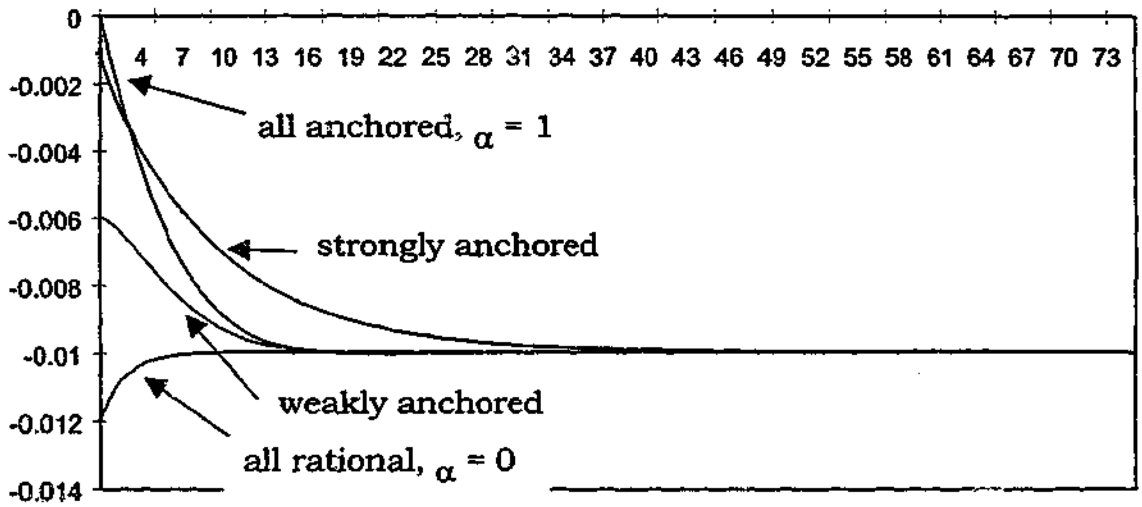
$$Y_\tau = \sum_{n=1}^{\tau} \frac{0.4}{\lambda}.(1-(\frac{1}{1+(\frac{\alpha}{1-\alpha}).(\frac{1}{\kappa}-1)})).(1-0.75.\beta)^n \qquad (\tau \geq t+2) \qquad (6.17)$$

This algorithm was formulated when the real exchange rate term was inoperative. The necessary assumption is that the addition of the above term will not unduly affect the performance of the algorithm in producing a consistent and reasonably accurate description of the exchange rate. Using the same settings as for diagram 5.7, but this time setting χ to 0.5, the trajectory of the exchange rate is illustrated in diagram 6.7.

[7] The new equilibrium for the exchange rate is –0.00995 given a 1% monetary shock.

Figure 6.7

The path and initial jump of the exchange rate in G&G with $\chi = 0.5$, $\alpha = 0.5$ and varying κ, as well as the extreme cases (α=1, α=0), when the market is subjected to a 1% monetary shock.



Compared to figure 5.7, there are marked differences, although the general characteristics are retained. Using the same settings as in chapter 5, but now that χ is positive, we obtain the result illustrated above. The all anchored case (α = 1) and the all rational case (α = 0) converge at quicker rates than in figure 5.7. In both of these cases convergence takes less than 20 periods (only about 10 periods when α = 0), compared to around 200 periods when χ is set to zero. The jump in the exchange rate for the all rational case is much less when χ = 0.5. This means that there is significantly less overshooting of the exchange rate than when χ = 0.

This less pronounced overshooting of the exchange rate leads to changes in how the integrated exchange rate behaves. In figure 6.7, α is set 0.5 and κ is varied as in figure 5.7. In figure 5.7, with the given settings, the weakly anchored case ($\kappa \leq ½$), leads to overshooting of the exchange rate, but in figure 6.7 the weakly anchored case displays undershooting. As well the weakly anchored case converges after approximately 16 periods in contrast to around 200 periods when the Anchored model was used ($\chi = 0$). In respect to the strongly anchored case, the jump in the exchange rate, in response to an unanticipated monetary shock, is less pronounced than before due to the smaller jump in the all rational case. The exchange rate in this scenario converges after about 50 periods — again significantly less than the 200 periods required in figure 5.7. A similar result is apparent when the above exercise is repeated for varying alphas (rather than kappas) and then compared to the results in figure 5.6.

The characteristics of the exchange rate behaviour when the Anchored-RER model is used in preference to the Anchored model are consistent with the qualitative behaviour outlined by Gruen and Gizycki. The integrated model incorporating the Anchored-RER model has less tendency to overshoot than the previous integrated model using the G&G formulation of anchored behaviour. The new integrated model, moreover, converges faster than the G&G formulation.

Chapter 7

A Comparison of the Inertia in EDBM and EGG

7.1 Introduction

The G&G framework is characterised by the introduction of anchored traders. This anchoring can be interpreted as a form of inertia. Such inertia means that in response to an exogenous shock, the economy as modelled will not instantaneously adjust to its long run equilibrium. The foundation of the Dornbusch model is that in response to a monetary shock, the goods price level does not jump, whilst the financial side of the economy adjusts instantaneously, placing all of the initial adjustment solely upon the domestic interest rate.[1] A form of inertia is present in all macroeconometric models; however the inertia usually enters the models through the real side of the economy. Inertia is evident wherever disequilibrium occurs, commonly entering a model via an error correction mechanism in contemporary models, or via distributed lags in older models. A summary of the lag mechanisms responsible for inertia in aggregate economic activity in the Murphy Model can be found in Powell and Murphy (1995)[2].

In order to help explain the Murphy Model in terms of DBM, the Extended Dornbusch Model (EDBM) was created[3]. This miniature successfully replicates the broad qualitative features of the Murphy Model when the latter is subjected to a monetary shock. The main features where MM and DBM differ in response to a monetary shock are that the exchange rate does not overshoot in MM and that the new equilibrium is not approached monotonically. The basic G&G framework encompasses the ability for the exchange rate to undershoot, overshoot or instantaneously

[1] This sentence refers to the version of the Dornbusch model presented in the chapters above in which the activity variable in the money demand schedule is exogenous (namely aggregate supply). Other versions exist in which the activity variable is demand oriented and endogenous, thus putting less pressure on the interest rate.

[2] Powell and Murphy (1995), p. 322

[3] ibid., ch. 25, 26.

attain the long run equilibrium, but unlike macroeconometric models, G&G attains the new equilibrium monotonically. EGG shares the properties of G&G.

To simulate the properties of the Murphy Model, EDBM employs an ad hoc lag structure imposed on aggregate demand[4]:

$$a_t = \psi\,\mu_t + \varphi_t\,(1-\psi)\,\mu_{t-1} + (1-\varphi_t)\,(1-\psi)\,\mu_{t-2} \qquad (t = 1,2,3,4....)$$

Lag weighting function $\qquad \psi_t = R\,e^{-\rho t} \qquad (R,\rho > 0)$

where: a_t is aggregate demand;

μ_t is the equilibrium aggregate demand[5] and;

φ_t is the value of the lag weighting function to be used in the lag distribution in period (t-1) after the imposition of a monetary shock.

With ψ set to 1, EDBM collapses back into the discrete time version of DBM; hence the inertia present at t=1 (the period of time where the shock impinges) is represented by $(1-\psi)$. This implies that as ψ approaches 0, the inertia in the economy increases. Thus the choice of the value of ψ dictates the size of the Dornbusch style jump that occurs in response to a monetary shock.

The term $(1-\psi)$ can be simply interpreted as the initial inertia present on the real side of the economy. Analogous to this term are the two variables, α and κ, in EGG. Note that α signifies the proportion of anchored traders in the economy (when α = 1, all traders are anchored) and κ is equal to the assumed proportional jump (relative to the DBM jump) in the exchange rate in the EGG model when the anchored and rational traders are evenly divided (α = 0.5). In DBM, EDBM, G&G and EGG, the primary source of inertia lies in the goods market where the price of the domestic good is sticky. In G&G and EGG the variables α and κ provide a secondary source of

[4] ibid.; for an explanation of the choice of the ad hoc structure see pp. 317 -321

inertia, whose genesis is in the financial sector of the economy. This secondary inertia introduced in moving from DBM to G&G (and EGG), being financial in nature, is in contradistinction to the secondary inertia introduced into DBM to obtain EDBM, which relates directly to the real side of the economy. Where ψ is purely ad hoc, α and κ are derived from a coherent theoretical base.

The lag structure that creates the cyclical dynamics of EDBM has no equivalent in EGG. Therefore the dynamics created by the lag structure in EDBM will be utilised in EGG when calibrating EGG to TRYM.

7.2 A comparison of the inertia variables in EDBM and EGG

As stated above, $(1-\psi)$ provides the initial inertia in EDBM. Thus depending on the choice of ψ, the exchange rate can exhibit overshooting or undershooting. Exactly the same range of responses is possible for the EGG model, but in this case there are two parameters, α and κ that can be varied. For simplicity, κ will initially be considered fixed and the implications of varying it will be considered later. With κ fixed, α assumes a role very similar to that of $(1-\psi)$ in EDBM in that α and $(1-\psi)$ in their respective models determine the size of the instantaneous jump in the exchange rate (relative to the jump that would occur in DBM given the same exogenous shock).

It is possible to supplant $(1-\psi)$ in EDBM with the G&G parameter α to perfectly replicate the response of the miniature model to a monetary shock.[6] This is due to the fact that α represents the amount of inertia in the economy as a proportion of 1, in a similar manner to that which $(1-\psi)$ does. Figure 7.1 illustrates the effect of ψ in EDBM. In this example ψ = 0.2 in

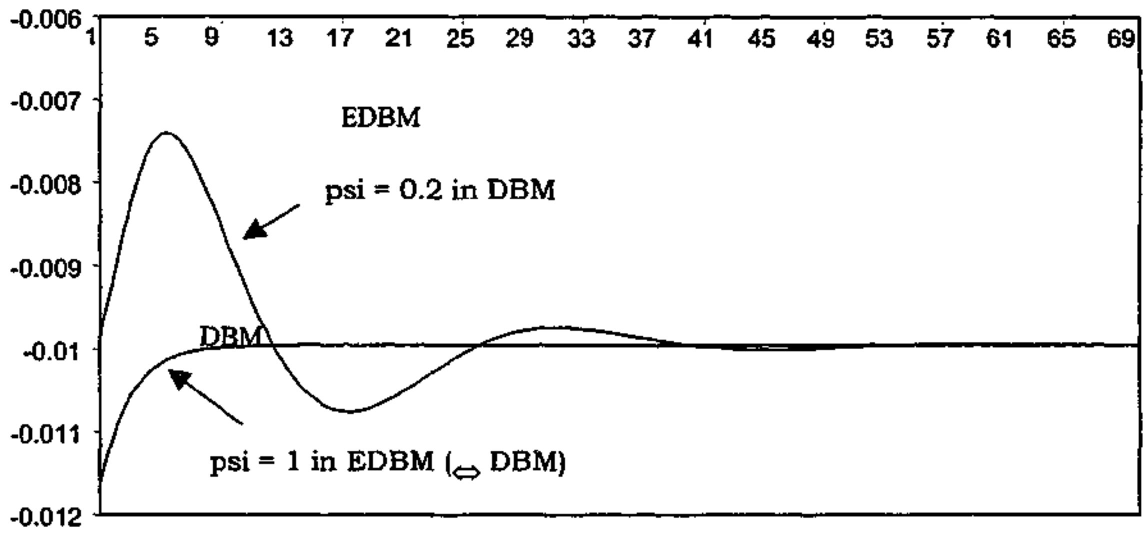
[5] In the original formulation of EDBM in Powell and Murphy (1995) p.319, μ is denoted as α. This deviation from the original nomenclature is to avoid confusion over α, which occurs in G &G.

EDBM with the remaining parameters set as indicated. With ψ set to 1, EDBM reverts to DBM as shown by the lower trajectory in Figure 7.1. With a 1% monetary shock the long run value of the exchange rate falls to –0.00994. In DBM, there is the classic Dornbusch overshooting outcome as the exchange rate instantaneously attains a value (approximately –0.106) which is below its long-run value. But with all the parameters identical except for ψ, EDBM

Figure 7.1

The role of the inertia variables on the exchange rate in EDBM and DBM when the economy is subjected to a 1% monetary shock

Parameters: $\pi = 0.8$, $\delta = 0.5$, $\lambda = 12$, $\sigma = 0.35$, $\psi = 0.2$ or 1, $\rho = 0.2$, $R = 3$.



exhibits undershooting, with the exchange rate only reaching a value of about - 0.0096. Furthermore the lag adjustment structure causes the exchange rate to further diverge from its long run equilibrium before it converges via a cyclical pattern towards long-run equilibrium.

[6] Due to the formulation of the lag structure in EDBM, it is necessary for the parameters in the lag structure to add to 1. Hence if the ψ is substituted for the first term in the lag structure, then ψ will need to be substituted in the rest of the lag structure that determines the dynamics.

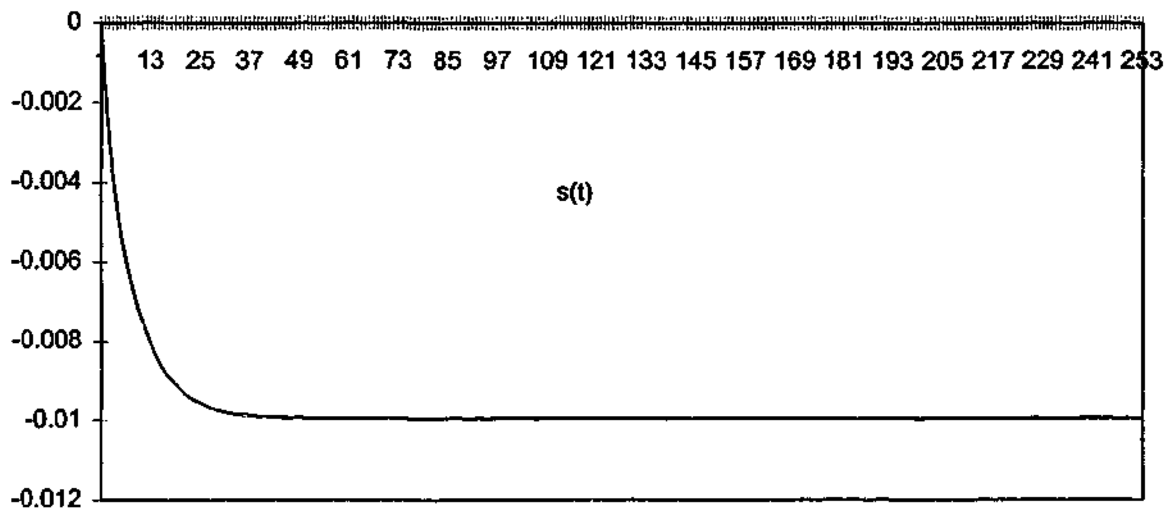
In the EGG model as illustrated in figure 7.2, an extra degree of inertia is introduced beyond the initial absolutely sticky prices that occur in DBM. This inertia, anchoring, means that in the period of the shock, when the market comprises solely anchored traders, the exchange rate is unmoved. This can be interpreted as an extreme case of undershooting. This simplified model does not embody any cyclical dynamics; thus the long-run equilibrium is attained monotonically.

So far in this chapter, inertia has been introduced in 3 ways. The first is the traditional absolutely sticky prices in DBM; the second is the ψ parameter in EDBM; while the third is the introduction of anchored traders. In the next section, the inertia parameters will be examined in the context of the EGG model.

Figure 7.2

The time path of the exchange rate in EGG when the economy is subjected to a 1% monetary shock.

$(\kappa = 0.5, \alpha = 1)$



7.3 The role of inertia in the EGG model.

The EGG model, being an amalgam of EDBM and ANCHORED-RER, encompasses all the inertia factors present in the two models including the inertia parameter, κ. Thus the inertia parameters that are available are the proportion of anchored traders α, the degree of inertia in EDBM, $(1-\psi)$; and κ which is the assumed proportional jump (relative to the DBM jump) in the exchange rate in the EGG model when the anchored and rational traders are evenly divided ($\alpha = 0.5$). While the initially fixed goods price concept in DBM is maintained and so is not parameterised, varying these parameters in EDBM and EGG results in differing initial reactions by the exchange rate. Keeping the non-inertia parameters in concert with the previous sections, the implications of each of the inertia parameters in the EGG model can be examined.

The next 8 figures (figure 7.3 – 7.10) illustrate the effects of varying the inertia parameters. The parameters take the following values: $\kappa = 0.5$ or 0.33; $\alpha = 0.5$ or 0.2, and $\psi = 0.5$ or 0.2.

Figures 7.3 –7.10
The role of the inertia variables in the EGG model when the economy is subjected to a 1% monetary shock for varying inertia parameter values.

Figure 7.3

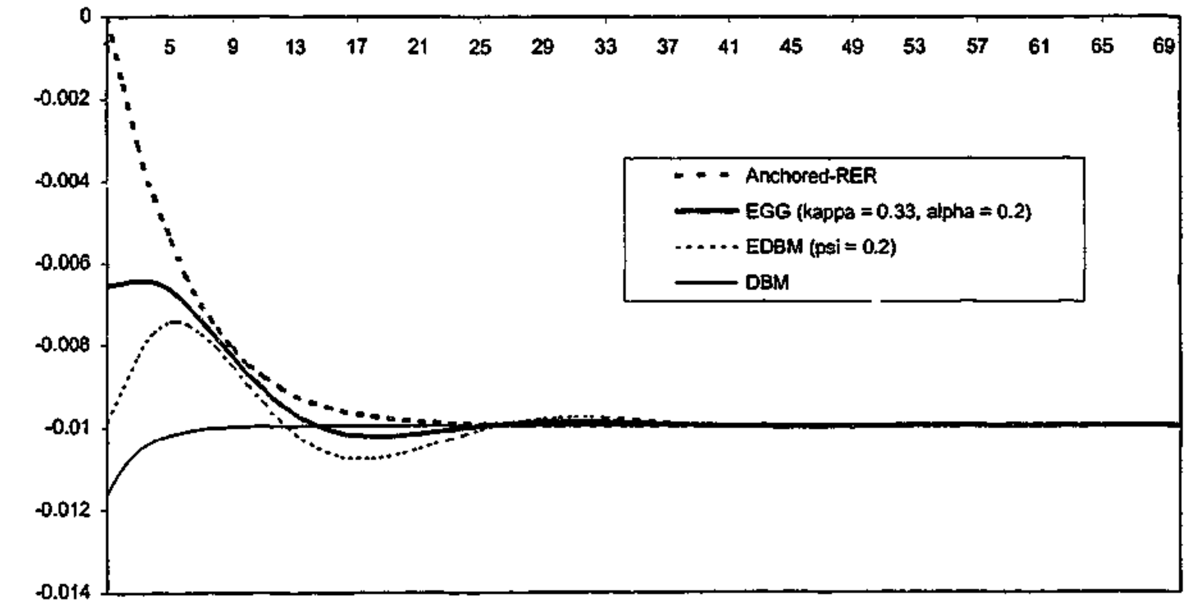


Figure 7.4

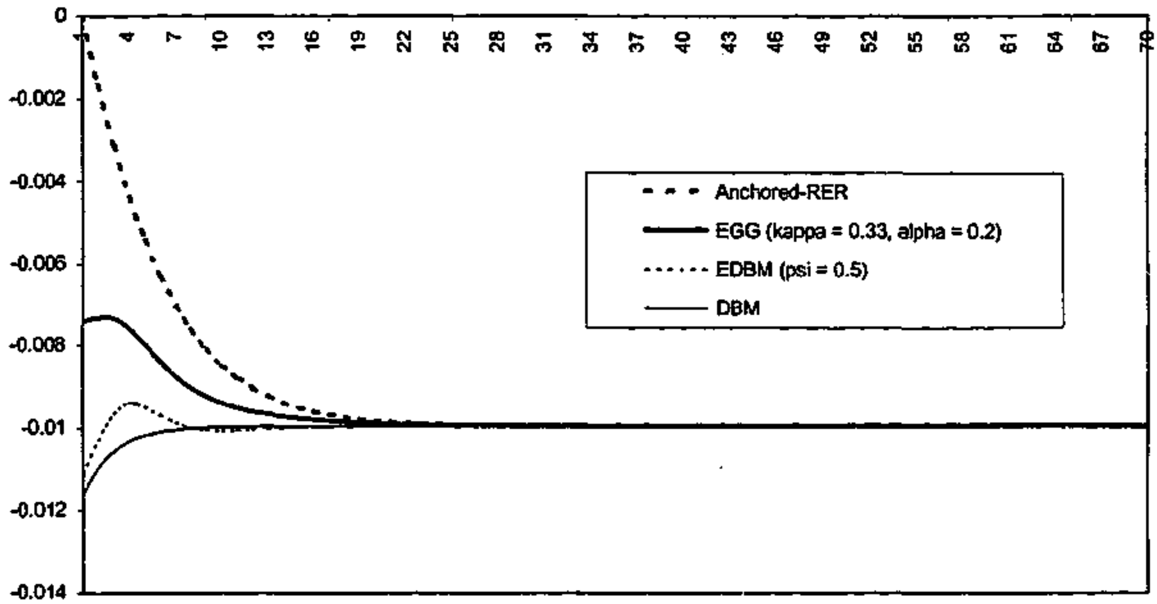


Figure 7.5

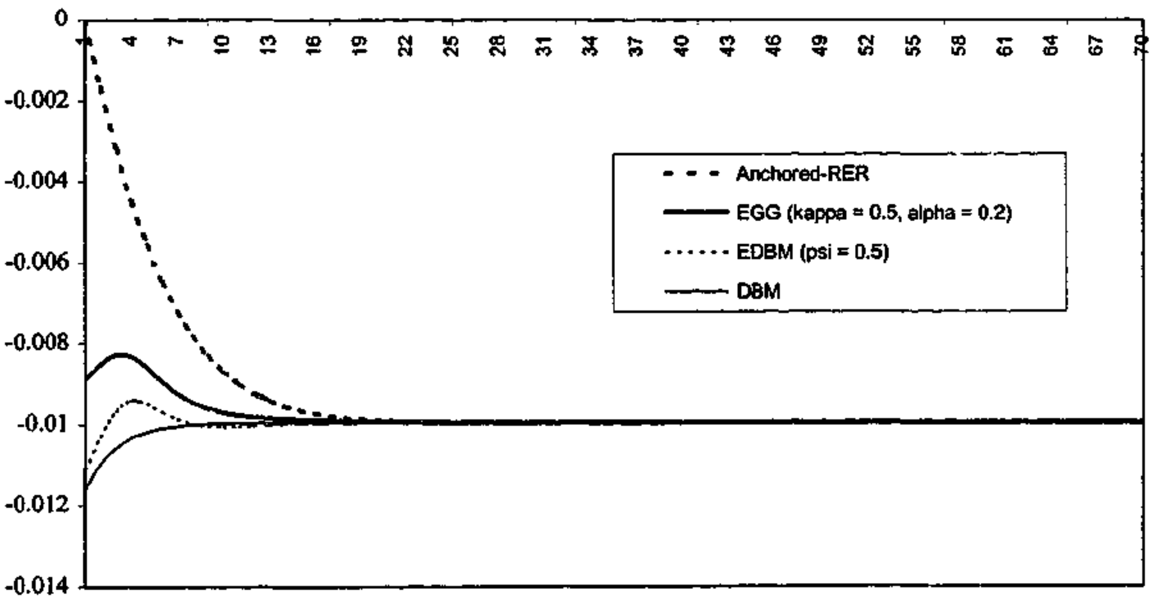


Figure 7.6

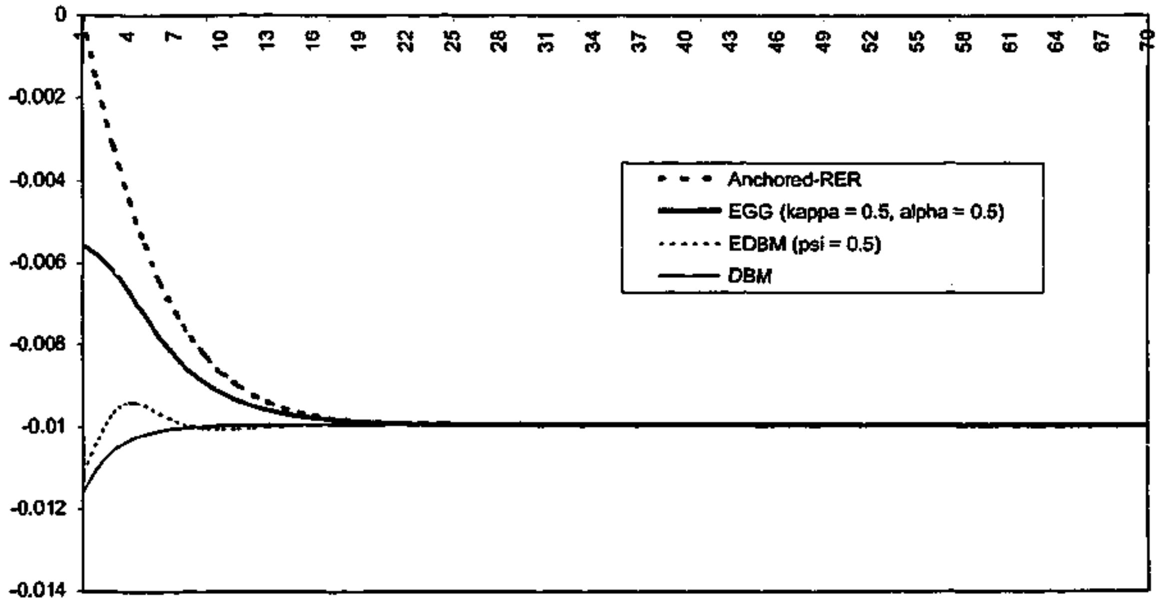


Figure 7.7

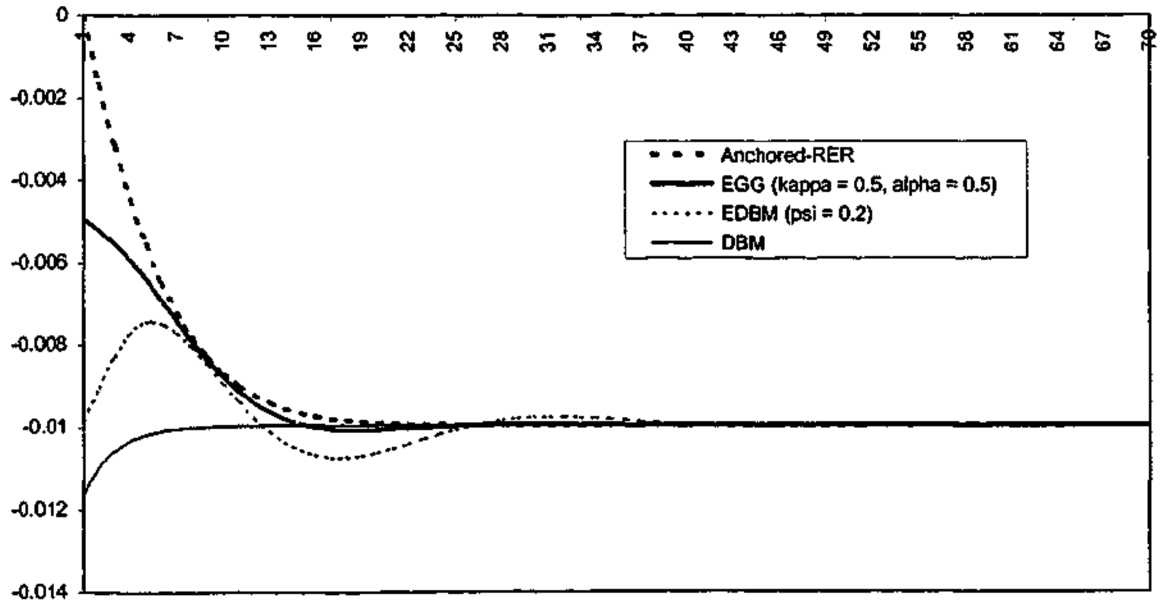


Figure 7.8

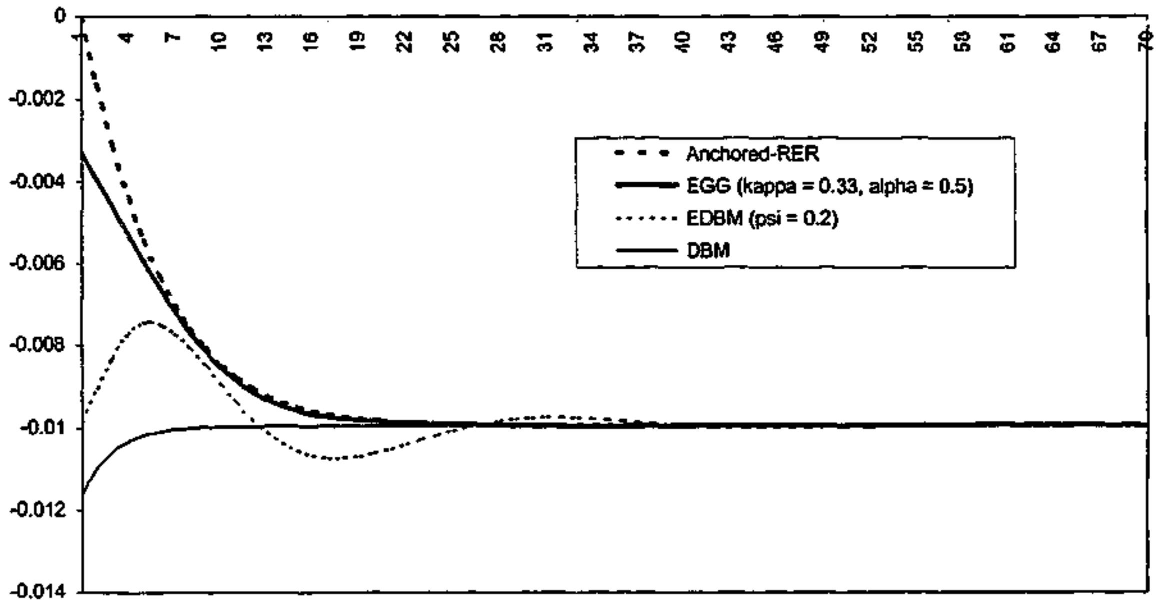


Figure 7.9

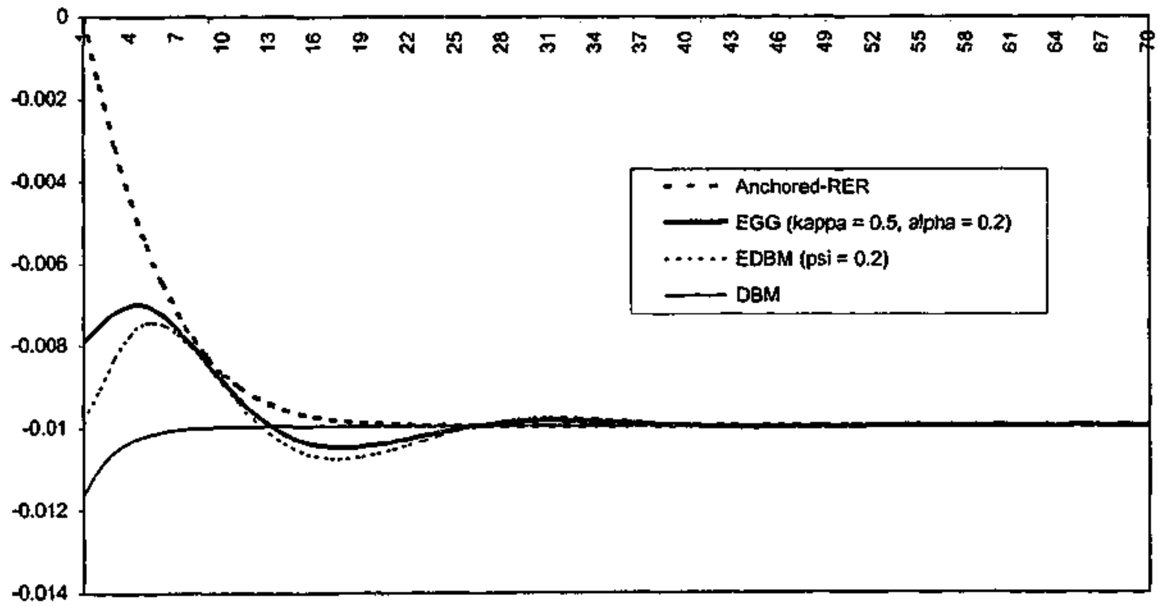
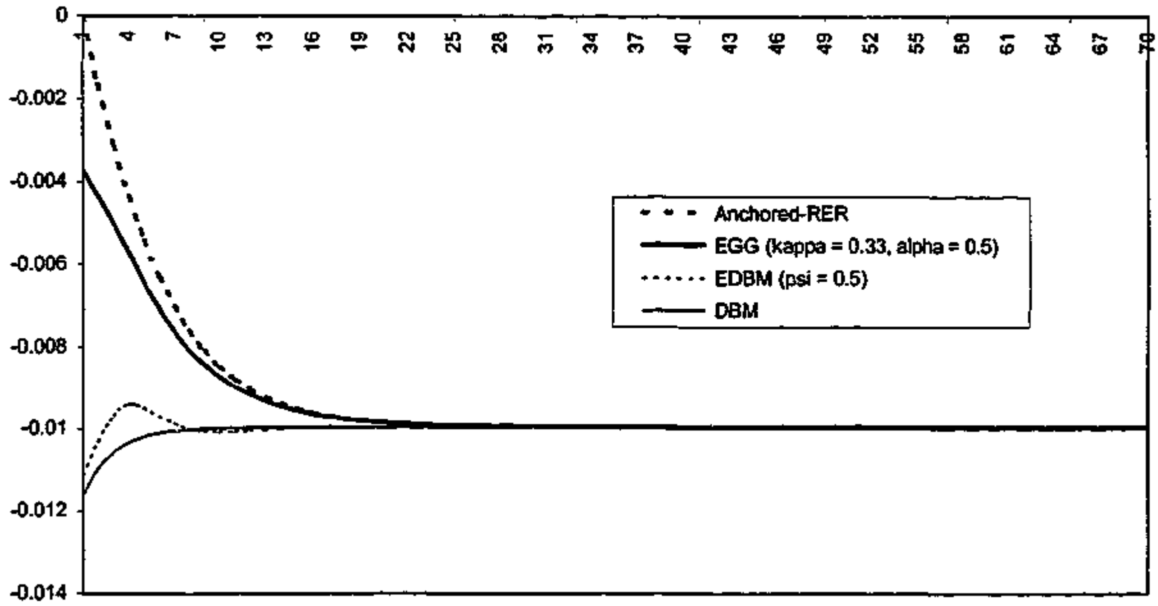


Figure 7.10



All eight graphs show four different paths of the exchange rate; namely, those generated by DBM, EDBM, ANCHORED-RER and the EGG model. But in all eight charts the order across models of the initial jumps is always the same. Remember that the pre-shock path of the exchange rate is in long-run equilibrium normalised at zero. Hence the ANCHORED-RER model (where all traders are rational) will always produce no movement in the exchange rate during the period of the unexpected shock, which thus remains at zero and sets the benchmark for undershooting. Conversely, DBM sets the boundaries for overshooting. Note that if there were no inertia present then the long-run equilibrium would be instantaneously attained as in a textbook IS-LM analysis.

The paths of the exchange rate in EDBM and EGG fall in between the two extremes. In the figures above, ψ is set to either 0.2 or 0.5 in EDBM. Thus the initial inertia present in EDBM is 0.8 or 0.5[7]. This means that the initial jump (as well as being bounded by 0) will be less than that achieved by DBM, by a factor that is determined by the inertia parameters. It is

[7] Initial inertia in EDBM is given by $(1-\psi)$.

evident that undershooting or overshooting is possible. EDBM has embedded in its structure the initial goods price stickiness as well as the ad hoc parameter, ψ. The initial jump of the exchange rate in EGG is itself bounded by EDBM and Anchored-RER. The exchange rate in EGG must jump less (or at least no more) than the exchange rate in EDBM because there is extra inertia added via the proportion of anchored traders, α, present in the market[8].

The cycles in EDBM are less pronounced when ψ is set to 0.5 rather than 0.2 (cf. figure 7.8 and 7.10). Interestingly in EDBM, when ψ = 0.2, the exchange rate only slightly undershoots (-0.00987 as against -0.00995), but due to the lag structure the exchange rate subsequently diverges away from long-run equilibrium.

In figures 7.3 – 7.10, the Anchored-RER model is only affected by the change in κ (given that all its other parameters are constant). A greater κ results in the exchange rate in Anchored-RER converging to the long-run equilibrium at a faster rate. Since none of its parameters change throughout any of the above scenarios, there is only one path for the exchange rate in DBM in these figures.

As an amalgam of Anchored-RER and EDBM, EGG will display certain properties of these models depending on the respective proportions. When there is no extra inertia above and beyond that present in EDBM, (that is, when α = 0), EGG will replicate EDBM. As demonstrated in figure 7.9, the exchange rate in EGG can be made to mimic the path in EDBM by a suitable choice of parameters. This is due to the low alpha (0.2) and high kappa (0.5). Conversely, in figures 7.8 and 7.10, where α = 0.5 and κ = 0.33 – the additional inertia is relatively high – the exchange rate in EGG tends to replicate the path of the Anchored-RER model, inheriting its main properties (undershooting and monotonic convergence to the new long-run equilibrium).

The mixed parameter settings in the eight scenarios display properties

[8] The value of κ determines the degree of this extra inertia.

of both models – Anchored-RER and EDBM. The exchange rate in EGG in figures 7.3, 7.4, 7.5 and 7.9, possesses at least one turning point and it significantly undershoots the long-run equilibrium in all cases.[9]

This set of scenarios illustrates the role that the four types of inertia have in the EGG model. The dynamics present in EDBM through the ad hoc lag structure can be overridden by extra inertia introduced through α and κ. The additional inertia in EGG (over and above that present in EDBM) dictates the degree to which the exchange jumps relative to the jump in EDBM, and also the type of path that the exchange rate follows towards long-run equilibrium.

7.4 Concluding Perspective

The theory and application of business cycles has a long history. Ever since Ragnar Frisch (1933) took economic theory from the static to the dynamic, economists have tried to describe and quantify the properties of the business cycle. Business cycles exist but their genesis is unresolved.

In terms of macroeconometricic modelling, the work on business cycles starts with the seminal contribution of Tinbergen (1937) (a model of the Dutch economy) and the first macroeconometricic model of the United States (Tinbergen, 1939). The next generation of models began with the Klein-Goldberger model (1955). In these models, business cycles were still determined by an ad hoc lag structure, in a similar manner to the ad hoc lag structure in EDBM (where the ψ parameter could be calibrated to replicate business cycles in a larger macroeconometric model).

The pioneering work of Muth (1961) and subsequently Lucas and Sargent (1979) led to the development of the rational expectations view of the business cycle[10] where unanticipated monetary shocks or random

[9] It is possible for the exchange rate to overshoot (whilst keeping α and κ fixed) by varying the other parameters.

[10] This is often referred to as the equilibrium business cycle approach. See Lucas (1977)

events are the main cause. The rise of the Real Business Cycle theory can be traced to Kydland and Prescott (1982). As its name suggests, the real business cycle is caused by non-monetary effects, specifically random real shocks to technology.

The above suggests that the cause of business cycles is still to be clarified, while observation of post-war history suggests that the catalyst, depth and duration of each business cycle may differ. The Gruen and Gizycki scenario does not include cycles and so its extensions will need to rely on an ad hoc structure, such as the structure embedded in EDBM. This is not necessarily detrimental, as ad hoc structures are inherent in macroeconometric models, and may indeed capture frictions that exist in the real world, but which are abstracted from in theory. The G&G scenario adds a plausible (small) degree of irrationality to the formation of exchange rates, especially in their initial reaction to unexpected monetary shocks. The G&G story also provides a possible resolution of the forward discount bias puzzle.

In the next chapter, the concept of anchored traders will be overlaid onto TRYM and simulations will be performed to gauge the effects that the introduction of anchored traders has on the economy and on the exchange rate.

Chapter 8

Simulation in TRYM using the G&G concept

8.1 Introduction

Over the previous chapters, the concepts introduced by Gruen and Gizycki have been incorporated into miniature models to demonstrate the unique properties that are associated with the presence of anchored traders. The initial aim was to directly overlay the resultant miniature model – Extended Gruen and Gizycki (EGG) – onto TRYM (the Australian Treasury's model, described briefly below in section 8.2). But this task proved to be intractable due to the complexity of inertia that exists in the real side of the large model.

In chapter 6, the EGG model was derived as a combination of the Anchored-RER model and EDBM. None of the formulations of the G&G model contain any cyclical behaviour, with post-jump behaviour of the exchange rate always following a monotonic path towards a long-run equilibrium. Thus any cyclical behaviour that was established in EGG was derived solely from the extensions to DBM (made in EDBM). The purpose of introducing EDBM was to enable the coupling of a numerical solution for G&G with a numerical version of DBM to demonstrate the properties of the exchange rate. Numerical solutions were necessary since forward looking expectations rule out analytical solutions in all but very special cases which do not apply to the larger practical policy and forecasting models which the coupled miniature is supposed to mirror.

In attempting to reconcile the miniature model EGG with TRYM, it was necessary to parameterise EGG to coincide with the larger macroeconometric model, TRYM. This proved to be impossible, although, prima facie, the task was reasonable given that EDBM was originally devised to replicate the behaviour embedded in the Murphy Model (which has design features broadly similar to TRYM's).

The addition of the extra inertia rate meant that whilst the jump in the exchange in TRYM could be replicated in EGG for any given set of parameters, the subsequent path in EGG was inconsistent with the path of the exchange rate in TRYM. As was noted in chapter 5, the EGG model was consistent with the behaviour of larger macroeconometric models over a limited range of parameters, but outside these ranges, the miniature behaved badly. Hence I was unable to directly incorporate the EGG model into TRYM.

This leaves the problem of how to demonstrate the impact of anchored traders on the exchange rate in TRYM. As the use of calibrated results from EGG has been ruled out, the use of a mechanism that incorporates the important properties of G&G has been introduced directly into TRYM. The two behavioural elements of anchored traders that need to be introduced are: a reduced jump in the exchange rate in response to a monetary shock as compared to the base case in TRYM; and a monotonic component in the path of the exchange rate that drives it towards a long-run equilibrium after the initial shock. The eventual attainment of a long-run equilibrium is common to agents in G&G and agents in TRYM; thus the mechanism is designed to decay so that the long-run equilibrium is unchanged by the modifications to TRYM.

In this chapter, the terms "steady state" and "long run" imply slightly different outcomes. Steady state refers to a theoretical "true" solution, whereas the long run solution refers to the outcome that is reached by the TRYM implementation after 80 quarters.

8.2 Brief Description of Treasury Macroeconomic Model of the Australian Economy (TRYM)[1]

TRYM is a quarterly macroeconomic model of the Australian economy that is used by the Commonwealth Treasury. TRYM contains 23 stochastic equations, 2 policy reaction functions and approximately 80

[1] The version of TRYM used here is that described in Taplin et al (1993) and implemented in the ESP software developed by Horridge (1992).

identities. Like most modern macroeconometric models, TRYM confines the forward-looking behaviour of agents to the financial markets. In contrast the expectations of agents in the goods markets and labour market are modelled as backward-looking.

In TRYM the financial market expectations are assumed to be what the Treasury calls quasi model-consistent (to be defined in the paragraph below). The modelling of financial markets differs from standard macroeconomic models in two key aspects. The first is that uncovered interest parity (UIP) does not hold at all times; UIP is assumed to hold in the long run but not (except by chance) in the short run. The second is that the short and long interest rates are correlated by an ad hoc term structure equation that reflects the historical movement of bond yields.

The financial agents must form expectations about the exchange rate and the price level 10 years hence. Agents are able to predict the effects that a particular shock will have on the exchange rate in the steady state and on the ultimate long-term inflation rate. However agents are unable to predict with certainty the effects that a particular shock will have on the exchange rate and the long-term inflation rate 10 years on. Expectations about these two variables are formed on the basis that the economy will have reached its steady state within 40 quarters of the time that a shock is applied. Since there is nothing in TRYM to ensure that the economy does reach its steady state in 40 quarters, expectations about the exchange rate and price level are not necessarily realised.

8.3 Applying G&G to the Exchange Rate in TRYM

As discussed above a mechanism is to be applied to the exchange rate in TRYM to simulate the presence of anchored traders without specifically calibrating the exchange rate to a miniature such as EGG.

In TRYM the exchange rate in any quarter is formed through an identity:

RTWI = RTWIX(+40)*exp(10*ln((1+RGL/100)/(1+WRGL/100)) (8.3.1)

where the notation is as follows:

RTWI	-	Exchange Rate (Trade weighted index)
RTWIX(+40)	-	Equilibrium exchange rate
RGL	-	Rate on 10 year Treasury bonds (percent per annum)
WRGL	-	Major trading partners' long-term interest rates (percent per annum)

To simulate G&G-type behaviour, the exchange rate in (8.3.1) was scaled by a multiplier or scaling factor of the form $\zeta^{1/t}$, where zeta (ζ) is an arbitrary parameter and t represents time[2]. Hence the new exchange rate identity takes the following form:

RTWI =
zeta^(1/TIME)*[RTWIX(+40)*exp(10*ln(1+ RGL)/100)/(1+WRGL)/100)]
(8.3.2)

where zeta is a parameter and TIME is the elapsed time after a monetary shock.

This mechanism has the attributes that it nests the original exchange rate identity by setting zeta to 1. Also it allows the jump in the exchange rate to be manipulated to ensure the desired outcome. The exchange rate's

[2] All macroeconometric models have the property that potentially more than one (and usually many) micro theories would be compatible with the macro behaviour posited by the macro model (at least in the applications of such a model to any given period of history). That is, so far as the variables that are recognised in the macro model go, several micro theories are observationally equivalent. Thus the scaling

response to a monetary shock can be now forced to yield a jump in either direction and by any amount. Another attribute is that the scaling factor decays in a monotonic fashion towards unity, ensuring that the exchange rate approaches the long-run equilibrium as specified in TRYM. This means that this simple mechanism captures all of the significant factors in G&G and simulations can be performed in the modified TRYM in a manner which is qualitatively faithful to the G&G exchange rate dynamics, except that the cyclical behaviour necessarily present in TRYM is also preserved.[3]

Figure 8.3.1

The path that the scaling factor, $\zeta^{1/t}$ takes when zeta = 1.02, 1.01, 1.00 and 0.99.

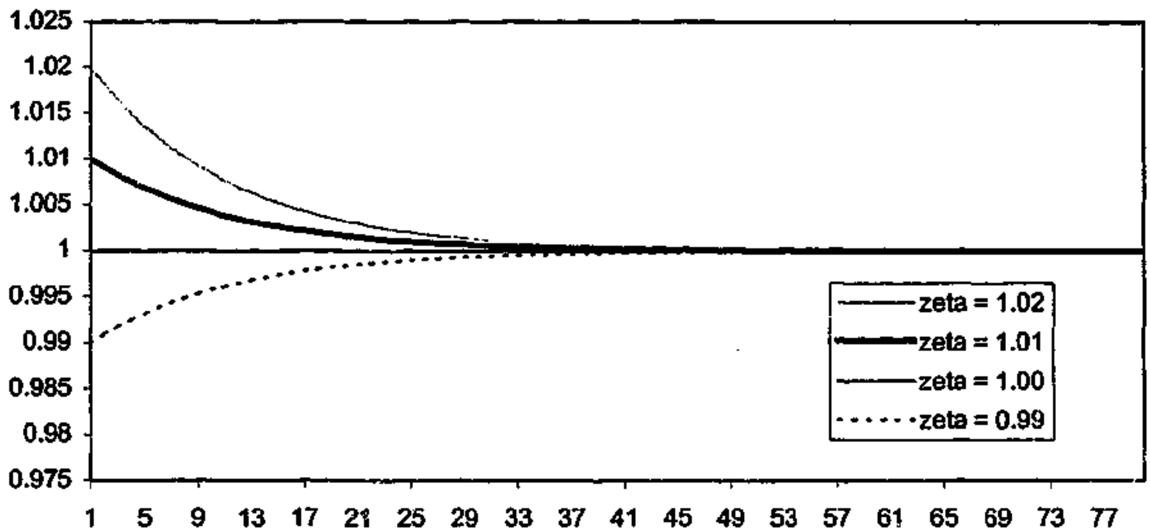


Figure 8.3.1 illustrates the path of the scaling factor when zeta equals 1.01, 1.02 and 0.99. The path exhibits properties similar to the exchange rate path in G&G – thus there may be an initial jump of either sign with the disequilibrium decaying monotonically. The size of the scaling factor determines the size of the initial jump. Its rate of decay depends on the elapsed time since the shock; for given zeta, this in turn depends on the length of the chosen unit of time. The time grid is common for all three

factor will not uncover evidence that relates exclusively to the presence or otherwise of anchored traders, but rather to see if the G&G framework would lead to a more attractive (modified) version of TRYM.

[3] The scaling factor method used in equation 8.3.2. encompasses the properties of any theory of the exchange rate that allows for backward looking expectations. This includes the alternative models cited on

examples. When applied to the RTWI identity the effect of the scaling factor is demonstrated in figure 8.3.2.

Figure 8.3.2[4]

The effect on RTWI using varying values for zeta when TRYM is subjected to a 1% monetary shock.

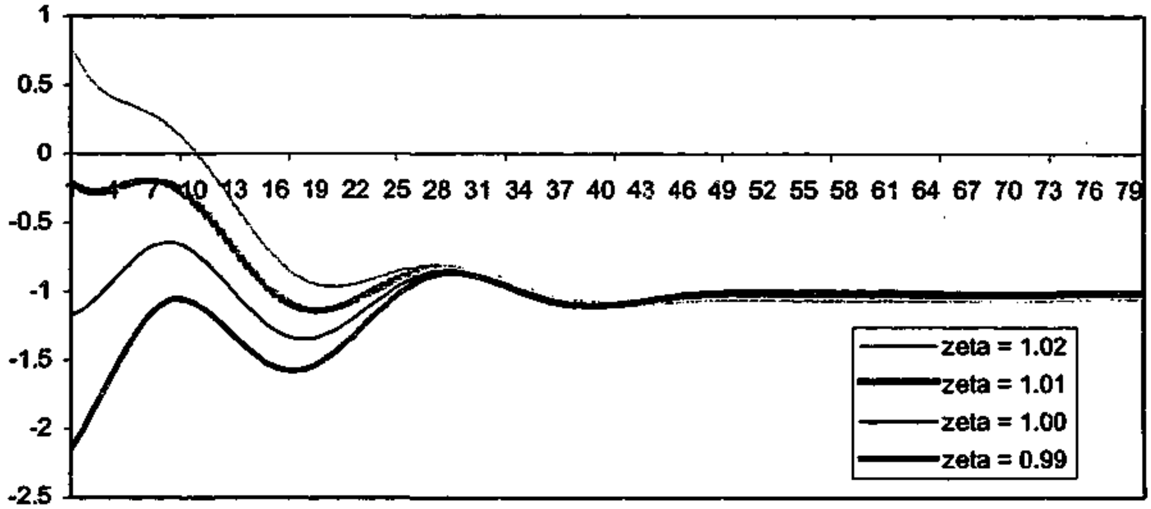


Figure 8.3.2 illustrates the effect that different values of the scaling factor have on the exchange rate (RTWI). When zeta equals 1, the scaling factor equals 1 at all times, hence RTWI follows the original path as in the standard TRYM specification. In the above simulation RTWI jumps to a value of −1.175 when zeta equals 1, thus signifying slight overshooting behaviour. This result for RTWI is subject to the parameter values used throughout the model. With a differing set of parameters, it is possible to engineer different outcomes for the initial jump of RTWI. A similar property holds for the Murphy model.

When zeta takes the value of 1.01, a jump in the exchange rate that is consistent with the presence of anchored traders is produced. The initial post-shock value of the RTWI is -0.199 which falls between the pre-shock

p.16. However, the scaling factor method ably demonstrates the behaviour of anchored traders in the exchange rate market.

[4] The comparable scale in previous chapters would be 0.01 to −0.025

value of RTWI of zero and the standard TRYM value of RTWI of –1.175[5]. When zeta takes the value 0.99, a jump that is reminiscent of Dornbusch is evident, in that there is substantial overshooting with respect to the new long-run equilibrium. Finally when zeta equals 1.02, the exchange rate immediately after the shock jumps in the wrong direction. This is consistent with the anecdotal evidence explored by Dixon et al. (1993).

8.4 The effect on other variables in TRYM

The exchange rate appears in eight equations other than the identity described above. These equations are for the following variables:

pmgs – price of imports
pxc – price of commodity exports
xnc – non-commodity exports
weopz – Australian holding of overseas equity
wdogfz – official reserve assets
wdpofz – private sector foreign currency debt
wdgofz – government foreign currency debt held by overseas sector
cab – current account balance.

These eight variables are illustrated in figures 8.4.1 – 8.4.8.

[5] To replicate this scenario, it is possible to have an economy that encompasses a particular proportion of anchored traders who possess certain attributes (see the parameter κ in Chapter 5). But this scenario will not be unique and a different proportion of anchored traders with varying attributes is certainly possible.

Figure 8.4.1

Path of pmgs after a 1% monetary shock for different values of zeta

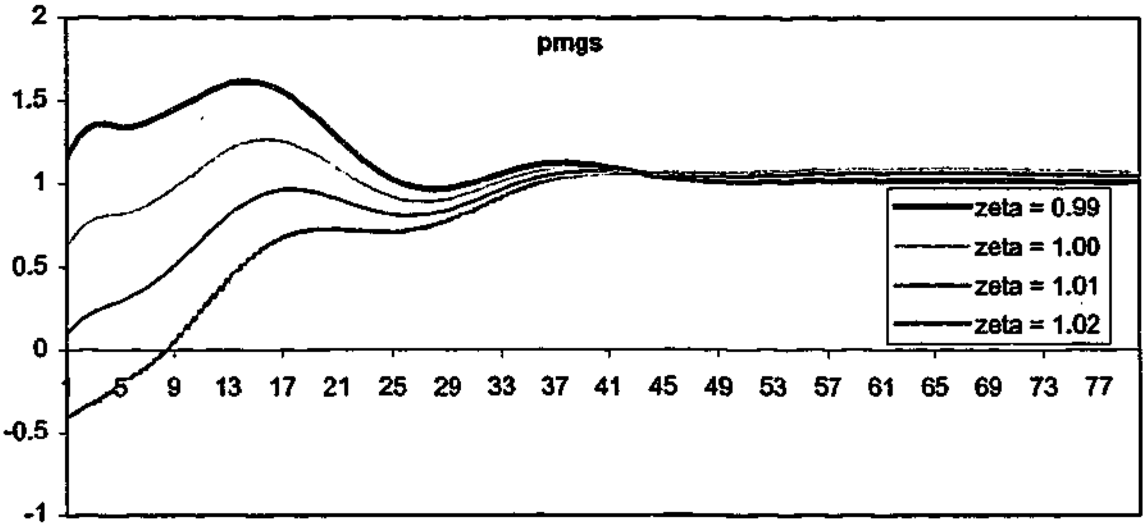


Figure 8.4.2

Path of pxc after a 1% monetary shock for different values of zeta

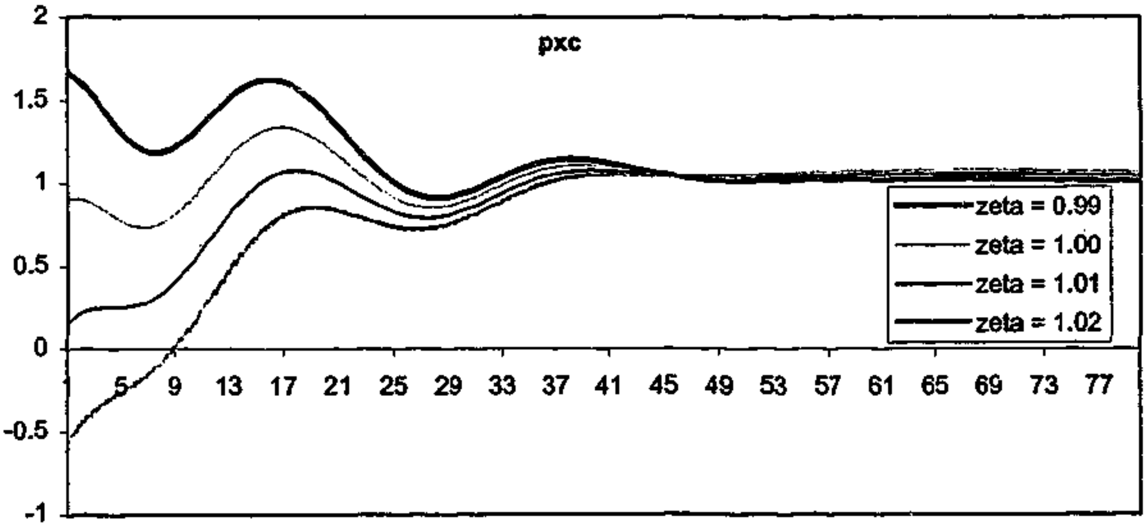


Figure 8.4.3

Path of xnc after a 1% monetary shock for different values of zeta

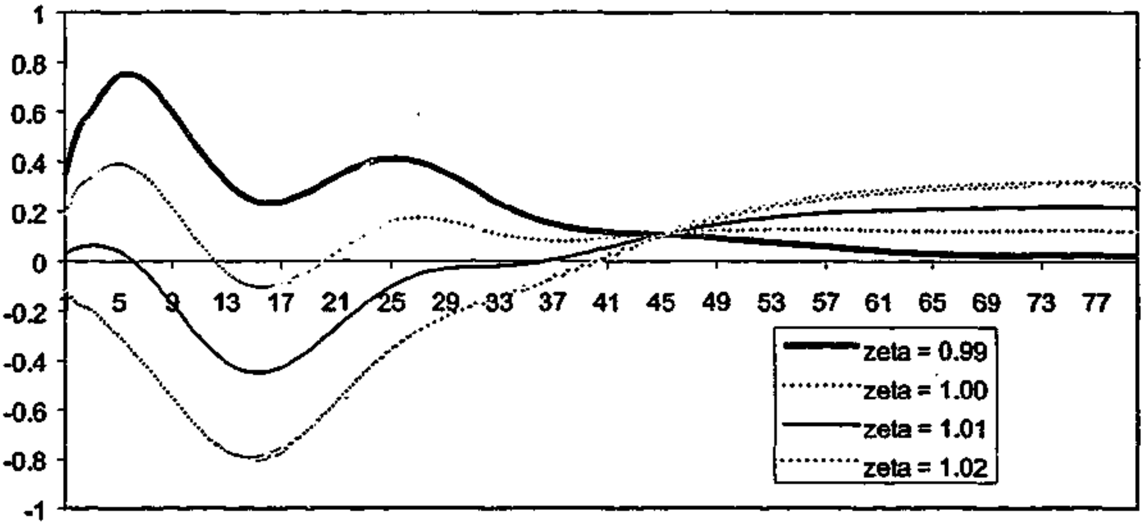


Figure 8.4.4

Path of weopz after a 1% monetary shock for different values of zeta

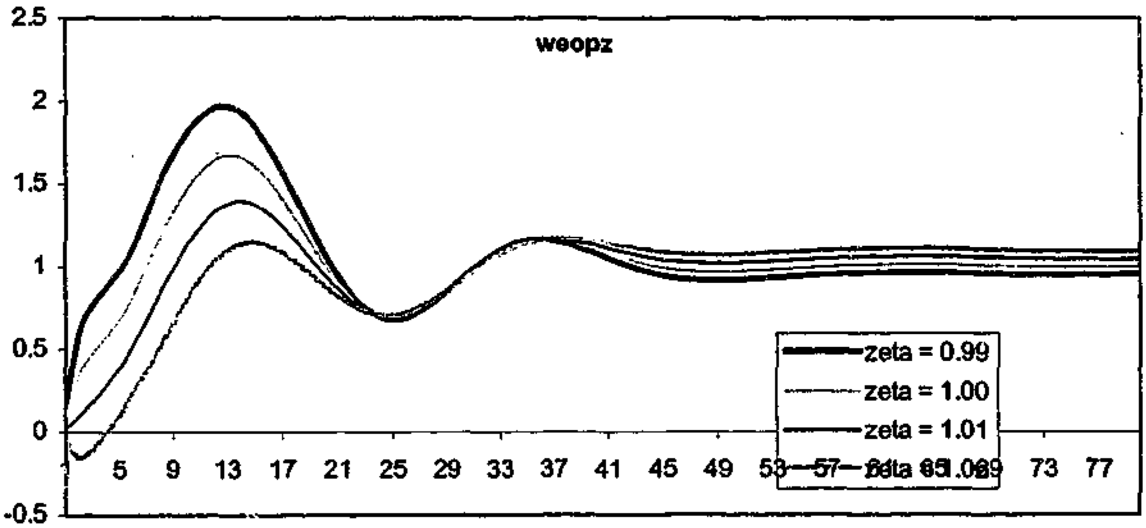


Figure 8.4.5

Path of wdogfz after a 1% monetary shock for different values of zeta

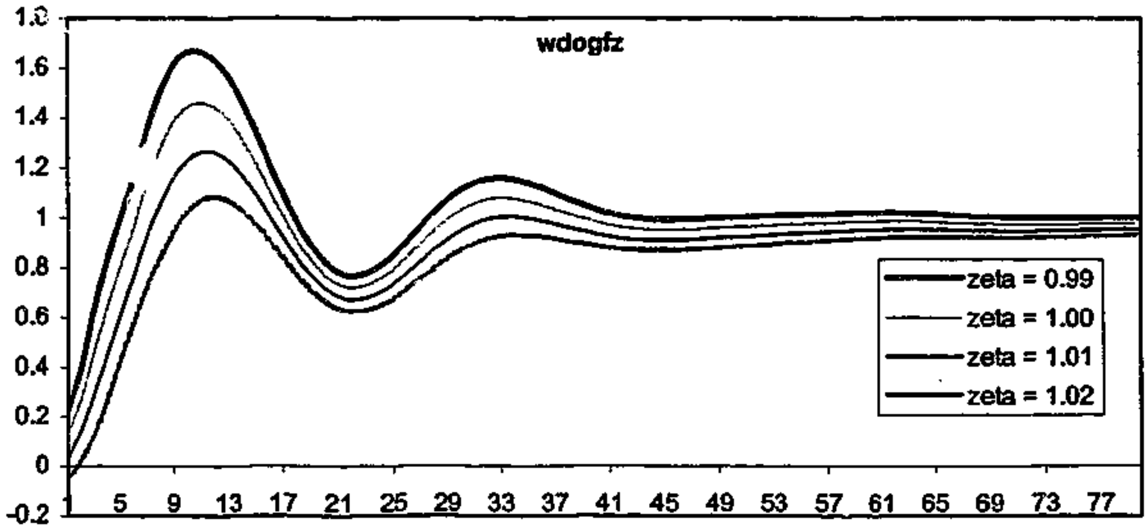


Figure 8.4.6

Path of wdpofz after a 1% monetary shock for different values of zeta

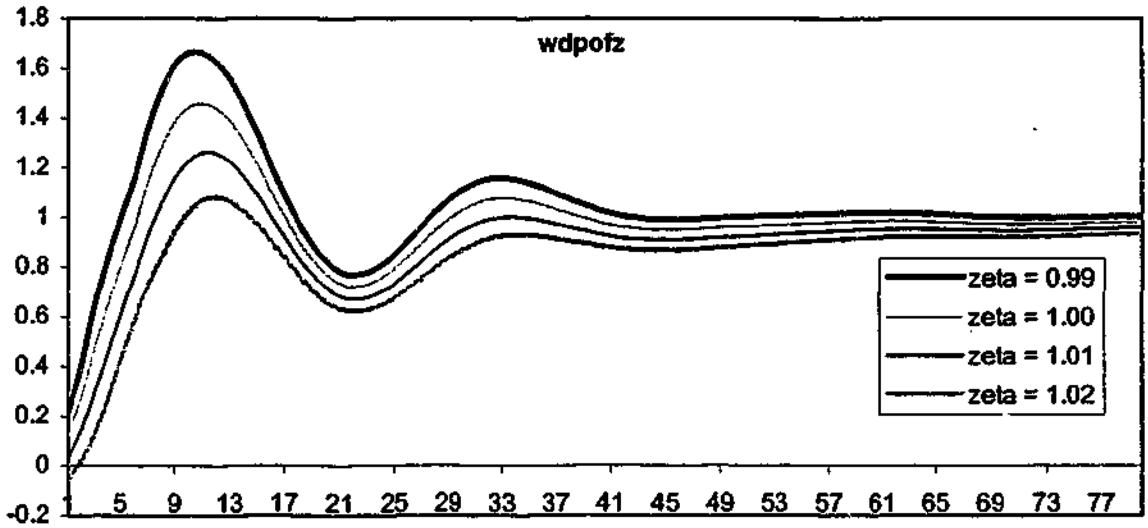


Figure 8.4.7

Path of wdgofz after a 1% monetary shock for different values of zeta

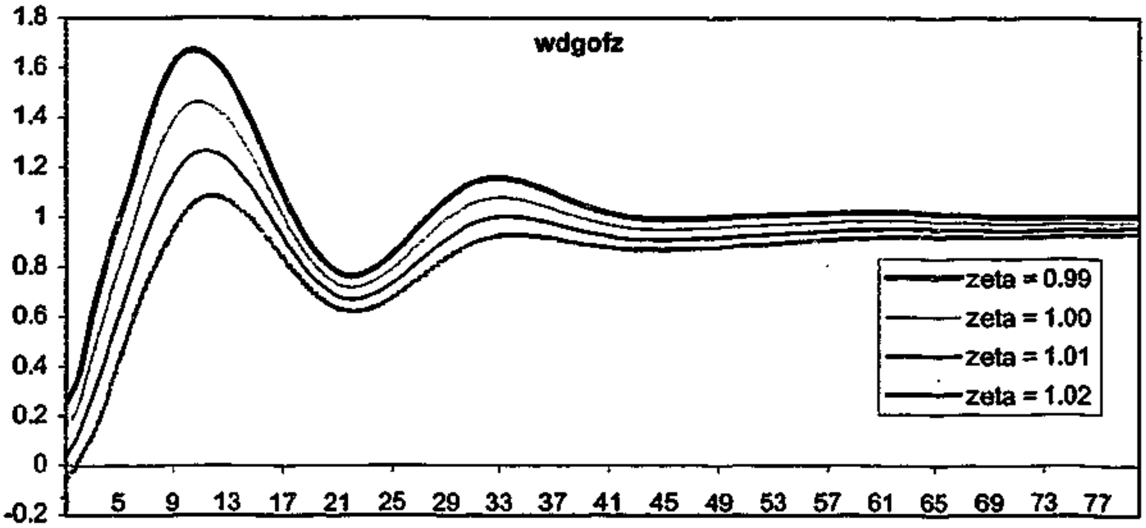
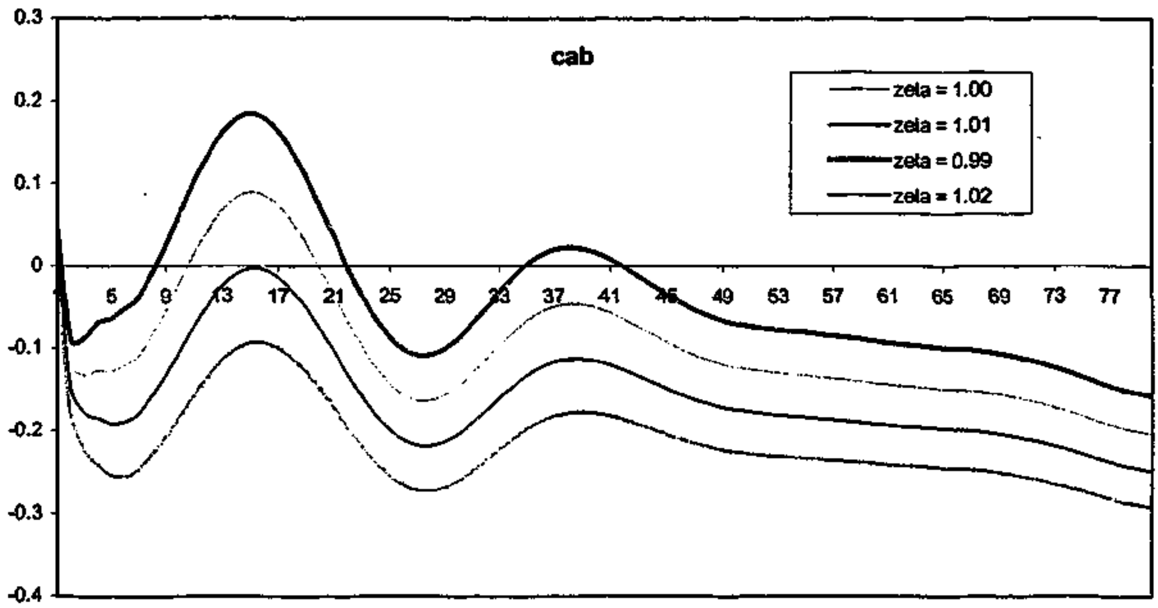


Figure 8.4.8

Path of cab after a 1% monetary shock for different values of zeta[6]



In explaining the results, I will begin with a brief explanation of the results obtained with standard TRYM (i.e. when zeta = 1) and then explain the results for the other three scenarios using this initial solution as a base case. The depth and duration of the cyclical behaviour is determined by the parameter settings as described in TRYM; these parameters encapsulate TRYM's characterisation of the business cycle.

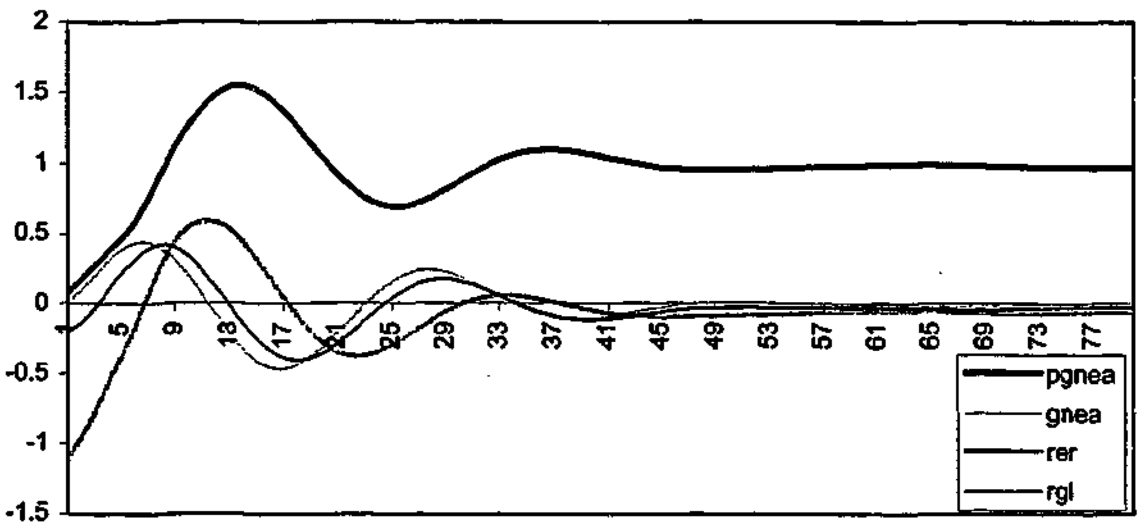
As the TRYM model has a standard long-run closure, a permanent 1% monetary shock will – via money neutrality and purchasing power parity – mean a 1% increase in prices and a 1% fall in the nominal exchange rate in the long-run. This is borne out by the steady state values of the price of GNE (PGNEAX) rising by 1% and the steady state value of the nominal exchange rate (RTWIX) falling by 1%.

There is an immediate fall in the short interest rate that stimulates GNE directly via investment and indirectly through personal consumption. The immediate effect on consumption is through the wealth component of the consumption function. As the housing Q-ratio is dependent on the long bond rate (RGL) – which is in turn dependent on the short term interest rate – household wealth is revalued upwards causing an increase in domestic consumption. In contrast the lower real exchange rate (RER) stimulates real exports. The net result is that real GNE increases in the short run (although there is a small immediate fall in real GNE) as the price level remains below its new equilibrium level and interest rates are still below their equilibrium level. The RER, the long term interest rate and GNE all return to their long-run equilibrium whilst the price level asymptotes towards a 1% increase.

[6] The cab illustration is reported as the difference between the base case and the forecast as a percentage of nominal GDP. As the current account balance can pass through zero, small numbers can give misleading results in terms of percentage deviations from control.

Figure 8.4.9

Effects of a permanent 1% monetary expansion in standard TRYM on the GNE Deflator (PGNEA), Gross National Expenditure (GNEA), Real Exchange Rate (RER) and the 10-year Bond Rate (RGL)

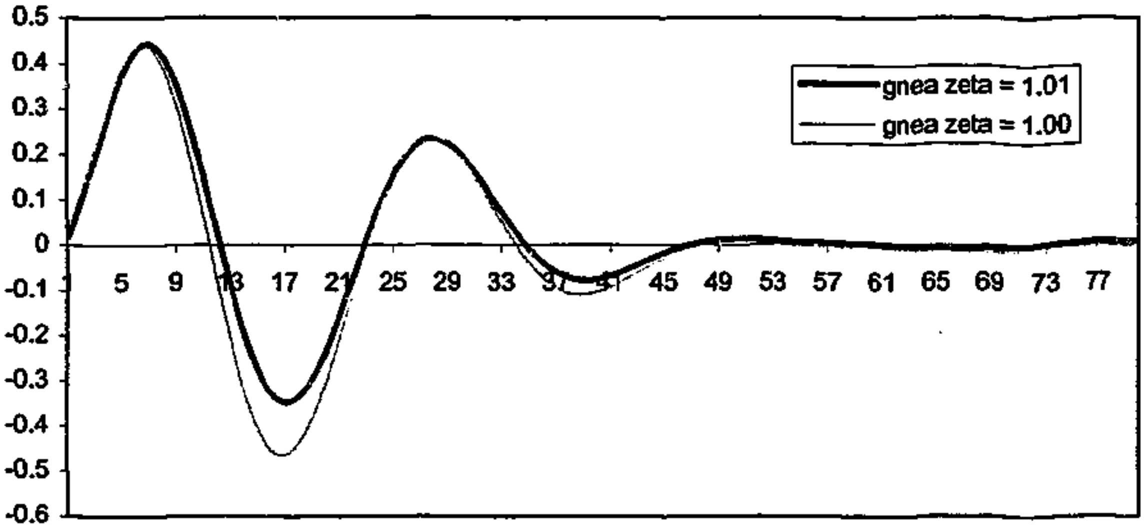


As output in the long-run is unaffected, the initial increase in GNE must be offset and this is achieved by a contraction of similar magnitude to the original expansion as the price level increases and overshoots its equilibrium level. Then all variables follow damped cyclical behaviour towards long-run equilibrium.

When zeta equals 1.01, a jump in the exchange rate analogous to that occurring in the presence of anchored traders occurs. The initial effect on GNE is at all events very small – a jump of 0.006% in standard TRYM as compared to a jump of 0.012% when anchored traders are present (ζ = 1.01). After the initial jump the two paths of GNE track relatively closely as illustrated in figure 8.4.10. Interestingly at no time does the path of the anchored trader GNE fall below the path of the standard TRYM GNE. The excess GNE when anchored traders are present is mainly due to the consumption component of GNE.

Figure 8.4.10

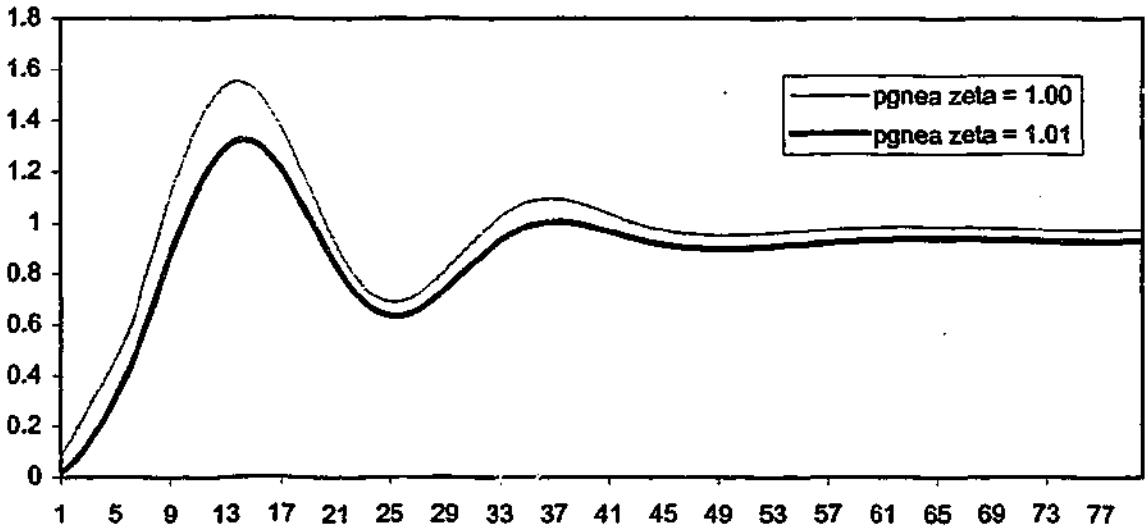
A permanent 1% monetary expansion in standard TRYM for GNE when zeta takes the values 1.00 and 1.01



The higher consumption on the zeta = 1.01 path is due to the different path of the price of consumption (PCON). The adjustment of prices in general is shown in figure 8.4.11. Here the price deflator for GNE, PGNEA, initially diverges further from its new long-run equilibrium due to the extra inertia introduced into the exchange rate by the anchored traders. This extra inertia in the exchange rate flows through to the general price deflator via the direct effect of the higher RTWI on the price of commodity exports (PXC) and non-commodity exports (XNC).

Figure 8.4.11

A permanent 1% monetary expansion in standard TRYM for the GNE Deflator when zeta takes the value 1.00 and 1.01



The price of imports (PMGS) is slower to react and there is initially a very small jump towards the new equilibrium in contrast to the jump in standard TRYM. RTWI appears in four asset equations as represented in figures 8.4.4 - 8.4.7. In the long run the permanent shock will cause the nominal exchange rate to fall by the equivalent percentage of the money shock. This will revalue any overseas assets.

Except for Australian holdings of overseas equity (WEOPZ), the effects on the overseas asset variables are less pronounced than the effects on the traded goods sector. The size of the effect is determined by the relative sizes of the flow, the size of the stock in the previous period and the magnitude of the revaluation of the stock in the current period.

Using private sector foreign currency debt as an example, the equation for this variable in quarter s is:

$$WDPOFZ_S = WDPOFZ_{S-1}*(1 - \ln(RTWI_S/RTWI_{S-1}) + U\_WDPOFZ_S) + BDPOFZ_S$$

where: WDPOFZ is private sector foreign currency debt;

BDPOFZ	is	new private foreign currency borrowing from overseas and;
U_WDPOFZ	is	an error term.

The current period private sector currency debt is made up of the flow in that period, BDPOFZ, an error term, U_BDPOFZ, and the remainder is the revalued stock. If the revaluation is large in comparison to the flow and the original stock ($WDPOFZ_{S-1}$), then the difference between in WDPOFZ in a given period when zeta = 1.00 and when zeta = 1.01 will be greater than when the flow and the original stock is large compared to the revaluation.

The reason that the shift in CAB is small is that the exchange rate revalues two items in the current account balance that are relatively small: migrant transfer credits and non-investment income and other unrequited transfer debits. The long run effects on GNE are very small (but finite): however these effects are not due to any numerical inaccuracy of the model. Thus the main effects on the model of varying zeta are through the trade side. The effect on GNE is persistent due to the extra inertia forced onto the price level through the effects on exports and the price of exports. This effect flows through to create a permanent increase in real consumption.

The effects when zeta = 1.02 are a magnified version of when zeta = 1.01. The degree of the initial jump in the exchange rate is greater as zeta increases but the mechanisms that flow through the model are the same as for zeta = 1.01. Similarly when zeta = 0.99, the trade side of the model is again the important determinant of the different path and jump in the exchange rate.

The above section provides a qualitative description of the result of varying zeta away from unity in order to replicate the behaviour of anchored traders, but it does not indicate whether the model benefits from this extension to the determination of the exchange rate. This issue is examined in the next section where an historical validation of the TRYM model is used to test the extended formulation of the exchange rate.

8.5 Fiscal Simulation in TRYM

To again illustrate the effect of a Gruen and Gizycki type response, a temporary fiscal shock is applied to TRYM. The shock is a 5% reduction in government consumption for two years, after which the share of government spending in GDP is returned to its pre-shock value. The reduction in government spending is instigated by the repurchase of governments bonds through open-market operations. In this section, a brief analysis of the shock is discussed. In section 8.6, the scaling factor is utilised to demonstrate the impact of Gruen and Gizycki type behaviour on the exchange rate and the economy, which can be related to the "euphoric behaviour" seen in the exchange rate market described in Dixon (1996).

As TRYM possesses a "neo-classical" (supply driven) long-run closure and a "Keynesian" (demand side driven) short-run, a separate discussion of the initial effects (short-run effects) and the long run effects follows.

Short-Run Effects

The 5% reduction in Government spending has the direct initial effect of lowering domestic output. Because the Government purchases from overseas, there is an immediate reduction in demand for imported goods. As well with the government debt to GDP ratio fixed there is an immediate drop in the rate of labour tax (figure 8.5.1) (and through an identity, a proportional drop in the rate of tax on capital income). These effects flow through to other parts of the model.

The financial sector is linked to the real sector via an inverted money demand equation. With the money supply unchanged in this scenario, the short-term interest rate must fall to compensate for the fall in the demand for output. The magnitude of this drop is determined by the semi-elasticity of money demand[7]. The lower interest rate stimulates Gross National

Figure 8.5.1
The path of the rate of tax on labour income (RTN) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

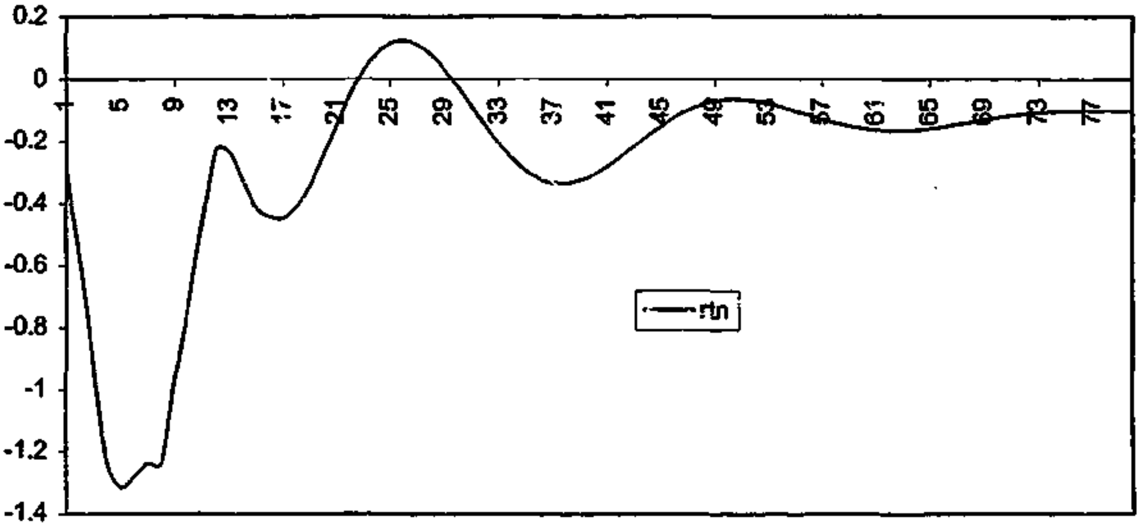
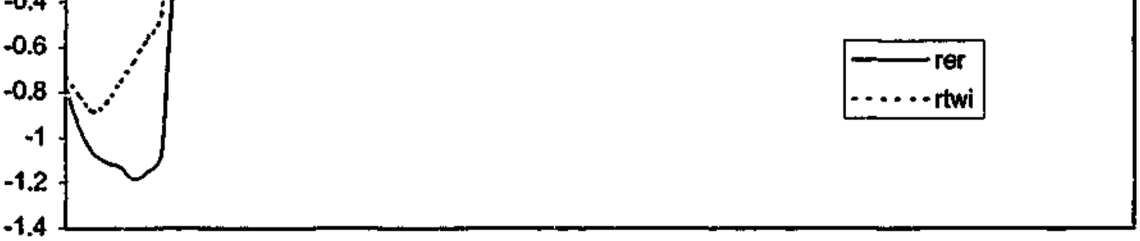


Figure 8.5.2
The path of the real exchange rate (RER) and the nominal exchange rate (RTWI) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.



[7] The relevant parameter is set 0.012408 giving a semi-elasticity of money demand of 0.81. This means that for a 1% fall in nominal transactions, the short-term interest rate will fall by 0.81 percentage points. This semi-elasticity differs to the semi-elasticities (λ) used in chapter by a factor of 100 due to the different units

Figure 8.5.4
The path of exports in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

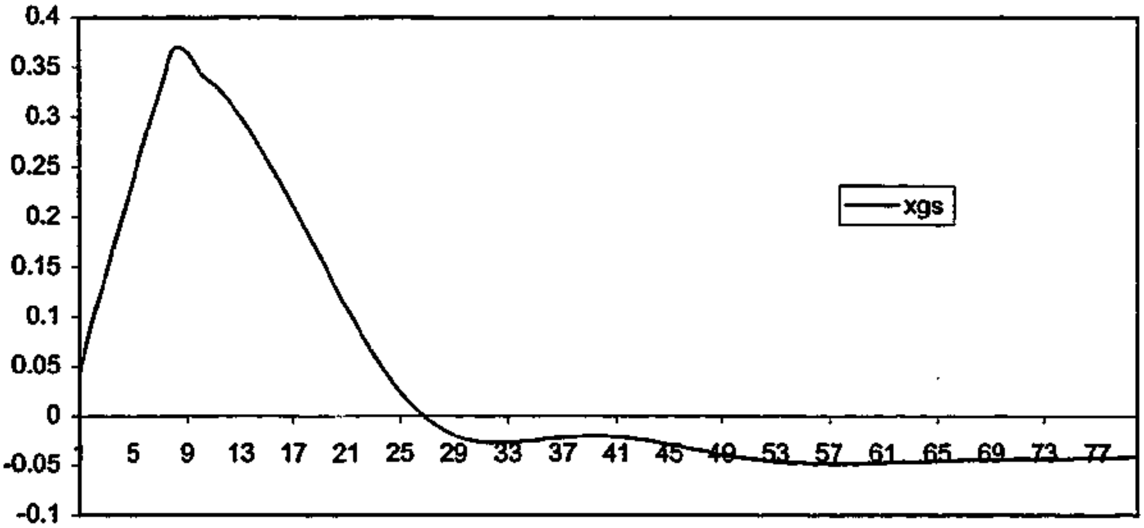
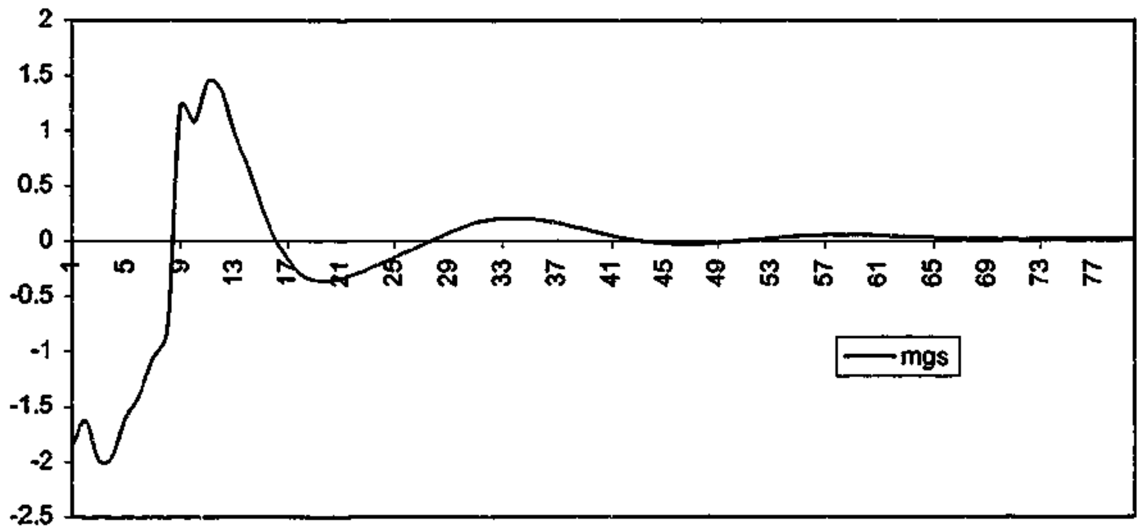
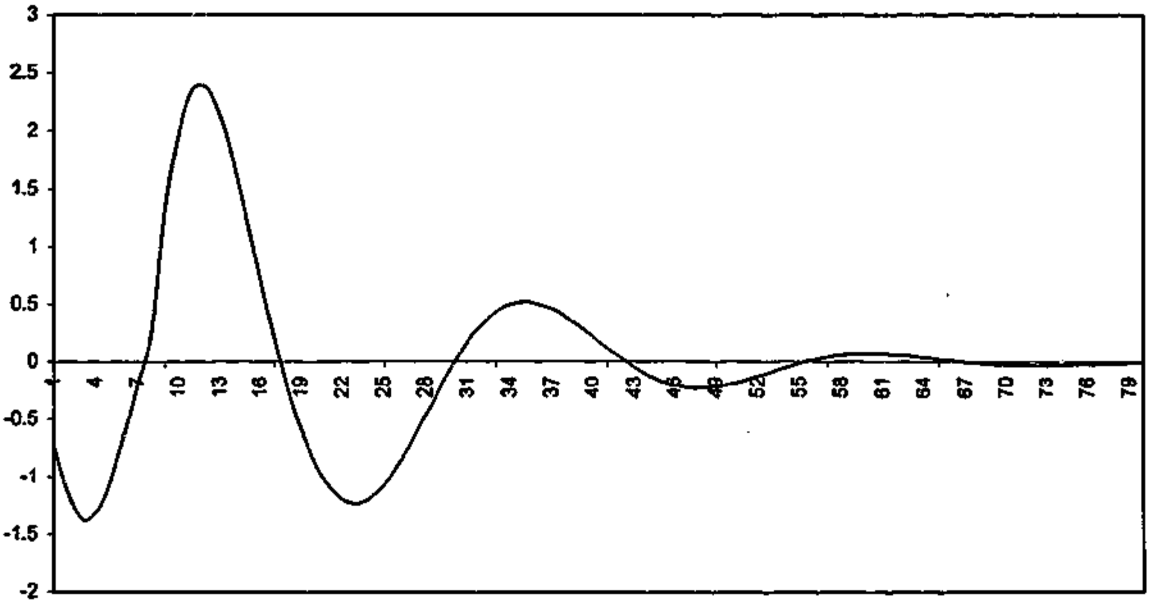


Figure 8.5.5
The path of imports in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.



used for the interest rate. In TRYM, interest rates are in percentage form (i.e. 7%). In the miniatures, interest rates are in proportional form (i.e. 0.07).

Figure 8.5.6
The path of private investment in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.



Expenditure (GNE) through consumption, investment and imports. As well, the decrease in short-term interest rates causes the nominal exchange rate to fall (as well as the real exchange rate - see figure 8.5.2). Unlike other macro models TRYM uses real long bond rates in the uncovered interest parity condition that links the exchange rate and interest rates. The short term interest rate and the long bond rate are linked by the 10 year bond yield equation. The equation is formulated to determine the real component of the 10 year nominal bond rate. The equation has been calibrated to reflect the historical movement of bonds. The parameter that determines the extent of the impact of a shift in short-term rates on long bonds is set at 0.2 in the long run. When there is a shock to the short-term interest rate (direct or indirect), there is a contemporaneous effect on the exchange rate via changes in the equilibrium domestic real short term interest rate.

Since the world long bond rate is fixed, the jump in the nominal exchange rate is determined by the change in the local real long bond rate (see equation 8.5.1). The long bond rate falls by more proportionally than the nominal exchange rate does because inflationary expectations rise. The price deflator of GNE falls due to the reduction in aggregate demand (equation 8.5.2). This fall in the price deflator relative to the unchanged future expectation of the equilibrium price of GNE, means there is an increase in inflationary expectations over the period of the simulation (equation 8.5.3). With an increase in inflationary expectations, the real bond rate falls by less than the fall in the nominal bond rate, hence the exchange rate does not fall as much proportionally as does the nominal long bond rate.

$$RTWI = RTWIX(+40)*\exp(10*\ln((1+RGL/100)/(1+WRGL/100)) \qquad (8.5.1)$$

$$PGNEA = GNEAZ/GNEA \qquad (8.5.2)$$

$$INFEX = \exp(\ln(PGNEAX(+40)/PGNEA)/10)*100-100 \qquad (8.5.3)$$

With the devaluation of the local dollar, the trade balance improves, with both higher exports (figure 8.5.4) and lower imports (figure 8.5.5). The increase in the price of imports combined with the lower economic activity means substantially lower imports.

The closure used has the tax on labour income adjusting to keep the GDP to debt ratio constant. Hence with the temporary reduction in government demand, there is an immediate drop in the rate of tax on labour income. This flows through to labour income, but is not large enough to prevent disposable income falling due to the overwhelming effect of the fall in wages. Real aggregate income is basically unchanged as the consumption price deflator falls in unison with nominal income.

The rise in unemployment tends to reduce the level of consumption, but aggregate consumption is unmoved in the first period due to the countervailing effect of the fall of the consumption deflator on the immediate past level of wealth. As the effects of the increase in wealth – mainly due to benefits from the improved current account balance via the need for the private sector to borrow less from overseas – impact on private consumption, the increased wealth overwhelms the negative factors and consumption rises, reaching a peak after 9 quarters (see figure 8.5.8). Once the temporary fiscal contraction is withdrawn, consumption begins to fall towards its pre-shock value path, although there is a small permanent long run effect.

Private investment (figure 8.5.6) initially falls as capacity utilisation falls. This leads to a delay in investment in the short term as it signals there is a temporary excess of demand over supply. As the Tobin's Q-ratio (see figure 8.5.11) effect kicks in with the reversal of this balance, investment regains its pre-shock level before the temporary reduction in government spending is lifted.

Long Run Effects

Because this is a temporary shock, we do not expect substantial long run effects. That said, there are small permanent effects to areas of the model. In figure 8.5.1, the rate of tax on labour income does not re-attain its pre-shock value. This is due to the permanent increase in nominal GDP that has the effect of causing a real reduction in the value of government debt. Note that real GDP is unchanged as prices rise by the same amount in the long run. As the model enters the steady state there is an increase in nominal wealth (figure 8.5.7) of approximately 0.45%. As general prices have risen by only around 0.012%, there is an increase in real wealth reflected in the long run rise in real consumption (figure 8.5.8). The rate of tax on labour income settles permanently below its original path (figure 8.5.1), as does the level of exports of goods and services. The level of imports rises but the price of imports falls via the exchange rate adjustment leaving nominal imports essentially unchanged.

The real exchange rate enters the steady state at around 0.36% higher with the trade weighted nominal exchange rate finishing at about 0.023% higher (figure 8.5.2). Both the short and long interest rates are marginally higher as the model enters the steady state (figure 8.5.12 below).

This is probably due to a numerical problem within the model related to the relatively small number of quarters (80) before the model is deemed to have entered the steady state.

By way of explanation, there appear to be three main areas that are impacting on these results. These are: **(i)** the composition of government bonds between domestic and foreign owned[8]; **(ii)** the fact that consumers are not required to intertemporally optimise their spending habits (or equivalently, savings habits)[9]; and **(iii)** that by the time the model enters the steady state the Q-ratio for the housing sector is still significantly less than one[10].

The composition of the ownership of foreign bonds becomes crucial in that the residents of Australia pay all the tax required to satisfy the targetted debt to GDP ratio, but only receive the interest on those bonds that are owned domestically. Hence if there is a shift in the proportions owned domestically versus foreign there will be real effects on private income and wealth. In this simulation, government consumption is cut by 5% temporarily for 8 quarters. As the debt to GDP ratio is fixed, there are immediate falls in both the volume of bonds required and in the rate of tax on labour income (and through an identity, the rate of tax on capital income). These factors combine to reduce the amount of government bonds that are required. When the volume of government bonds falls, the consumer's tax burden falls by an amount that is greater than the fall in income that previously was garnered by them from the interest on government bonds withdrawn. This causes an adjustment in the trade balance to ensure the current account is brought back into balance to satisfy the required debt to GDP ratio. Thus there will be a fall in exports that is offset by an increase in consumption. This implies there will be no change in domestic output and should leave prices and the interest rate unchanged. The above scenario explains a certain part of the long run

[8] For a more detailed explanation see Parsell et al. (1991) pp. 109-110.
[9] For a detailed explanation see Powell and Murphy (1995) ch. 27, especially section 27.5.
[10] This appears to be a glitch in TRYM that requires further investigation.

results; however in this simulation there are (small) permanent effects on

Figure 8.5.7
The path of nominal wealth (WMZ) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

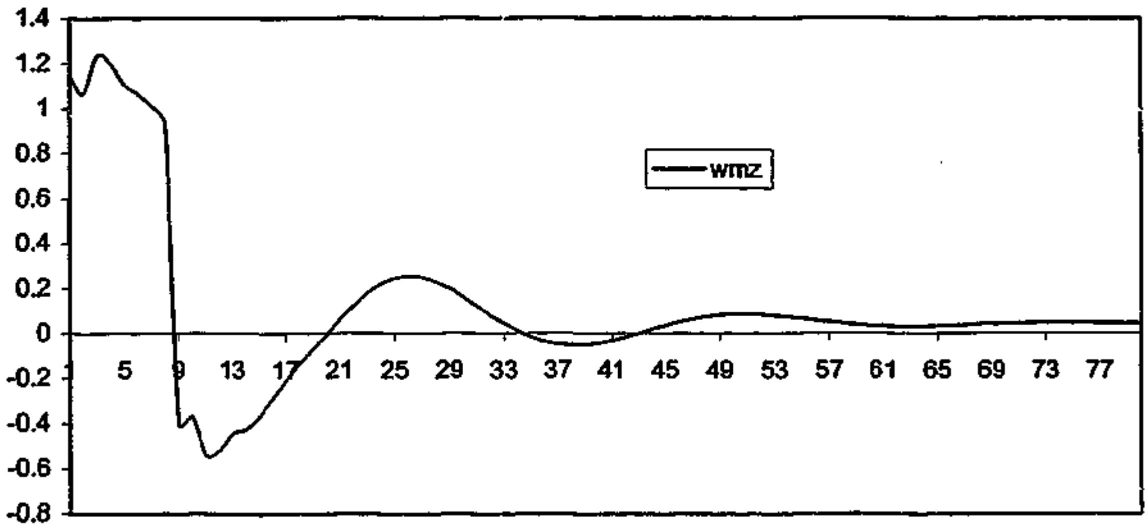


Figure 8.5.8
The path of real consumption (CON) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

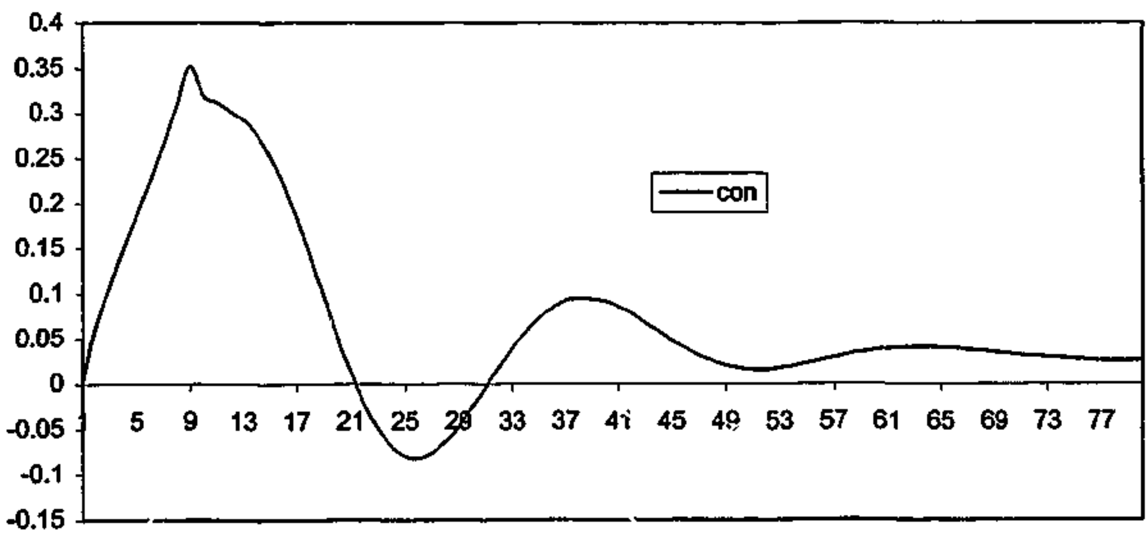


Figure 8.5.9
The path of the price of rent consumption (PCRE) and the price of dwelling investment (PIDW) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

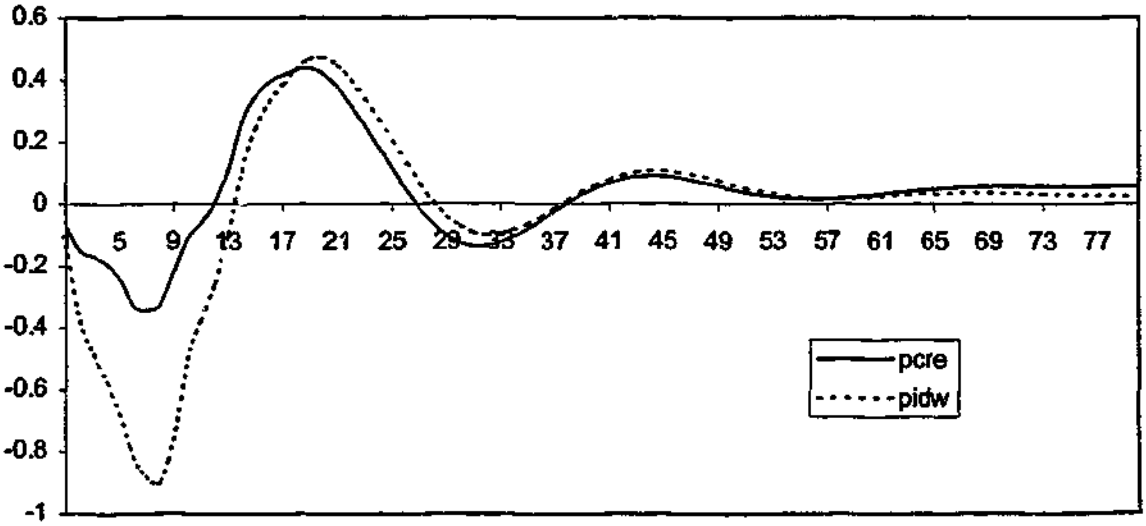


Figure 8.5.10
The path of the Q-ratio for housing (QRATH) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

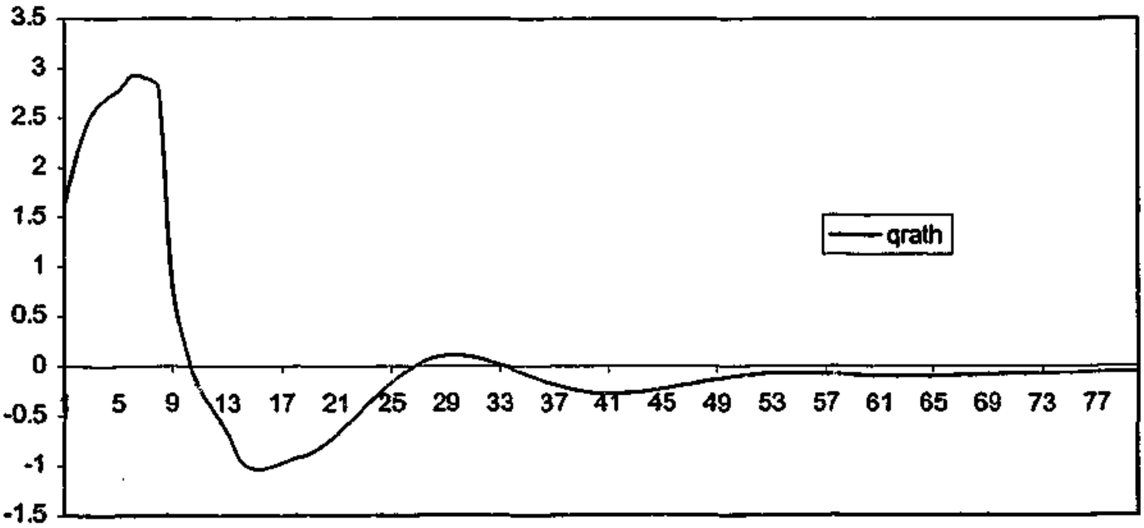


Figure 8.5.11
The path of the Q-ratio for investment (QRAT) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.

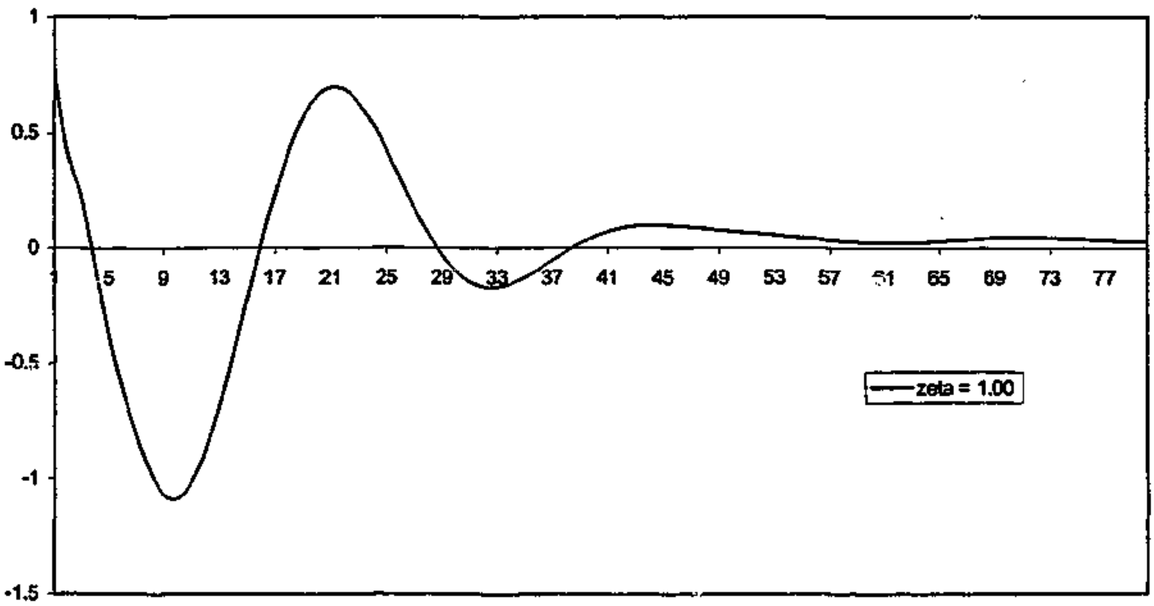
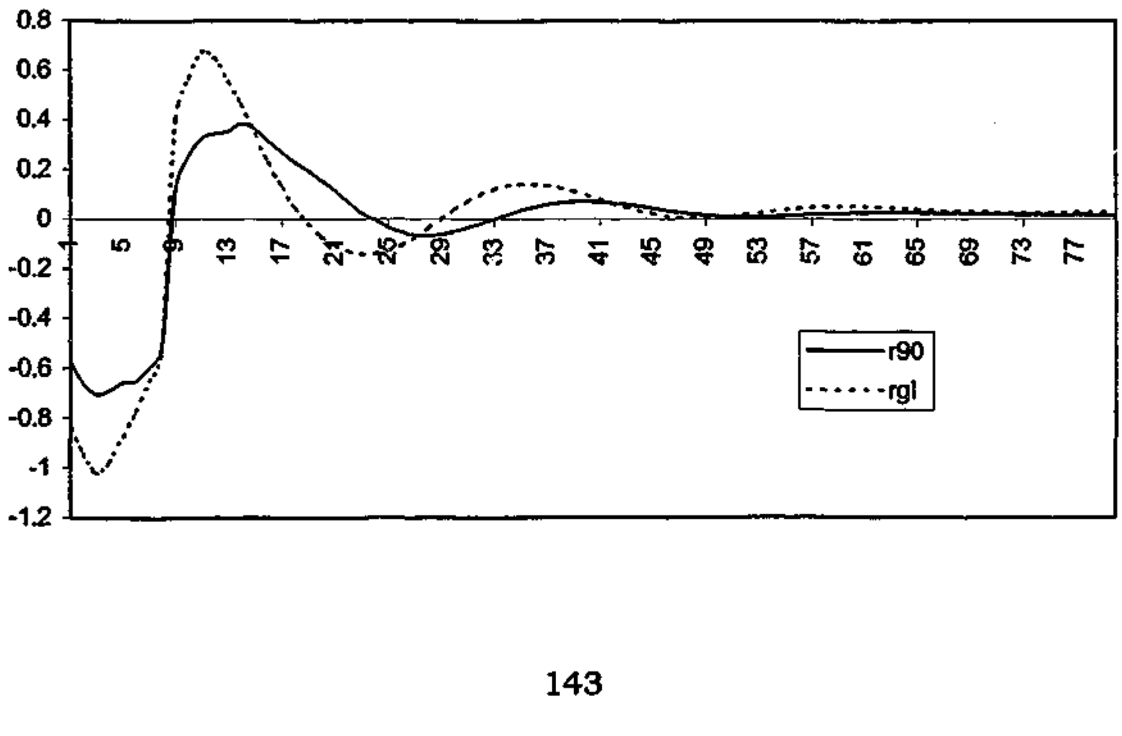


Figure 8.5.12
The path of the short term interest rate (R90) and the path of the long term bond rate (RGL) in standard TRYM after a temporary (8-period) 5% contraction of Government consumption.



prices and interest rates and the causes of these effects lie in other parts of the model.

Another area that allows for long run real effects is that consumers[11] are not required to optimise their savings over time, allowing for a temporary fiscal shock to have permanent effects on the model[12]. The consumption function is in line with the Ando and Modigliano (1963) life-cycle hypothesis. This means that long run consumption is dependent on real household disposable income and real non-human private wealth. Real private wealth represents the future income potential of the underlying assets. However there is no long run relationship linking a permanent change in debt levels to the savings patterns of consumers[13]. Hence through the change in debt composition, households do not realign their savings to reflect this change in income flow. This leads to small long run effects on the economy. There is a rise in both long and short interest rates. This rise leads to a fall in investment due to the fall in capital stock. The change in long term interest rates permanently raises the nominal exchange rate, and combined with the permanent rise in prices, an even greater rise in the real exchange rate.

The two factors described above – the form of the consumption function and the composition of bond ownership – explain most of the long run effects in TRYM93. However there is another factor that is accentuating – rather than causing – the long run results. This is that the price of rental consumption upon entering the steady state is still significantly above the rise in the price of dwellings and above the rise in the general price level.

Households are modelled to first determine their overall consumption and then make a choice between rental consumption and non-rental consumption. In the long run, the consumption of rental services relative to the consumption of non-rental services is a function of the price of rental services relative to the price of non-rental services. Hence, a coefficient of

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[11] In TRYM there is only one type of consumer who makes decisions about consumption, saving, labour supply, dwelling investment and the mix between rental and non-rental consumption.
[12] This conclusion is echoed in Commonwealth Treasury (1996b) section 4.6.

substitution between rental services and all other consumption items as a bundle is implicit in the model. In the short run, rental services are essentially fixed, so it is the relative price that adjusts rather than the stock of dwellings. The levels of rental services and non-rental consumption enter the long run without finding their "true" steady state value. Figure 8.5.9 illustrates that the price of rental services deviates from the base case by more than the price of the price of dwellings. Even with the higher rental prices, the stock of dwellings is still below control at the end of 80 periods. It is not clear whether this is a numerical problem or some inherent feature (intended or otherwise) in TRYM.

This problem finds its way into the consumption function through the nominal wealth identity. In valuing both dwelling stock and all other stock, the respective Q-ratios are used. For example in valuing current wealth, the stock of dwellings is valued as follows[14]:

(Price of dwelling stock) * (volume of dwellings)$_{-1}$ * (dwelling Q-ratio).

With the Q-ratio above one for the first two and a half years, producers are valuing their old stock at new replacement prices. In figure 8.5.10 the housing Q-ratio is illustrated and it is clear that initially as interest rates fall, it becomes profitable to increase the rate at which dwellings are built. However with the subsequent rise in interest rates, the adjustment in housing's Q-ratio has not been fully realised, so that it remains below one after 80 periods [15]. This has direct effects on the wealth function and on dwelling investment. The lower level of investment demand (compared to a scenario where the housing Q-ratio is back at 1) has ramifications right throughout the model.

[13] In Powell and Murphy (1995), such a link is modelled via a consumer's debt sustainability function in a miniature model: S3MM, section 27.5 (b). Debt sustainability is not explicitly modelled in TRYM (or Murphy) and may be considered an area for future development.
[14] The wealth valuation also includes inventories, non-housing assets, bonds and money.
[15] The housing Q-ratio is -0.051 below control after 80 periods. With the housing Q-ratio at 1 in the growth path (control) solution, this results in a housing Q-ratio of 0.949.

At least in the implemented computational version of TRYM, the first two issues discussed above (foreign versus domestic ownership of domestically issued bonds and the lack of a rigorous intertemporal budget constraint on consumers) result in permanent effects as a result of the temporary fiscal contraction to government consumption. These are genuine long run or steady state properties of the model. In contrast the third problem discussed above (lack of convergence to unity in housing's Q-ratio) is a characteristic of the parameterisation of the model. With a different set of parameters this problem with the housing Q-ratio may disappear[16].

In the next section, the scaling factor introduced in section 8.3 is used to ascertain the effects of Gruen and Gizycki type behaviour when the economy is subjected to a temporary fiscal shock.

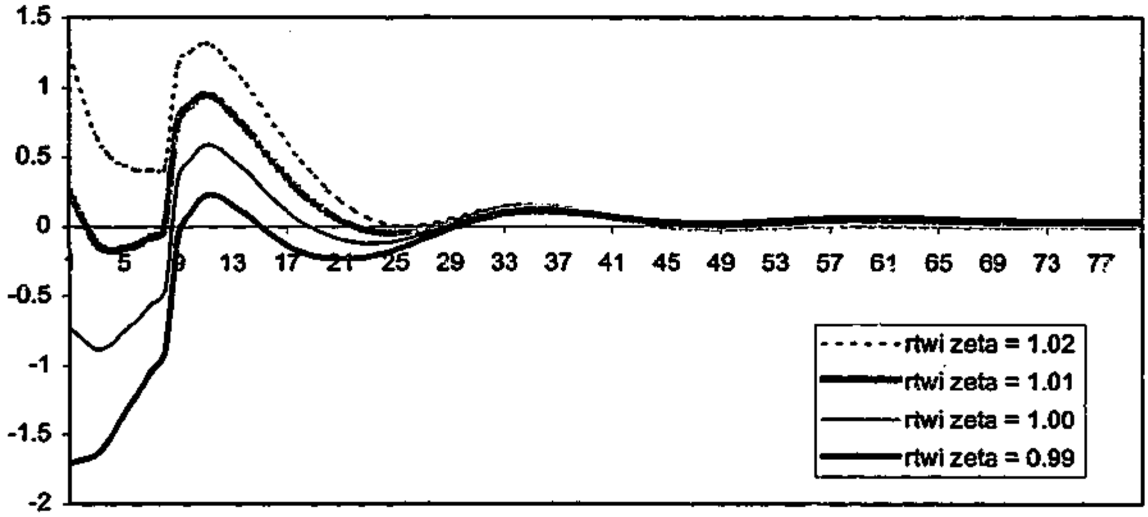
8.6 Effect of the Scaling Factor when TRYM is Subjected to a Temporary Fiscal Contraction

As with the 1% monetary shock, the nominal exchange rate is now subjected to the same four scenarios illustrated in figure 8.3.1. This results in the four paths of the exchange rate illustrated in figure 8.6.1.

[16] In TRYM95 (Commonwealth Treasury (1996)), the demand for rental services equation has been re-estimated with a resultant elasticity of substitution of 4.464. This is extremely elastic in comparison to the value used in TRYM93 and is likely to correct this problem.

Figure 8.6.1

The effect on RTWI using varying values for zeta when TRYM is subjected to a 1% temporary fiscal contraction (figures reported are percentage deviation from base case)



Again it is useful to distinguish between the short run effects and the long run effects. The initial jump in the nominal exchange rate and the terminal value for each alternative value of zeta are given in table 8.6.1.

Table 8.6.1

The values that the nominal exchange rate (RTWI) takes for the initial post-shock jump and the terminal value for varying zetas. (figures reported are percentage deviation from base case)

	Initial Jump	Terminal Value (T = 80 Quarters)
zeta = 0.99	-1.709	0.039
zeta = 1.00	-0.728	0.023
zeta = 1.01	0.253	0.006
zeta = 1.02	1.234	-0.009

The value for the nominal exchange rate when zeta equals 1 is the scenario (hereafter denoted the base scenario) discussed in section 8.5. The value that the nominal exchange rate takes immediately after the temporary contraction of Government spending is -0.728% below the value in the growth path (base case) simulation. The value for the nominal exchange rate in the standard scenario at the conclusion of 80 periods is 0.023. This deviation could be solely due to the numerical inaccuracy of the implemented model; however I believe that at least part of the deviation is due to deficiencies in the model as discussed in the previous section.

When zeta takes the value 1.01 – which correlates to the presence of anchored traders – the jump is in the opposite direction compared to the original scenario (zeta = 1.00), with the exchange rate jumping by +0.253%. This result concords with the scenario described in Dixon et al. (1996), where in response to a fiscal shock the exchange rate is assumed to jump in the "wrong" direction from the viewpoint of conventional theory. The authors of this paper explain this behaviour by:

> "Exchange rate appreciation might reflect market euphoria associated with the implementation of government policies consistent with the views of many participants in financial markets."[17]

The behaviour of the nominal exchange rate in response to a temporary fiscal shock is dependent on the composition of the traders in the marketplace. When the financial market contains a sufficient number of anchored traders[18], the response of the nominal exchange rate to a fiscal shock is a jump in the opposite direction to the jump in the base scenario.

When zeta =1.02, the effect of anchored traders is magnified even further. Here, the exchange rate jumps to 1.234% above the control path. Conversely, when zeta =0.99 the exchange rate falls immediately to –1.709. Interestingly, the long run is different for all the scenarios and is inversely related to the initial jump (but in all cases small in absolute value). In the base scenario, the initial jump was –0.728 and the long run value for the exchange rate was 0.023. When zeta = 1.01, the long run value falls to 0.006. When zeta = 1.02 the nominal exchange rate jumps further than when zeta = 1.01, but in the long run the exchange rate settles at –0.009 below the control path.

[17] Dixon et al. (1996) p. 98.

[18] The percentage of anchored traders in the marketplace is dependent on the whether anchored traders are weakly or strongly anchored (value of κ). See chapter 6.

Central to these results is the differing outcome for private sector debt. The terminal values for private sector debt are shown in table 8.6.2. As is evident, the values vary markedly. If anchored traders are present (i.e. when zeta = 1.01, 1.02), then the model enters the steady state with more private sector debt which is counter to the base scenario result (a −1.135% change from the growth path control). In fact, the qualitative association between terminal private debt and the terminal exchange rate is very strong (see figure 8.6.2). This result stems from the reasons discussed in section 8.5. The jump in the exchange rate flows through to other variables in the model and the two effects discussed previously – the composition of ownership of public debt and the lack of a savings response mechanism – cause differing long run results. As Table 8.6.2 and figure 8.6.3 demonstrate, the outcome for private debt is significantly different depending on the value that zeta takes.

Table 8.6.2
The terminal values for private sector debt (WDPOAZ) for a temporary 5% fiscal contraction in percentage change from control. (figures reported are percentage deviation from base case)

	Terminal Value
zeta = 0.99	-2.889
zeta = 1.00	-1.135
zeta = 1.01	0.581
zeta = 1.02	2.26

Figure 8.6.2
Association between Terminal Private Debt (WDPOAZ)and the Terminal Exchange Rate (RTWI)
(Terminal Values – % deviation from control)

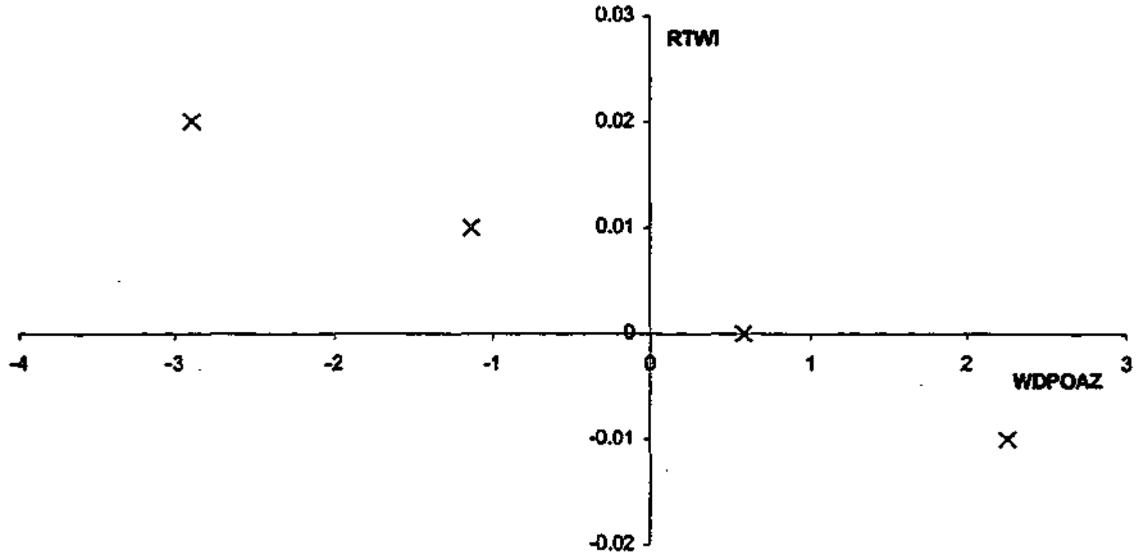
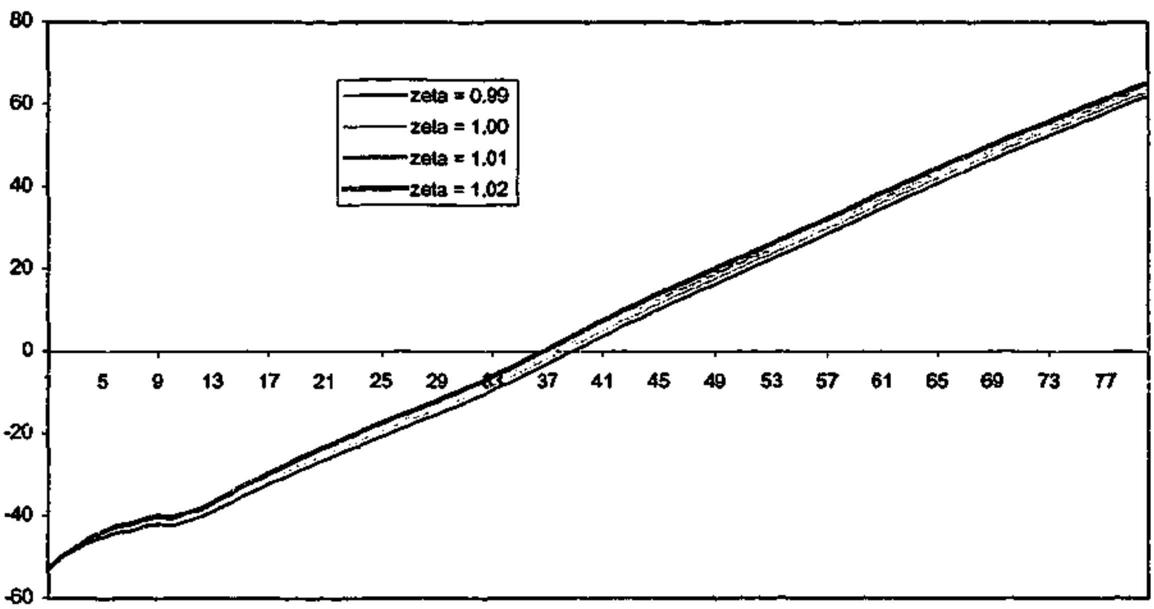


Figure 8.6.3
The path of private sector debt (WDPOAZ) after a temporary government consumption contraction for varying zetas[19]



[19] This variable is graphed as a percentage of nominal GDP (GTMAZ) rather than in percentage change as the variable passes through zero.

The direct impact of the changed path in the nominal exchange rate flows through directly to the same 8 variables listed in section 8.5. Figures 8.6.4 – 8.6.8 show the change in path for the price of imports, the price of commodity exports, the volume of non-commodity exports, the current account balance and Government foreign currency debt held by the overseas sector.

In the remainder of this section, the *control path* refers to the standard growth path of the TRYM model. The *base case* refers to the scenario where TRYM has been shocked by the 5% fiscal contraction and zeta is set to 1.00 (i.e. the standard TRYM formulation).

Figure 8.6.4
The path of the price of imports (PMGS) after a temporary government consumption contraction for varying zetas

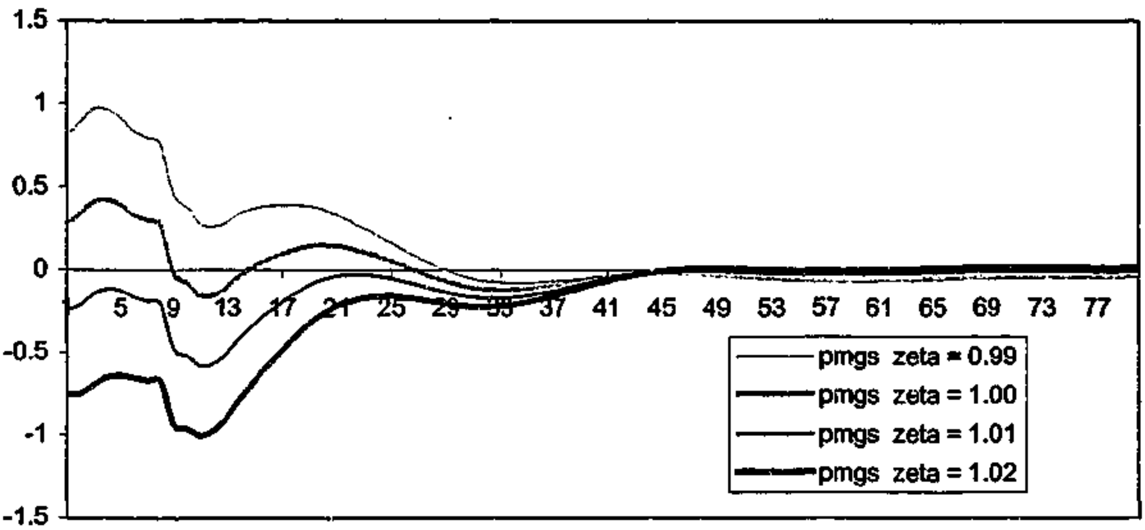


Figure 8.6.5
The path of the price of commodity exports (PXC) after a temporary government consumption contraction for varying zetas

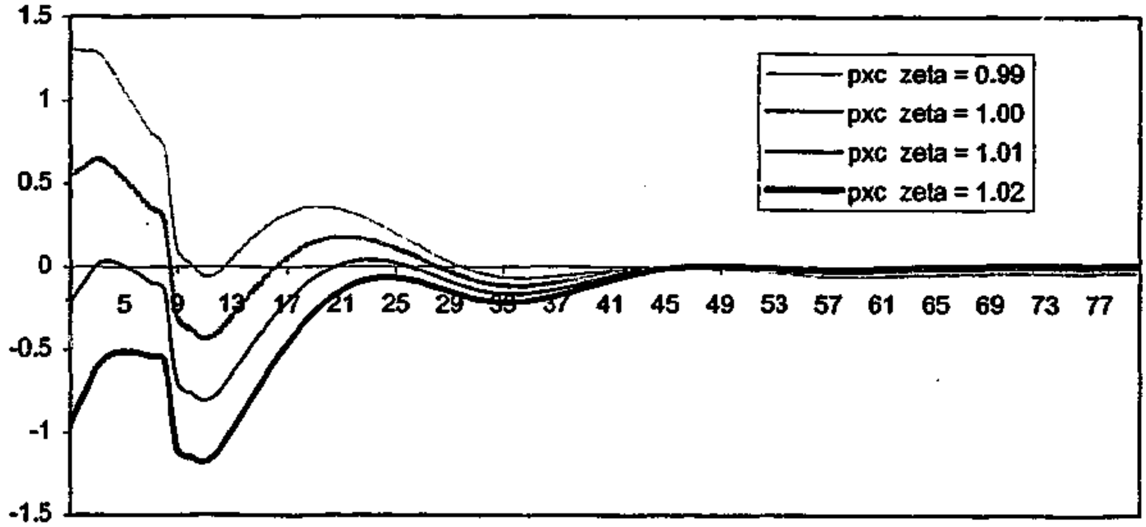


Figure 8.6.6
The path of non-commodity exports (XNC) after a temporary government consumption contraction for varying zetas

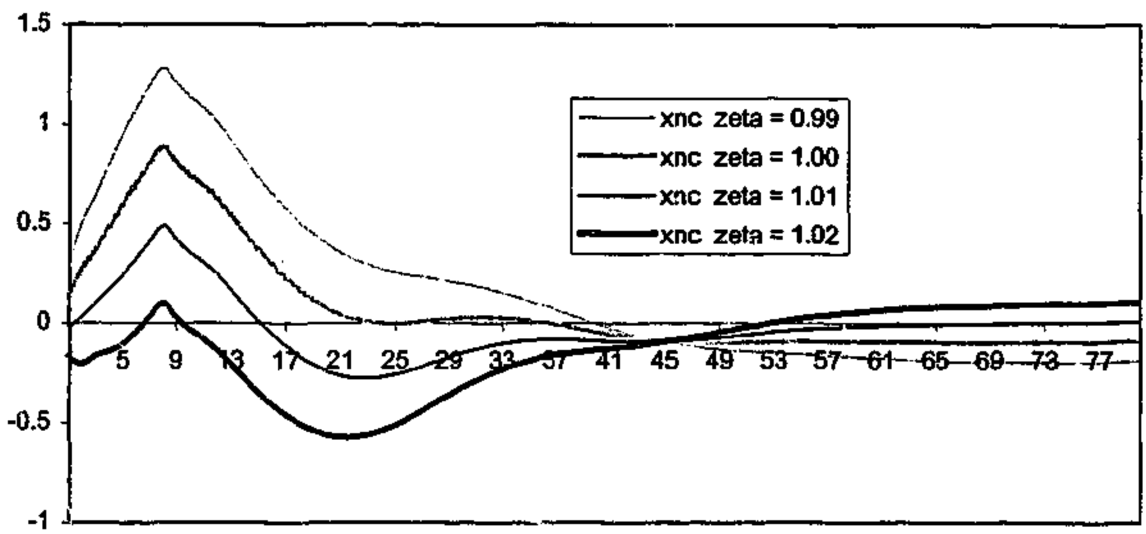


Figure 8.6.7
The path of the current account balance (CAB) after a temporary government consumption contraction for varying zetas[20]

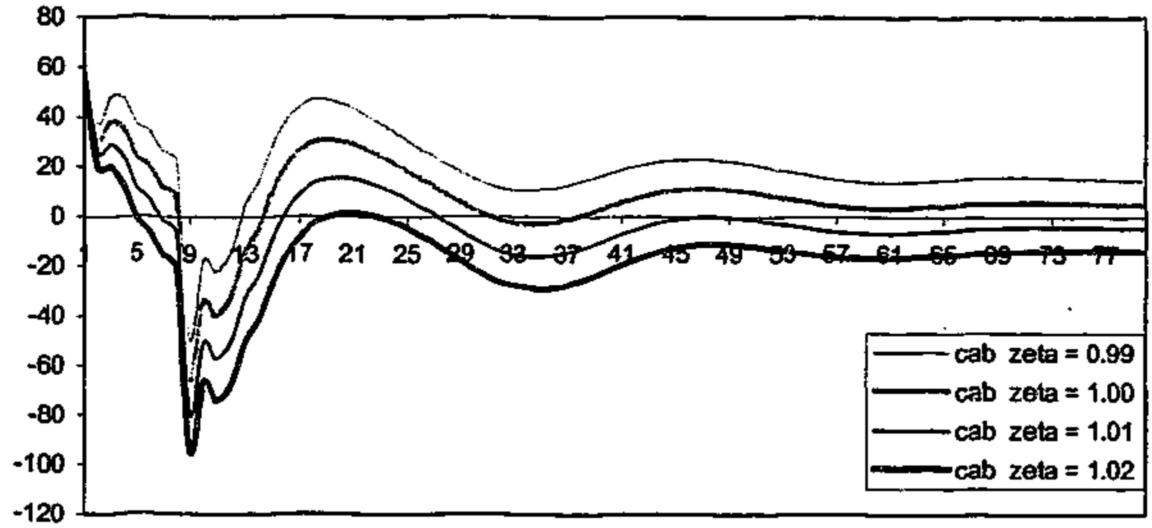
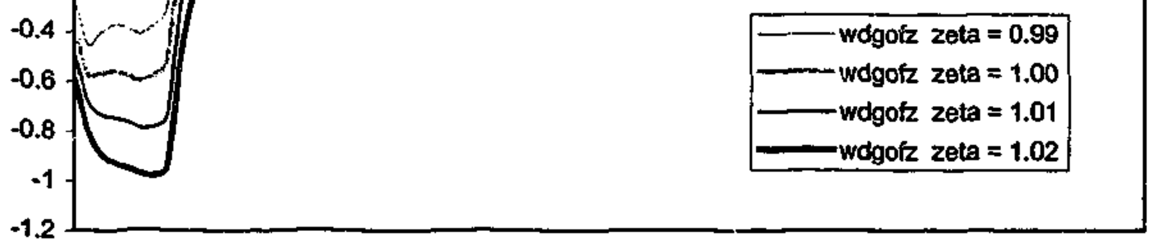


Figure 8.6.8
The path of Government foreign currency debt held by overseas sector (WDGOFZ) after a temporary government consumption contraction for varying zetas



[20] This variable is shown in change in the level rather than in percentage change as the variable passes through zero.

The first thing to note is that there are long run effects on the variables directly affected by the change in the nominal exchange rate. As the nominal exchange rate itself is affected in the long run, these variables are also likely to change their long run attributes. The above variables behave in a similar vein to the monetary simulation in the short run. That is that when anchored traders are introduced (zeta =1.01,1.02), the jump in the particular variable is less for both the monetary shock and the fiscal shock. For example, in figure 8.4.1 in the monetary simulation, the price of imports (PMGS) jumps by less than for the base case when the model is subjected to a monetary expansion. Given this information, for a fiscal contraction one would expect there to be a similar effect on the price of imports with the introduction of anchored traders. As is evident in figure 8.6.4, the scaling factor affects the price of imports in a similar manner irrespective of the type of shock or the direction of the shock (i.e. expansion or contraction). This is true for all the variables with strong links to the exchange rate.

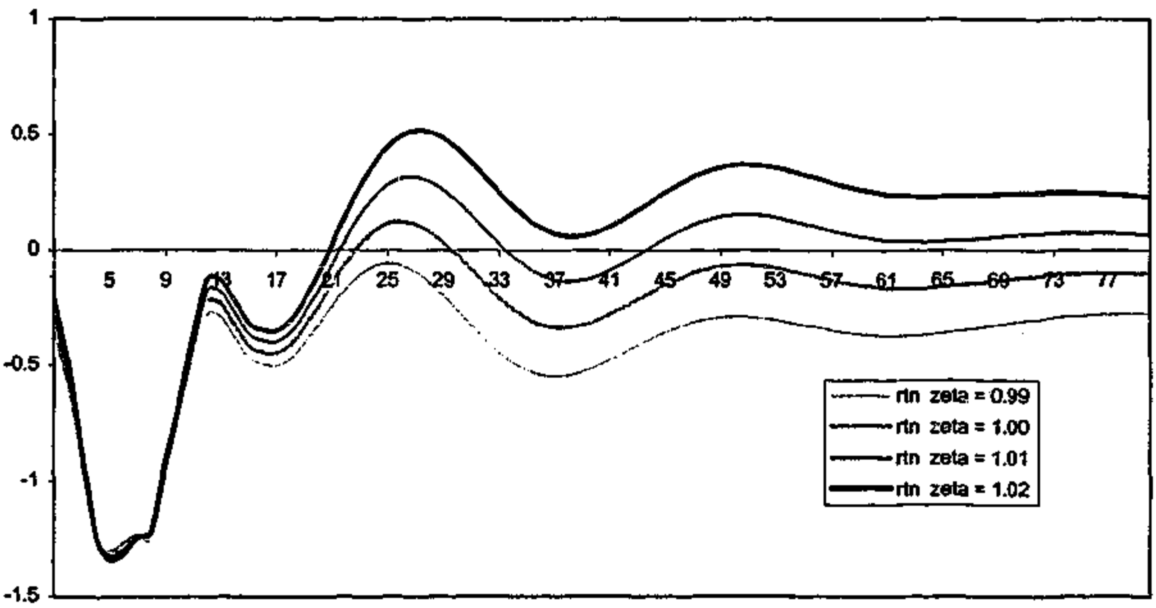
As in the monetary simulation, the alteration of the nominal exchange rate identity to allow for Gruen and Gizycki type behaviour flows through to the long run. For non-commodity exports, the value that zeta takes determines whether these exports are greater or smaller in the steady state. In the base case (zeta = 1.00), in response to the temporary fiscal shock there is a drop in the volume of non-commodity exports in the long run; however, when there are anchored traders present, the volume of non-commodity exports rises in the long run. Similarly, for the base case the current account balance ends the simulation in a worse position, but when there are anchored traders present the current account improves. These two variables have been directly affected by the change in the long run value of the nominal exchange rate. The temporary fiscal shock causes an increase in consumption in the medium term leading to the accumulation of private debt (figure 8.6.3). With the inability of the model to allow for intertemporal optimisation of consumers, the introduction of anchored traders accentuates this problem.

As mentioned previously, the long run effects are caused by an extension of the three effects discussed in the previous section. The change in the initial jump of the exchange rate flows through the model via two main mechanisms. The first is the change in the ownership of bonds and the second is the lack of a device to ensure that households intertemporally optimise their savings. These effects are dependent on the value that the exchange rate takes in the short run, thus flowing eventually through to the long run.

Short Run Effects

With the temporary 5% reduction in Government spending the rate of labour tax falls to a point that is invariant to the value that zeta takes. This is essentially true for the whole period during which the contraction is occurring (the first 8 periods). This is illustrated in figure 8.6.9.

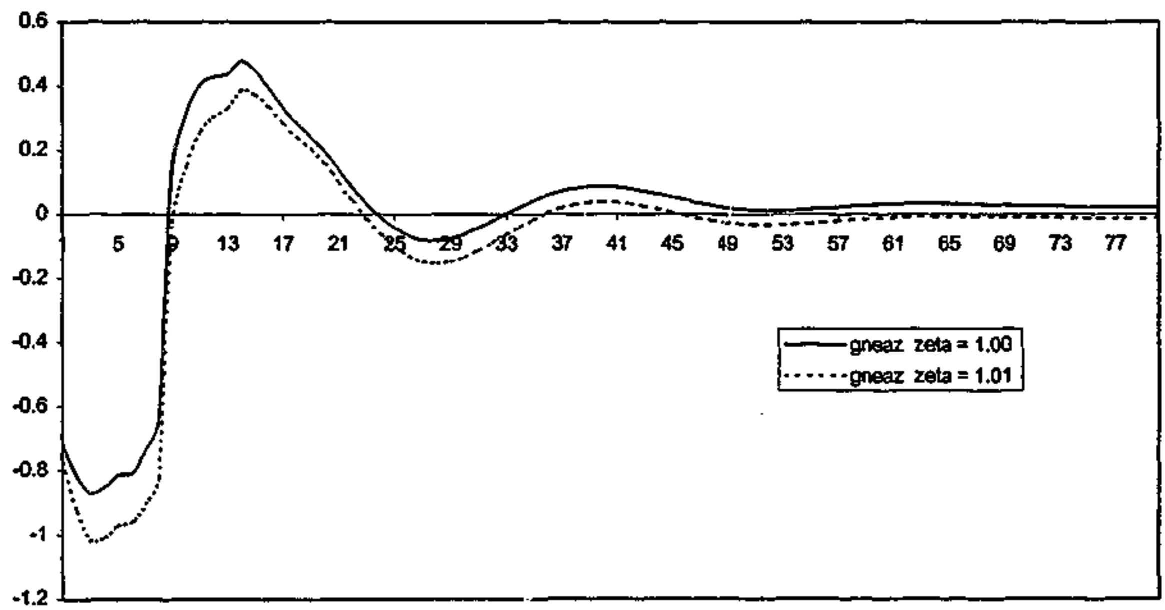
Figure 8.6.9
The path of the rate of labour income taxation after a temporary 5% fiscal contraction for varying zetas.



With money supply unchanged in all scenarios, the short term interest rate changes according to the (inverse of the) semi-elasticity of demand. Between the scenarios of differing zetas, the short term interest rate jumps to different levels immediately after the shock is implemented. The only other variable in the inverted money demand equation that can move across different scenarios is nominal gne. Hence when there are anchored traders present, there is a relatively larger fall in nominal gne (figure 8.6.10), due to the short term interest rate falling further (see figure 8.6.11)[21]. With the nominal exchange rate falling further in the short run when anchored traders form part of the economy, the long bond rate is forced to fall further than in the base scenario (zeta = 1.00).

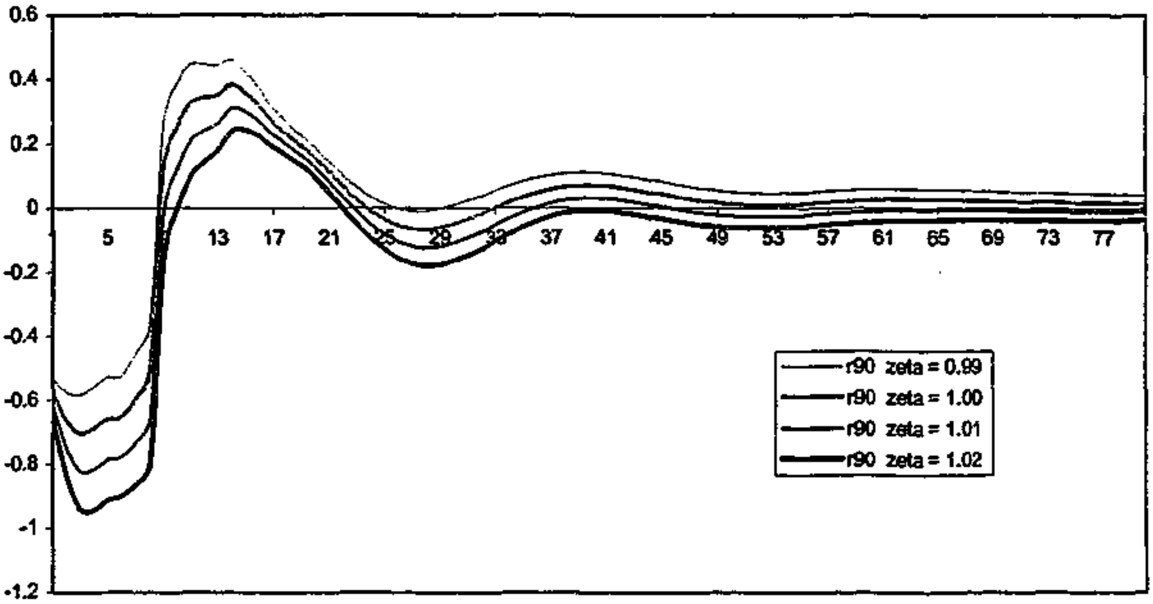
With anchored traders present there is a fall in the GNE price deflator due to the further reduction in aggregate demand. This flows through to inflationary expectations where there is a further increase over and above the increase in the base scenario for the period of the simulation. This means that there is a greater gap between the nominal bond rate and the nominal exchange rate in the short run.

Figure 8.6.10
The path of nominal GNE after a temporary 5% fiscal contraction
for varying zetas.



[21] See above for the link between short term interest rates and the exchange rate.

Figure 8.6.11
The path of the 90-day bill rate after a temporary 5% fiscal contraction
for varying zetas.



When there are anchored traders present, the dollar does not devalue immediately after the fiscal shock; instead the nominal exchange rate jumps in the opposite direction and actually appreciates. This flows through to the trade side of the model affecting both exports and imports (figures 8.6.12 and 8.6.13). As the effect of the fiscal contraction is tempered by the initial appreciation of the dollar, exports initially rise by less (or even fall) when anchored traders are present. With a stronger local dollar, imports initially fall by less.

Figure 8.6.12
The path of imports(MGS) after a temporary 5% fiscal contraction
for varying zetas.

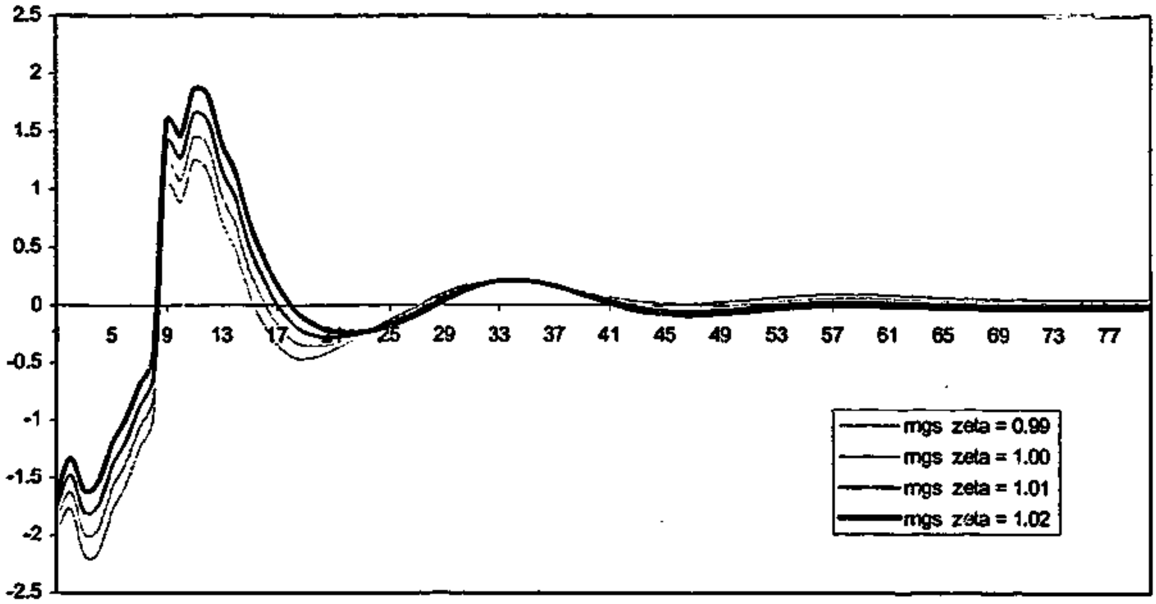
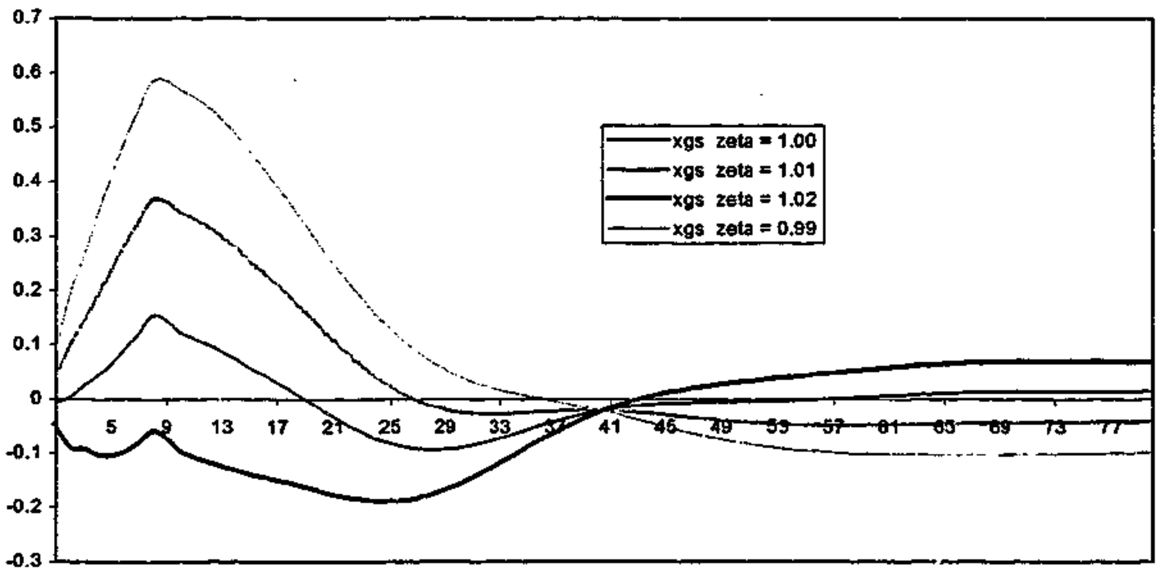
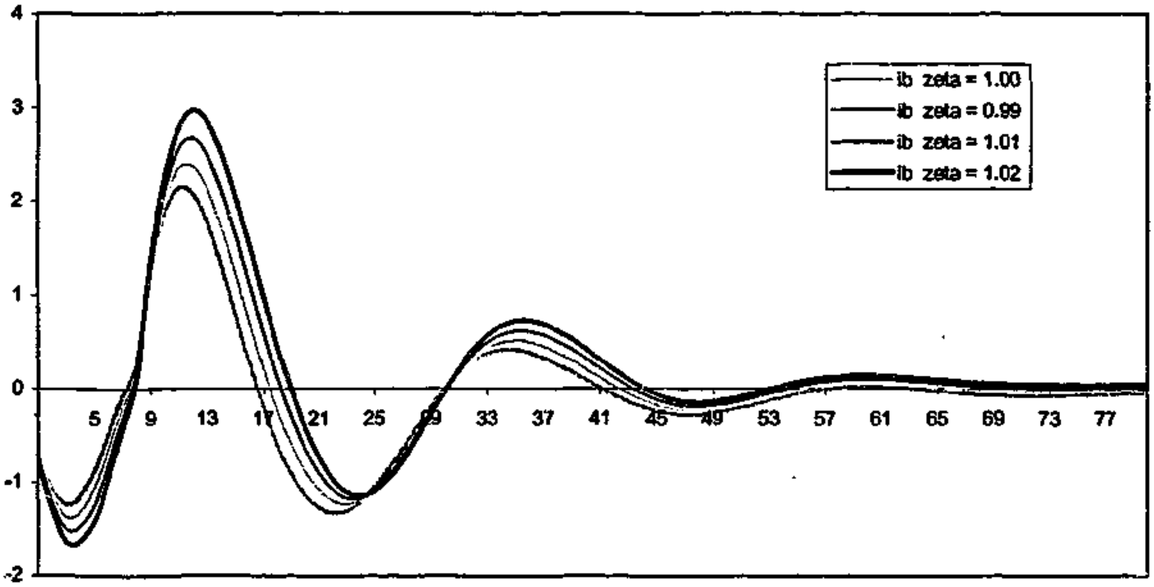


Figure 8.6.13
The path of exports (XGS) after a temporary 5% fiscal contraction
for varying zetas.



The initial jump in private sector investment (figure 8.6.14) is similar in the base case and in the anchored traders' scenario, with the anchored traders' scenario resulting in a slightly higher jump away from the control path. Throughout the rest of the simulation, the paths of the anchored traders' scenarios have a higher amplitude of divergence from control than the base case. All paths slowly converge over time.

Figure 8.6.14
The path of private investment (IB) after a temporary 5% fiscal contraction for varying zetas.



Long Run Effects

The long run effects in the simulation with anchored traders present, provides different outcomes for many of the main macroeconomic variables. Table 8.6.3 sets out the results for the base case scenario and the scenario where anchored traders are represented by the scaling factor set at 1.01.

In Table 8.6.3, the introduction of anchored traders through the use of the scaling factor has led to a sign reversal for many of the variables. Private sector $A debt has fallen in the base case but has risen in the anchored trader scenario. Conversely nominal private wealth rose in the base case but has fallen in the anchored trader scenario. In fact of the 18 variables reported in the above table only five have not changed sign: real GNE, real consumption, imports, 10 year bonds, the dwelling sector Q-ratio and the nominal exchange rate. But to keep this in perspective, most of these long run effects (in either scenario) are relatively small – which makes it difficult to discriminate genuine model results from numerical accuracy accidents.

Table 8.6.3

Long Run results for select variables for the base case (zeta =1.00) and when anchored traders are present (zeta =1.01) when the economy is subjected to a temporary fiscal contraction.*

Variable	Base Case (zeta=1.00)	Anchored Traders (zeta=1.01)
GNE	0.008	0.018
Nominal GNE	0.021	-0.012
GNE Price Deflator	0.012	-0.03
Investment	-0.011	0.021
Inflationary expectations	-0.022	0.054
Dwelling Capital	-0.014	0.137
Real Consumption	0.026	0.012
Imports	0.024	0.002
Consumption of Rental Services	-0.013	0.137
Price of Rent Consumption	0.056	-0.175
Dwelling Sector Q-ratio	-0.051	-0.1
Rate on 90-Day Bills	0.01661	-0.0096
Rate on 10-Year Treasury Bonds	0.026	0.007
Rate of Tax on Labour Income	-0.101	0.068
Exchange Rate (Trade Weighted Index)	0.022	0.006
Private Wealth	0.044	-0.026
Exports of Goods and Services	-0.041	0.015
Private Sector $A Debt	-1.135	0.581

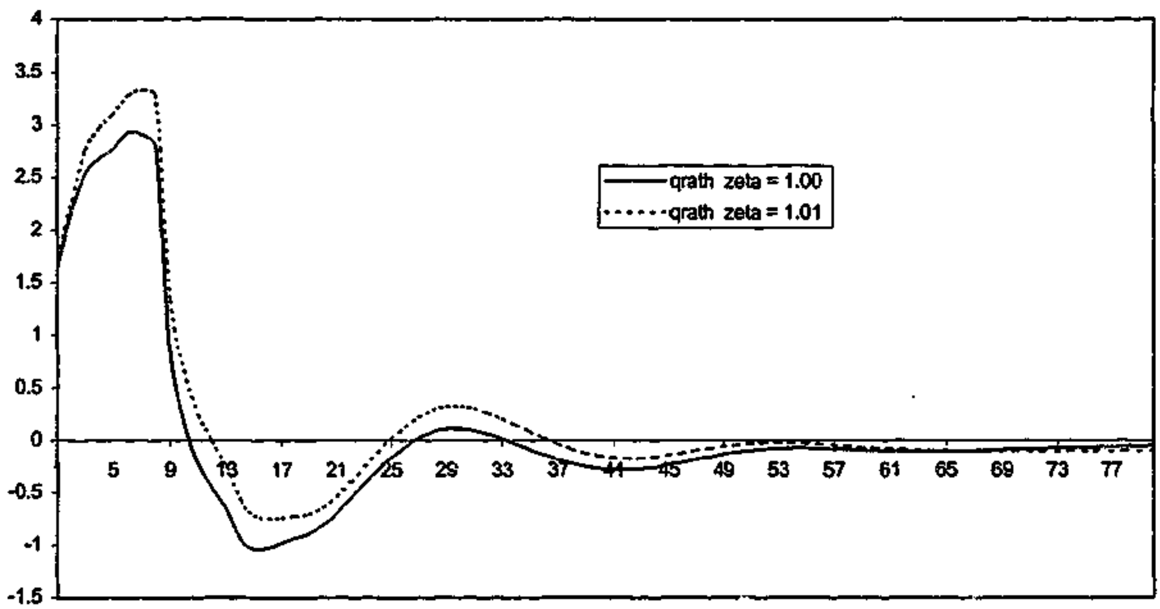
* Percentage deviations from control except for 90-Day Bills and 10-Year Treasury Bonds which are measured in percentage points from control

To the extent that the latter problem can be ignored, the long run outcome for all these variables is a consequence of the two factors outlined in the previous section. The change in ownership of Government bonds causes private wealth to fall and for there to be a switch in production from consumption to exports. The fact that consumers do not need to intertemporally optimise their savings (or consumption) habits leads to the change in real GNE, prices and interest rates. With the exchange rate jumping in the opposite direction when anchored traders are present, the reaction of households is different as they balance their budget quarter by quarter. There is still no relationship linking the effects a change in debt levels will have on the savings patterns of households.

The Q-ratio for the dwelling sector (figure 8.6.15) behaves marginally worse in the anchored trade simulation. This flows through to the nominal wealth variable that values stock at current prices via the Q-ratio. The final deviation from control value for the dwelling sector Q-ratio is –0.10 in the anchored trader scenario (zeta = 1.01) compared to –0.05 in the base case.

Figure 8.6.15

The path of the dwelling sector Q-ratio after a temporary fiscal contraction for the paths of the base scenario and the anchored trader scenario



The above results illustrate the importance of the formulation of the exchange rate in TRYM. By creating some inertia in the reaction of exchange rate traders, there are lasting and important effects incumbent upon the model. Which way the exchange rate jumps immediately after a fiscal contraction (or expansion) will affect the long run (and short run) outcomes for all variables. The long run effects, although small, are predominantly of opposite sign for the two scenarios[22]. For example, short term interest rates fall when anchored traders are present, whereas these rates rise in the case of the base scenario. Another significant result in terms of policy is the rate of tax on labour income. In the base case the rate of tax permanently fell, but in the anchored trader scenario, the rate of tax on labour income actually rose in the long run.

So far in this chapter the focus has been on the simulation properties of TRYM with and without modifications to the exchange rate. The emphasis has been primarily theoretical. We now turn our attention away from simulation properties to the issue of data admissibility: does TRYM track observed history more accurately with or without the Gruen and Gizycki inspired modifications to exchange rate behaviour?

A logical first step in attempting to answer this question is to find out how TRYM (without modifications) tracks the historical record. We can then modify the model and determine whether this enhances or causes a deterioration in the model's tracking of key variables.

8.7 Historical Validation of TRYM

By assuming that all future values for the exogenous variables are known (that is, the modeller had perfect foresight for the exogenous variables) TRYM produces results for the endogenous variables. This is known here as the historical validation of the model, as we are able to see how accurate the model is in replicating history, when it is given the values for all forward exogenous variables.

We are again using the model described in section 8.2. However instead of an 80 period model, we are using a 25 period model.[23] The data

[22] This analysis assumes that the results are statistically significant and that numerical inaccuracy does not affect the general flavour of the analysis.
[23] A 25 period model of TRYM93 was used because it proved impossible to force all the error terms to zero in the 80 period model. The large disequilibrium seems to be caused by the debt sector block. An attempt is currently in progress to force the errors to zero in the longer period model.

period runs from September 89 to September 95 giving us 25 quarters of data. The model was solved in several steps. First a static one-period equilibrium model was produced that displayed the long-run properties that are inherent in neoclassical, balanced growth models. All the growth variables grow at rates that are a combination of 4 parameters – the labour-augmenting (Harrod neutral) rate of technical progress, the foreign rate of inflation, the long-run rate of growth of the money supply and the long-run rate of growth of the population and the workforce. The long-run steady state provides the underpinning of the model and prevents variables from displaying implausible long-run behaviour.

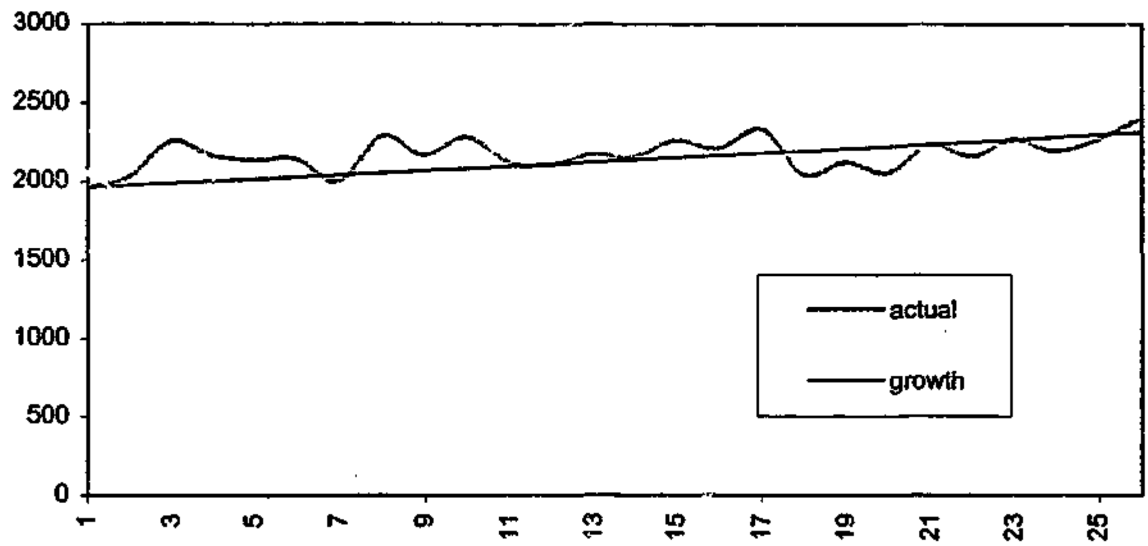
The underlying long run equilibrium (or steady state version) of TRYM93 can be thought of as a single period model, constructed by replacing each lag (lead) variable in the dynamic model with a time-independent variable divided (multiplied) by an appropriate growth factor. The solution of the steady state submodel after a shock to the exogenous variables represents a full restoration of equilibrium. The solution to the steady state has identical properties to the solution of the full model once the dynamic equations of the full model have converged to balanced growth thus eliminating all disequilibrium. The steady state submodel is the comparative static version of TRYM93 and can be used as an attractor for the dynamic model. This approach is used extensively in the specification of behavioural equations in TRYM93 via the incorporation of error correction mechanisms using the general to specific approach of David Hendry[24].

This equilibrium model has been given the exogenous values as at September 1989. Once an equilibrium model is established we can create a dynamic model by growing the variables both forwards and backwards according to their assigned growth factor. This gives a growth path solution for the dynamic 25 period model. This is the model we would normally use for policy analysis, as we are interested in deviations from a base level and there is the implicit assumption that the deviation is not path dependent.

[24] See Hendry and Richard (1983).

We now need to give the exogenous variables their actual values rather than their growth values. In figure 8.7.1 the path for IGG (government investment) is shown for both the growth path and the actual path over the period 1989q3 – 1995q3. Using the method explained in the last paragraph, we have a solution that follows the smooth growth path. Next we replace the growth path values of endogenous variables with their actual values to give a new solution that encompasses the actual data for the exogenous variables over the period 1989q3 – 1995q3. All predetermined values for variables are also replaced in the closure. In the growth path solution, as noted above, variables are grown backwards as well as forwards – for example, the values for the variable NAP (adult population) are defined for periods –10 to 25; hence the 10 predetermined values will also enter the historical evaluation rather than the growth values.

Figure 8.7.1
Comparison of actual data and smooth growth path data for IGG (government investment) for 1989Q3 through 1995Q3



To ensure that the model has as much information as possible to facilitate the historical closure, the residual terms in the estimated equations are swapped with the "naturally" endogenous variables (i.e. CON is swapped for u_con in the consumption function). Thus the residual terms become endogenous and the actual values for the swapped exogenous variables can be utilised in equations containing the actual values of the relevant endogenous variables. Once this is successful the residuals are again made exogenous, releasing the endogenous variables for determination by the model. The residuals are shocked to equal zero so that all of the models' equations are satisfied exactly. This forces the discrepancies that resided in the error terms to be distributed across the endogenous variables in the model. This solution gives us the required outcome, namely time paths for all of the endogenous variables that are consistent both with the model and with historically observed data on exogenous variables and on initial conditions. This enables us to ascertain the accuracy of the model over the 1989q3 – 1995q3 time period.[25, 26]

Results for Historical Model

Figures 8.7.2 – 8.7.5 illustrate the paths of the actual data and the historical simulation data for a selection of key variables. The results are somewhat disappointing as can be seen in all the figures below. For example, simulated consumption (figure 8.7.2) falls below actual consumption at the start of the simulation diverging by up to 12% (57,160 – actual, 50,869 – simulation). The historical simulation implies a decrease in real consumption for 10 consecutive quarters during almost all of which actual consumption was increasing – an entirely inadequate performance for the model. Such poor performance is reflected in other variables to a similar degree as consumption. With consumption so poorly replicated it is not surprising that the results for GNE are poor as well (figure 8.7.3). Here there is an immediate divergence of the actual and simulated data of approximately 3.7% with the two series slowly diverging until they are over 12% apart. The GNE simulation suggests negative growth for 12 consecutive periods (a depression!). Business investment performs relatively better

[25] The parameters used for the 25 period model are those used for the 80 period model. The parameters were re-estimated for the 25 period model but these supplied nonsensical results in certain cases due to the short time period.
[26] A list of the closures is given in Appendix B.

Figure 8.7.2
Real Consumption

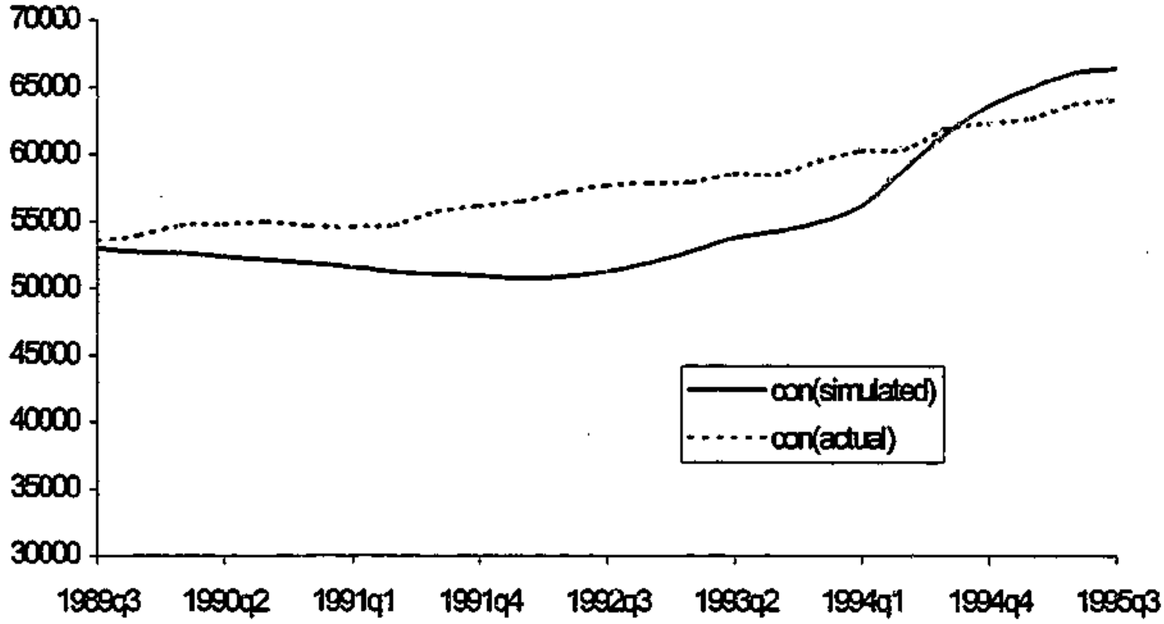


Figure 8.7.3
Gross National Expenditure

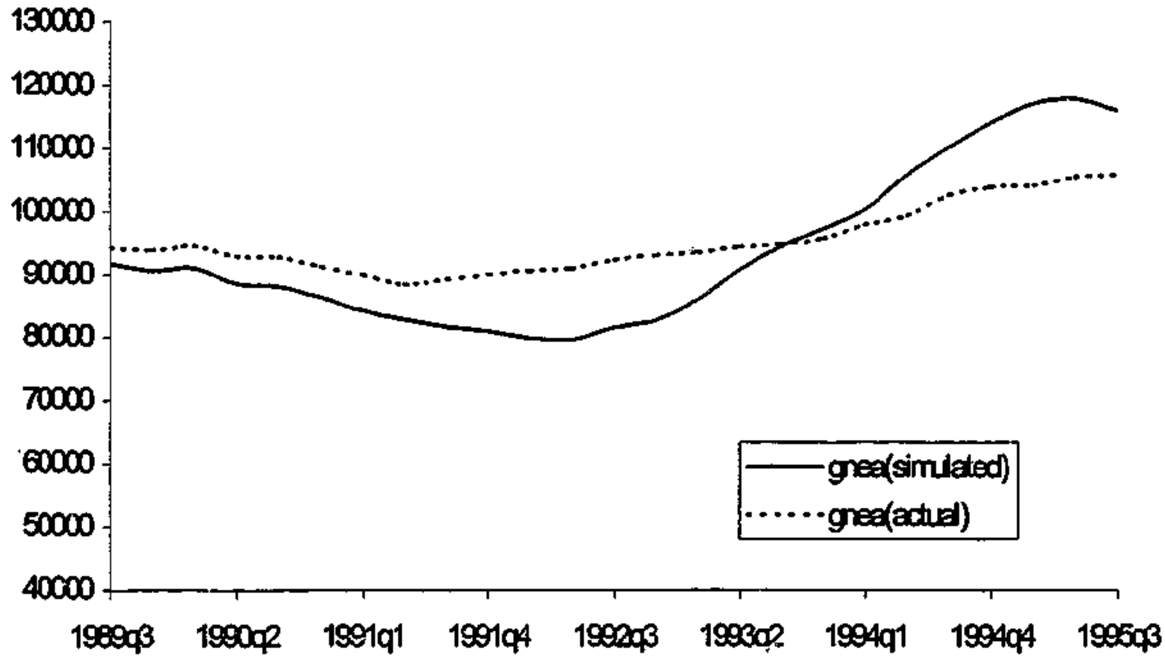


Figure 8.7.4
Business Investment

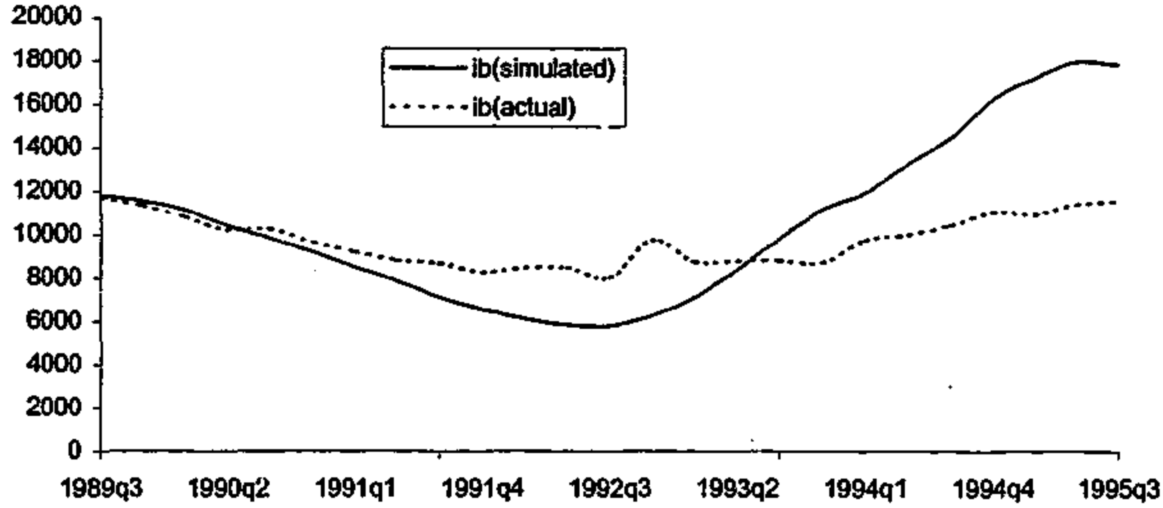
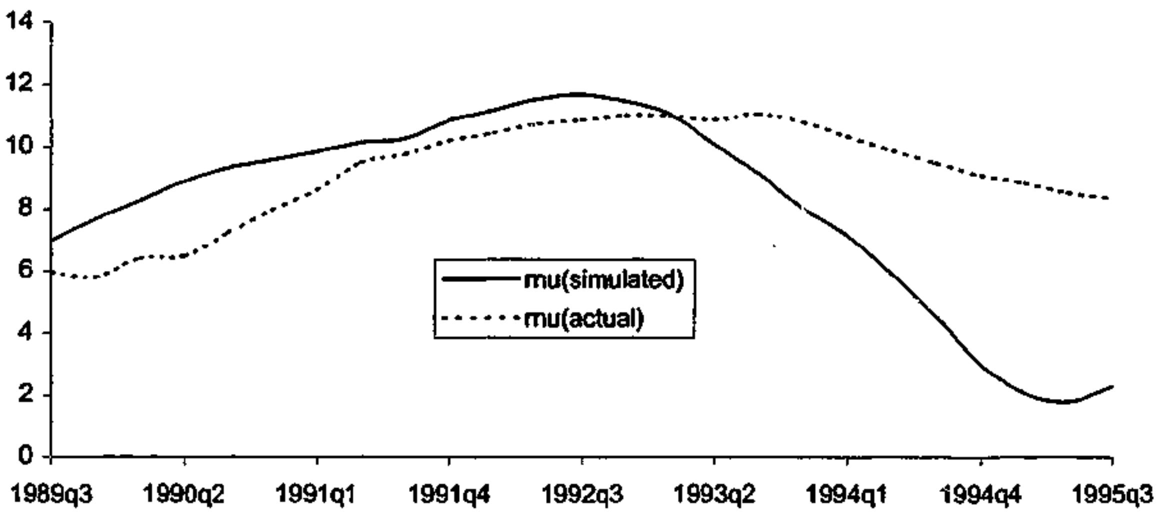


Figure 8.7.5
Unemployment



(figure 8.7.4) especially in the early quarters. Following the results for GNE and consumption, it is not surprising that unemployment in the simulation (figure 8.7.5) is above the actual unemployment in the early period of the simulation.

Within the financial block, the results are illustrated in figures 8.7.6 – 8.7.9. Figure 8.7.6 demonstrates the path of RGL (Rate on 10 Year Treasury Bonds). In the historical simulation there is a small jump at the start of the simulation and there remains a divergence throughout the 25 periods with the simulated rate on the bonds constantly below the actual rate. Figure 8.7.7 illustrates the paths of the actual and simulated rates for 90 day bills. This correlation is very poor and an explanation will be proffered later in this section.

Figures 8.7.8 and 8.7.9 illustrate the two variables RTWI (the nominal exchange rate) and INFE (inflationary expectations) respectively. These two variables are formed via identities using expectations variables related by an identity.

$$INFE[s] = \exp(\ln(PGNEAX[s+40]/PGNEA[s])/10)*100 - 100 \qquad (8.7.1)$$

$$RTWI[s] = RTWIX[s+40]*\exp(10*\ln((1+RGL[s]/100)/(1+WRGL[s]/100))) \qquad (8.7.2)$$

In equation 8.7.2 the nominal exchange rate is dependent on the equilibrium exchange rate (RTWIX) and the domestic and major trading partners' long term interest rates (RGL & WRGL). This is a formulation of uncovered interest parity (UIP) that is discussed in section 8.6. Thus the identity relates the deviation of the exchange rate from its long run equilibrium to the difference in the two respective long bond rates.

This formulation is in keeping with the Treasury's modellers' attempt to imbue some forward looking behaviour on market participants. Agents understand the steady state equilibrium and assume that this equilibrium will be attained within 10 years, but agents can make systematic errors in the short run. The equilibrium may fail to reach its steady state target within ten years.

Inflationary expectations are formed by agents again looking 10 years forward to the equilibrium price level (PGNEAX), comparing this value with the current level of prices (PGNEA)[27] and evaluating an average rate of inflation over the 40 periods.

8.7.6
Rate on 10 Year Treasury Bonds

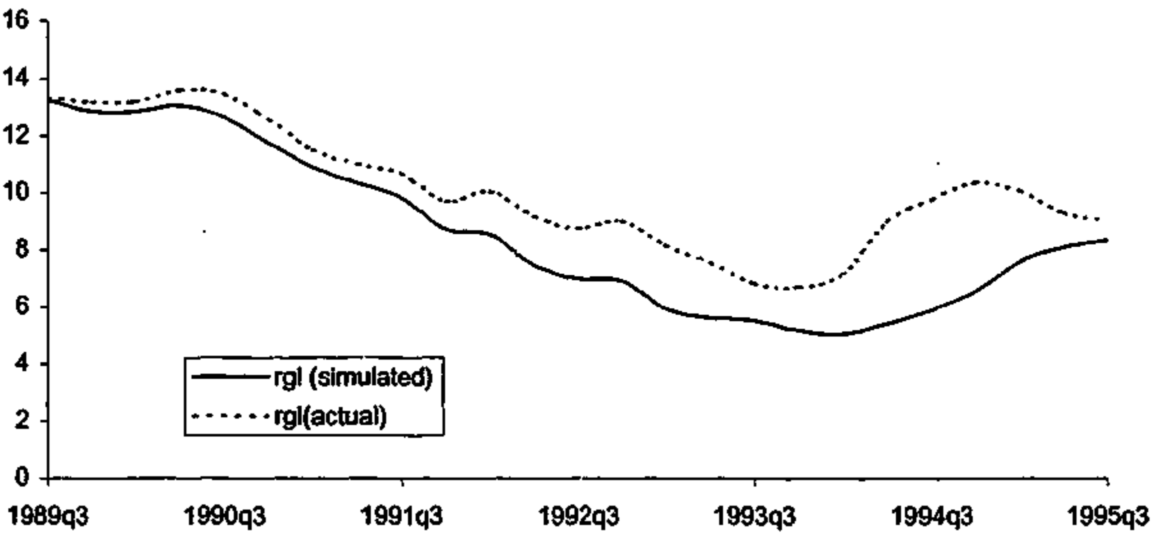
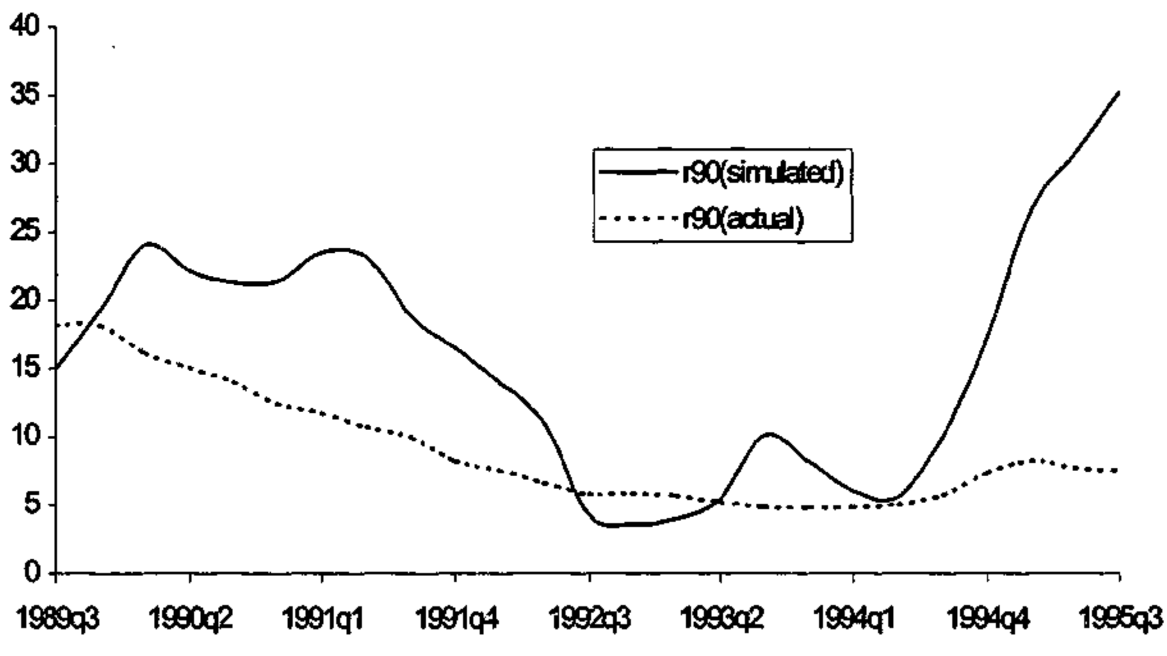


Figure 8.7.7
Rate on 90 Day Bills



[27] In TRYM, PGNEA = GNEAZ/GNEA where GNEAZ is nominal GNE and GNEA is real GNE

Figure 8.7.8
Exchange rate

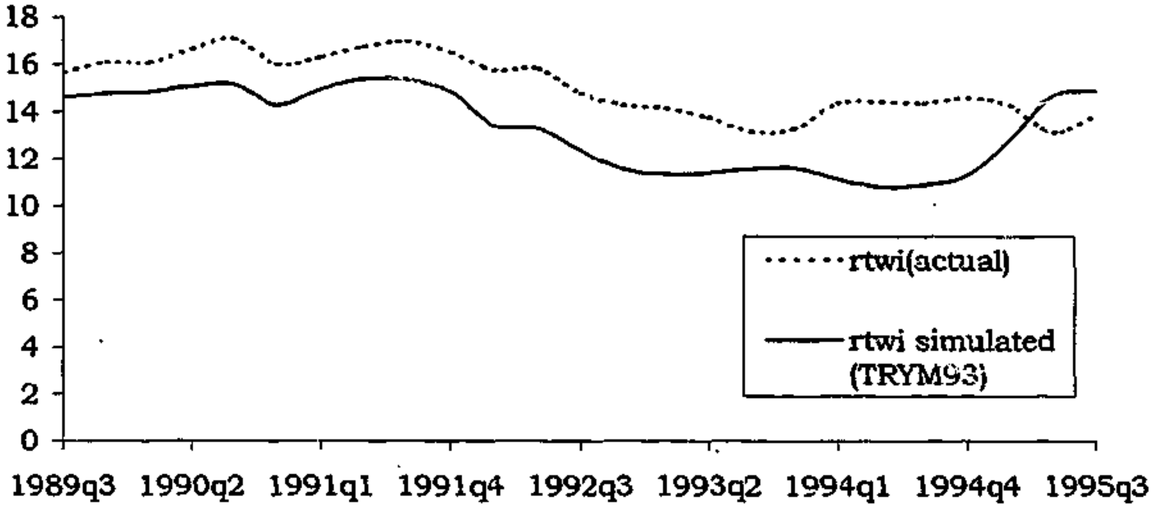
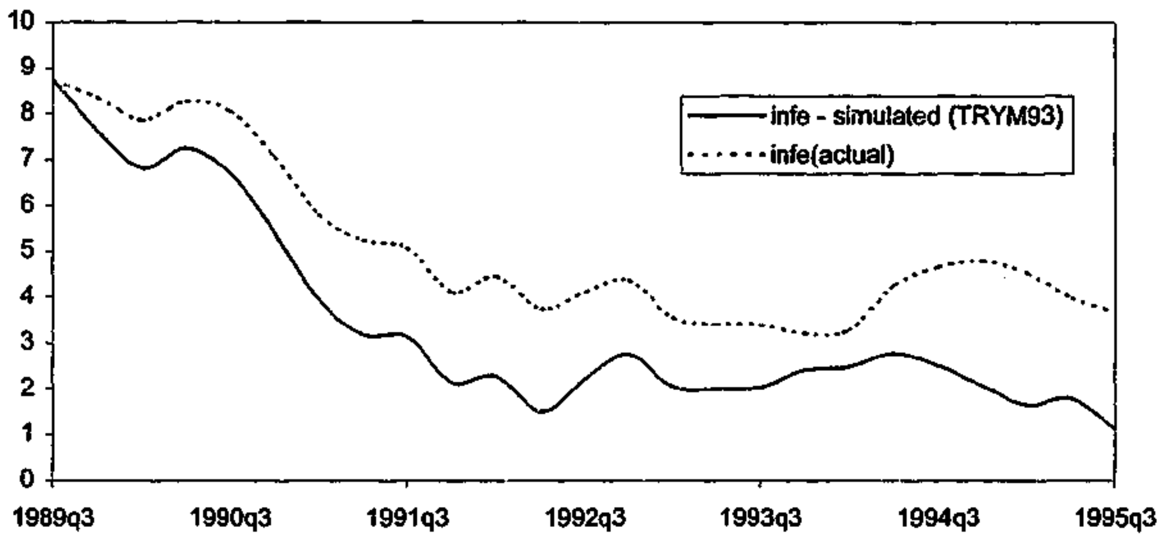


Figure 8.7.9
Inflationary Expectations



From figures 8.7.8 and 8.7.9, there is a problem in that the simulated variables for RTWI and INFE are permanently below their actual counterparts. For RTWI there appears to be a relatively constant difference between the two series implying that the identity is misspecified. In the 1995 version of TRYM the Treasury's modelling section have added a variable to the exchange rate equation (8.7.2), namely RIP (Differential between Australian 10 year bonds and world 10 year bonds). This has been interpreted in TRYM95[28] as the "persistent differential between the model's measure of domestic and world interest rates". They are keen to note that this differential should not be interpreted as a permanent risk premium and point to measurement problems in determining world bond rates and inflationary expectations. The differential in the 95 model has been set at 2 percentage points per annum.

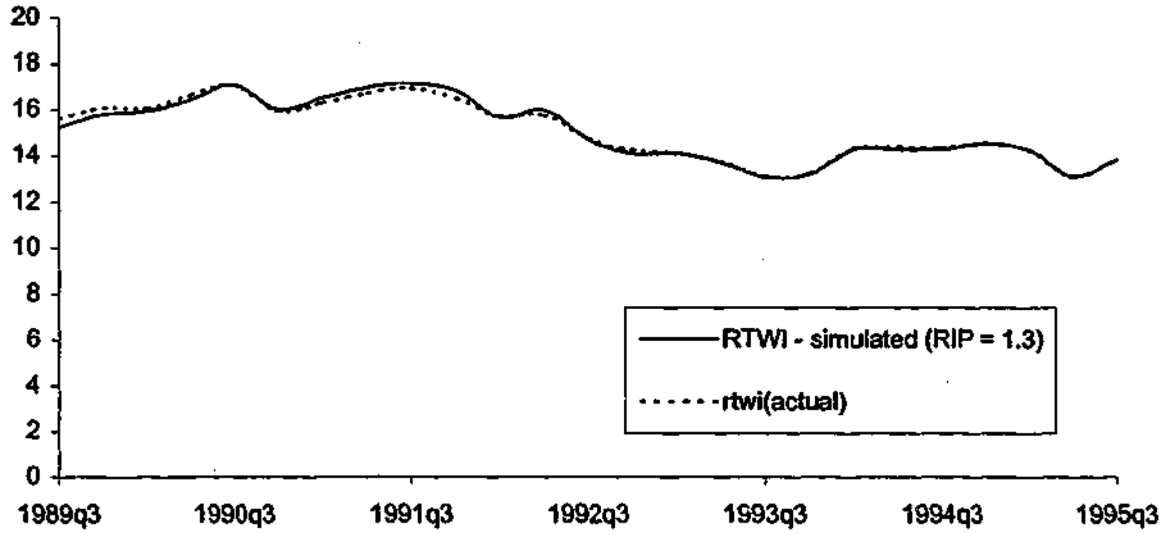
I have reworked equation 8.7.2 to reflect the exchange rate equation in TRYM95:

$$RTWI[s] = RTWIX[s+40]*\exp(10*\ln((1+RGL[s]/100)/(1+(WRGL[s]+RIP)/100))) \quad (8.7.3)$$

The only difference is the addition of the term RIP, which has the effect of raising the world bond rate by a constant. As my data set encompasses a different period, I have set the value of RIP to minimise the sum of squares between the actual path and the simulated path resulting in a value of RIP of $1.3\dot{3}$. This gives the path of RTWI (the exchange rate) illustrated in figure 8.7.10.

[28] See section 6.2.6 in the Documentation of the Treasury Macroeconometric (TRYM) Model of the Australian Economy (1996).

Figure 8.7.10
Exchange Rate (RTWI) including RIP variable



As is evident, the fit between the actual RTWI and the simulated RTWI is considerably improved. This provides a reasonable basis to conduct analysis relating to the Gruen and Gizycki framework.

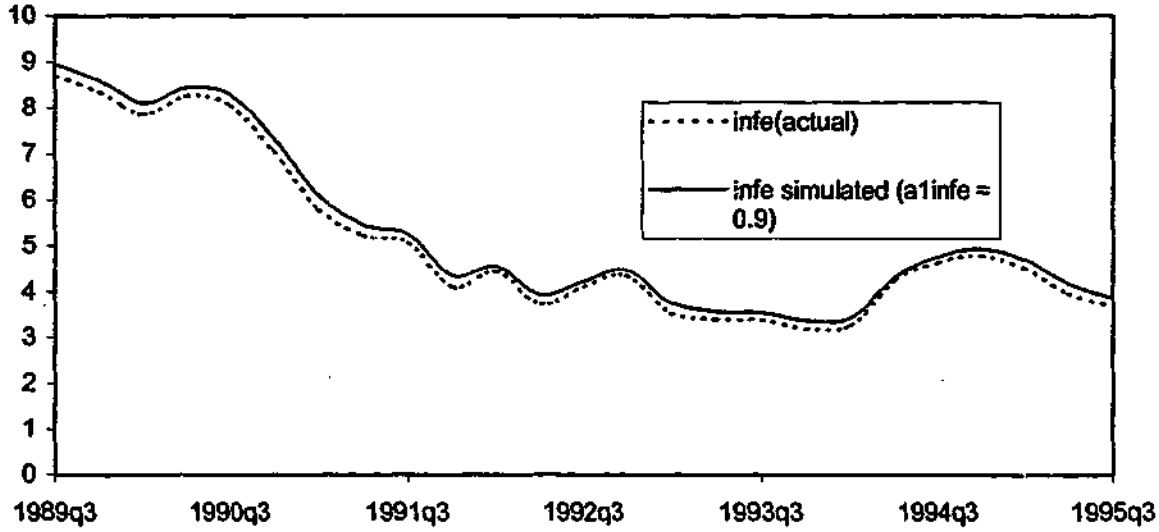
In line with TRYM95, inflationary expectations have been reformulated. In contrast to RTWI, a new partial adjustment equation is introduced of the form:

INFEX[s] = exp(ln(PGNEAX[s+40]/PGNEA[s])/10)*100 – 100 (8.7.5)

INFE[s] = (1-a1INFE)*INFE[s-1] + a1INFE*INFEX[s] (8.7.6)

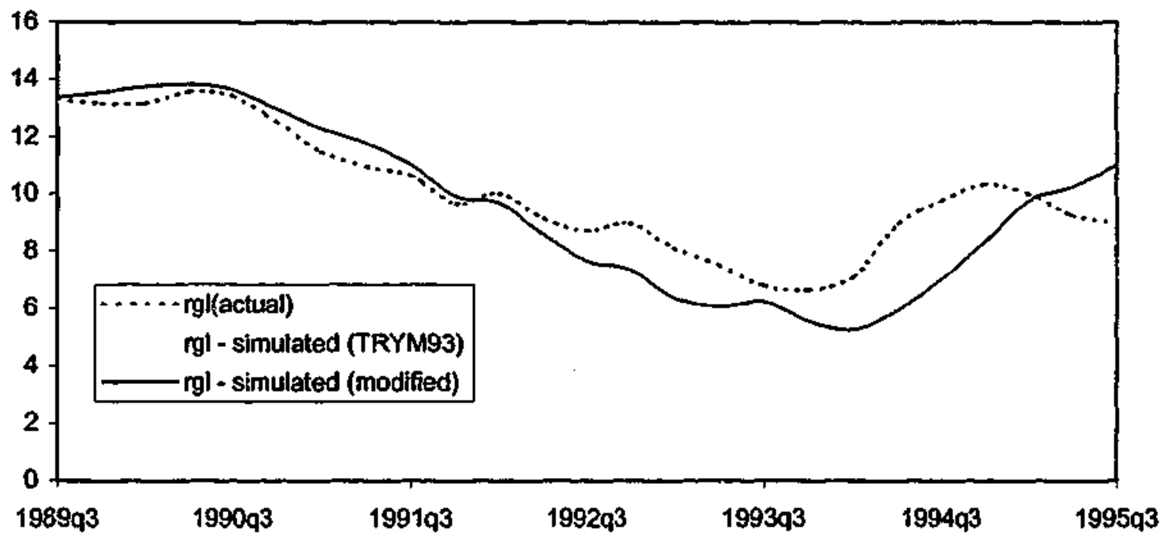
Now INFE (long run inflationary expectations) is determined through a two step procedure that first involves evaluating INFEX (full information inflationary expectations) and then using the partial adjustment mechanism (eq. 8.7.6) to evaluate INFE. In concordance with TRYM95, I have set a1infe at 0.9. This gives the result illustrated in figure 8.7.11.

Figure 8.7.11
INFE (inflationary expectations) including partial adjustment mechanism



Clearly the fit between the actual INFE and the simulated is much greater after the alteration to the two expectation equations. This has flow-on effects to other variables within the model. The variable directly affected is the long bond rate (RGL). The resulting fit is improved although not spectacularly so.

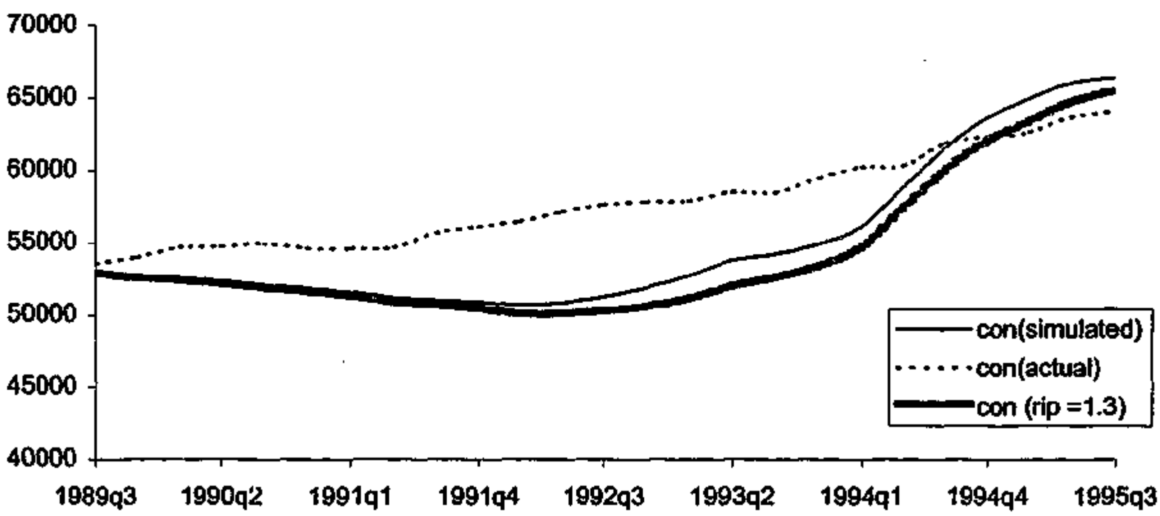
Figure 8.7.12
RGL after modifications to the two expectation equations.



The dotted line in figure 8.7.12 is the actual value for RGL over the period 1989Q3 – 1995Q3. The shaded line is the path for RGL in the original TRYM93 formulation. The solid line is the path of RGL after the modifications are made to the two expectation equations. The effects on the real side of the economy are less impressive than the effects these adjustments have on the financial sector variables.

For example, the path of CON (real private consumption) as illustrated in figure 8.7.13 is worse than with the original configuration of the exchange rate identity. This is generally true for all the variables. This implies that the model requires reparameterisising but as has been stated before, due to the combined problems with the 25- and 80-period models[29], this has not yet been possible.

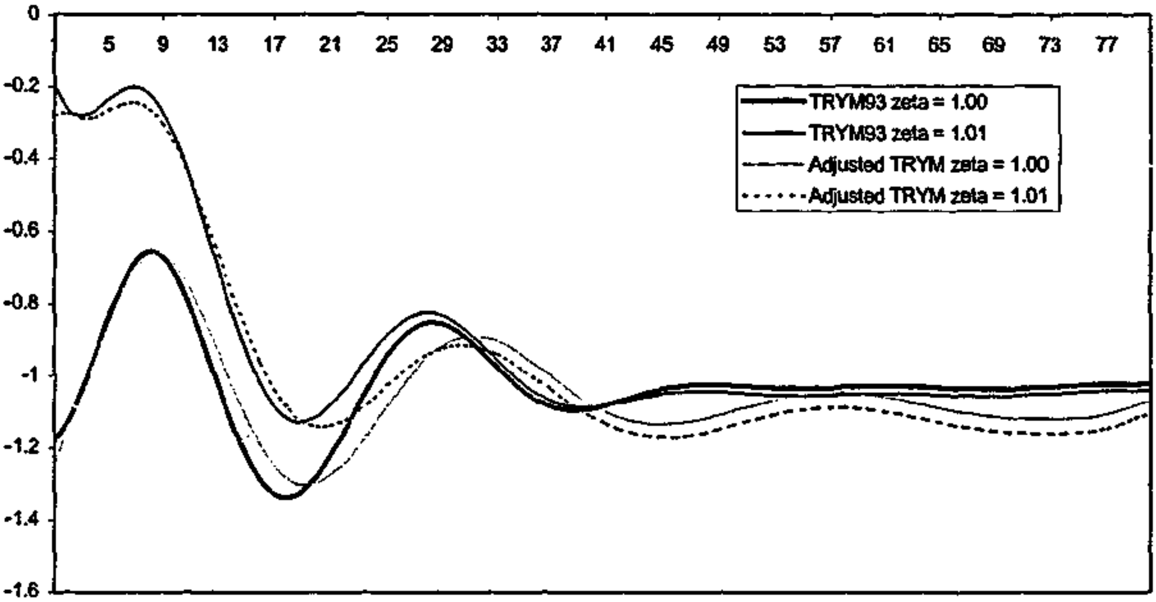
Figure 8.7.13
CON after modifications of the two expectation equations.



[29] As stated before, I have used the 80-period parameters for the 25-period model, which explains the poor performance of the endogenous variables. I have yet been unable to create an historical version of the 80-period model to which the parameters apply. Conversely, I have not been able to obtain a sensible set of parameters for the 25-period model. To make sense of the endogenous variables, either of these problems needs to be solved. However for the purpose required in this thesis, the modified formulation of the exchange rate identity is sufficient.

With the modification of the two expectation equations (eq. 8.7.3, 8.7.5 and 8.7.6), the behaviour of the exchange rate in response to a monetary shock will be slightly different. The original path for varying zetas is illustrated in figure 8.3.2. In figure 8.7.14 the same exercise is performed with the modified expectations equations. Figure 8 7.14 encompasses the two simulations in figure 8.3.2 that relate to the original TRYM93 specification when zeta is equal to 1.00 and 1.01. As well figure 8.7.14 has

Figure 8.7.14
The paths of the exchange rate in response to a 1% monetary shock for standard TRYM and the adjusted TRYM when zeta = 1.00 and zeta =1.01



paths for the exchange rate for the adjusted exchange rate identity and the adjusted inflationary expectations equations when the model is subjected to a 1% monetary shock. The adjustments to the equations involved adding a constant of 1.33 percentage points per annum premium to the uncovered interest parity relationship. The adjustment to the inflationary expectations equation involved the creation of a new partial adjustment mechanism (eq. 8.7.6), where the adjustment parameter has been set at 0.9 in line with TRYM95.

The path of the exchange rate in figure 8.7.14 is not significantly affected by the reformulation of the above two equations for either the base case (zeta =1.00) or for the anchored trader case (zeta = 1.01). When zeta = 1.00 the exchange rate jumps slightly further when using the adjusted TRYM formulation but quickly rejoins the path of the original exchange rate until period 5 whereupon the two exchange rate paths diverge. The main difference is that in the long run the TRYM93 configuration has essentially gained the long run equilibrium. In the adjusted formulation the exchange rate is still cyclical and has not found equilibrium. The same differences are evident when zeta = 1.01. The exchange rate jumps further in the adjusted form of TRYM93 and the exchange rate struggles to gain the long run equilibrium.

Comparison of Historical Exchange Rate Formulations

In figure 8.7.14 the path of the exchange rate is shown under the optimised value for RIP[30]. The question is whether having anchored traders will improve the relationship between simulated exchange rate and the actual exchange rate. To answer this, the simulations have been rerun with anchored traders represented by setting zeta to 1.01. The result is shown in figure 8.7.15. for the 25 periods of the model.

In figure 8.7.15 the historical simulation including anchored traders tracks the actual path of the exchange rate closer than the original formulation of the exchange rate. The effect of the anchored traders is small and is better illustrated in figure 8.7.16 which shows the first 4 periods of the simulation where most of the anchored traders effects are evident.

[30] RIP was chosen to minimise the sum of squares between the actual exchange rate and the model's historical simulation of the exchange rate.

Figure 8.7.15
The paths of the exchange rate for the 25 periods of the historical simulation when zeta = 1.00 and when zeta = 1.01 as compared to the actual exchange rate.

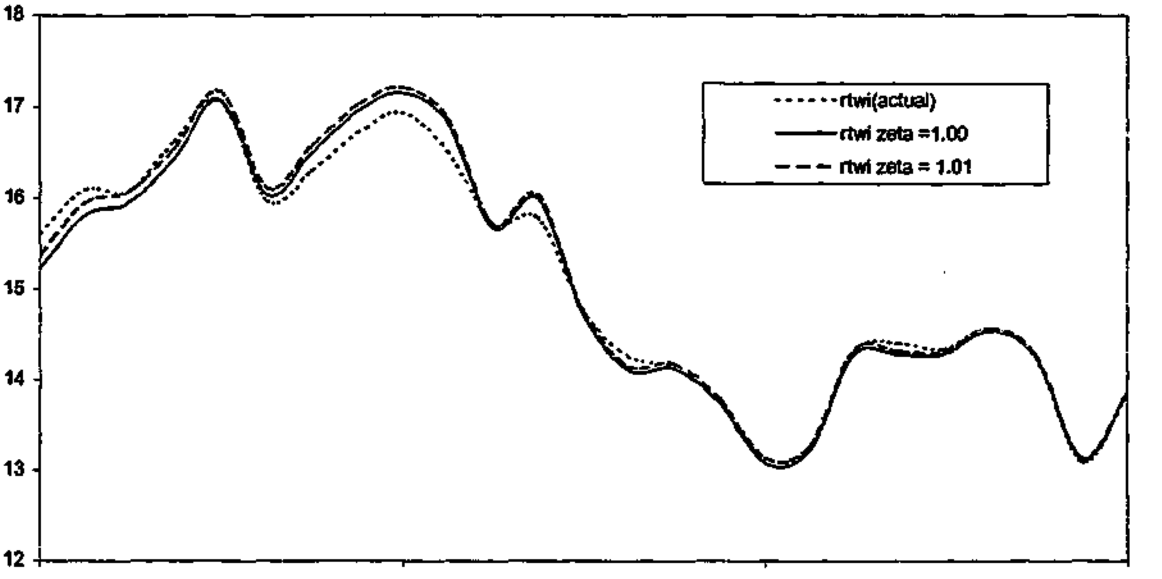


Figure 8.7.16
The paths of the exchange rate in the first 4 periods in the historical simulation for zeta = 1.00 and zeta = 1.01 and for the actual exchange rate.

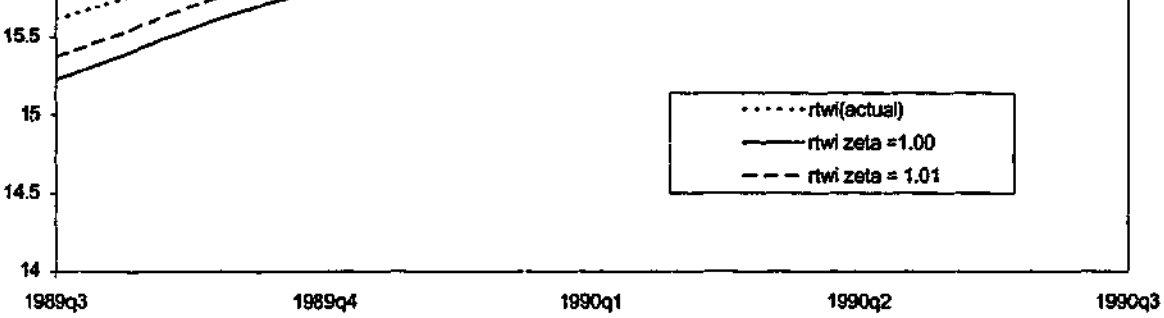


Table 8.7.1 shows the root mean square error between the actual path of the exchange rate and the two simulated paths of the exchange rate that relate to when zeta equals 1.00 and when zeta equals 1.01.

Table 8.7.1

The root mean square error (RMSE) between the actual value of the nominal exchange rate (RTWI) over the period 1989q3 – 1995q3 and the simulated values of the exchange rate using the adjusted formulation of TRYM when zeta takes the value 1.00 (base case) and 1.01 (anchored traders)

	RMSE
Adjusted TRYM – zeta = 1.00	0.793512
Adjusted TRYM – zeta = 1.01	0.767658

The RMSE for the exchange rate in the historical simulation using the adjusted equations for the exchange rate and inflationary expectations results in a figure of 0.793512. This compares to a marginally lower number of 0.767658 for the scenario where there are anchored traders are present. This means that the simulated exchange rate has better replicated history when anchored traders are present.

Chapter 9

Conclusion

At the start of this thesis, I started with two propositions. The first was posed by Gruen and Gizycki who included a behavioural heuristic, anchoring, within a rigorous model to help explain the sometimes enigmatic behaviour of the exchange rate. The second proposition was that this unconventional behaviour of the exchange rate would result in both monetary and fiscal policy having major unorthodox consequences for the economy. These real effects occur in both the short term and in the longer run.

These effects on the economy were illustrated by Monash model simulations in the paper by Dixon et al. (1996). There in response to a fiscal contraction the exchange rate was assumed to jump in the opposite direction to that predicted by conventional economic theory due to what was termed "market euphoria".

The above propositions were studied initially by developing suitable miniature models. Then exchange rate behaviour redolent of that proposed by Gruen and Gizycki was imbedded in a large macroeconometric model, TRYM, on which simulations were performed to see whether anchoring type behaviour could cause the type of "market euphoria" represented in Dixon et al.

The series of miniature models that were developed, starting with the purely anchored model of Gruen and Gizycki, provided useful information about the possible behaviour of the exchange rate. In chapter 5, the Anchored miniature model was solved numerically. By combining this model with the numerically solved Extended Dornbusch model, a numerical algorithm was developed that was calibrated to the original closed form model of Gruen and Gizycki. This enabled the development of a model that was numerically solved and which allowed for any proportion of anchored traders. The simulation properties of the Anchored model were illustrated, providing a stark contrast to the rational expectations driven Dornbusch model.

By varying the proportion of anchored traders, the response of the exchange rate to a monetary shock was able to range from the one extreme where all traders were anchored and there was no initial jump, to the other extreme where the exchange rate emulated the overshooting response of the Dornbusch model. All points in between these extremes is possible for the exchange rate (after a monetary shock), including an immediate jump to the long-run equilibrium, depending on the proportion and characteristics of the anchored traders. Thus in this synthetic model a monetary shock could result in: (a) overshooting à la Dornbusch; (b) undershooting; or (c) no instantaneous jump whatsoever. Which particular outcome occurs depends on the prevalence of anchored traders.

The synthesis was been extended in chapter 6 to include the real exchange rate – missing in Gruen and Gizycki – in the domestic demand function. Following the process used in chapter 5, the Anchored model was extended to establish the Anchored-RER miniature model. This was again numerically solved and combined with the Extended Dornbusch model giving us the Extended G&G (EGG) model. This model possesses exchange rate behaviour qualitatively similar to the closed form model of Gruen and Gizycki. The EGG model has less tendency to overshoot the new equilibrium and converges faster than the G&G formulation.

All of the models discussed possess a form of inertia. Inertia in this sense means that the long-run equilibrium is not immediately attained unless by pure coincidence where different forms of inertia perfectly offset each other. The inertia introduced into the original Dornbusch model is the assumption that goods prices are sticky and that these prices take time to adjust to any shock to the economy. In EDBM the inertia is imposed in an ad hoc manner on the aggregate demand function to replicate the cycles that are embedded in the Murphy model. This ad-hoc structure is analogous to the inertia introduced into macroeconometric models largely through error correction mechanisms that are used to model the real side of the economy.

Anchored traders introduce a new form of inertia into the economy, entering through the financial sector rather than through the real side of the economy. Ever since the minor revolution created by rational expectations, the financial side of the economy has been modelled so as to replicate an efficient market. However empirical evidence has shown that this mathematically and intuitively appealing formulation of expectations has consistently failed. This has led economists to look elsewhere for answers to this problem – including the elegant inclusion of anchored traders by Gruen and Gizycki. In contrast to the real side inertia incumbent in the Dornbusch model and in complex macroeconometric models, under Gruen and Gizycki's formulation there is extra inertia in the financial sector. What has been discovered in chapter 7 is that inertia entering through the financial sector can have the same qualitative effects on the economy as inertia (such as sticky prices) entering through the real side of the economy.

Unfortunately, I was unable to incorporate the miniature models directly into TRYM, but they have provided interesting conclusions in themselves. To replicate the behaviour of anchored traders in TRYM, a scaling factor – itself a function of the time elapsed since the shock impinged on the economy – was applied directly to the exchange rate. By varying the parameter of this scaling function it is possible to generate either the original behaviour of the exchange rate in TRYM, or to modify this path to emulate the effects predicted by the presence of Anchored traders in the foreign exchange market. The main pass through from the financial to the real sector was via the trade sector of the model. As trade is a comparatively small component of total output, the effects on gross national expenditure are not large. Nevertheless there is a distinct effect, especially on the GNE deflator, due to the differing effects of the alternative paths of the exchange rate on the price of imports.

To facilitate a comparison with the Dixon et al. experiment, a temporary fiscal contraction of 5% was implemented in TRYM. We find that the exchange rate jump can be reversed depending on the value ascribed to the parameter governing the scaling factor (zeta). This suggests that in response to a fiscal shock, the presence of anchored traders in the market can explain the "market euphoria" referred to in Dixon et al. That is, it was not necessarily market euphoria driving the seemingly "incorrect" jump in the exchange rate, but rather this jump could have been generated by the presence of a substantial number of foreign exchange traders who anchor their expectations to the forward exchange rate.

Finally, performing an historical validation of TRYM provided a framework where the modified exchange rate formulation could be tested to see whether it improved the modelling of the exchange rate. It was shown that it was possible to improve the fit of the exchange rate using the scaling factor, suggesting that a foreign exchange market is better modelled when the presence of anchored traders is taken into account.

Two important conclusions can be reached from this work. The first is that inertia in the financial sector can play the same role as does inertia that is embedded in the real sector. The second conclusion is that anchoring of expectations of foreign exchange traders is able to explain an anomalous direction for the jump in the exchange rate in response to a fiscal shock.

In a similar vein to the work of Frankel and Froot on chartists and fundamentalists[1], the proportion and characteristics of anchored traders in the foreign exchange market can be variable. Frankel and Froot postulate that the volatility in the exchange rate is due, in part, to the switch between the way traders formulate their expectations for the exchange rate (that is whether they use fundamental or chartist techniques). This concept also applies to anchored and rational traders.

It is possible to endogenously determine a long run equilibrium proportion of anchored traders[2]; however any short term modelling of the exchange rate would be subject to many unpredictable fluctuations. Further complicating any short term modelling is that actual characteristics of

[1] Frankel and Froot (1990).

[2] Gruen and Gizycki (1993) pp.21-23.

foreign exchange traders are largely unknown. Detailed information on the behavioural charateristics of traders is required. This may well be the direction that future research is headed as more researchers become concerned with the individual behaviour and characteristics of traders.

Appendix A

Derivation of the jump in the exchange rate for the numerical algorithm.

We have the solution for the exchange rate, equation 3.b.46:

$$\Delta s_{t+1} = \eta fd_t + (1 + \frac{\theta\eta}{\lambda})v_{t+1} + e_{t+1} \qquad \text{A.1}$$

= 0.5 when $\beta = 1/\theta$ and $\alpha = 0.5$;

= 0.1 when $\beta = 9/\theta$ and $\alpha = 0.5$.

This leads to:

$$\beta = \frac{x}{\theta}, \qquad \text{A.2}$$

where $x = \frac{1}{\kappa} - 1$, hence $\frac{1}{1+x} = \kappa$, where κ is the proportion of the rational jump when $\alpha = 0.5$.

By substituting in the expression for η, equation 3.b.42

$$\eta = 1 - \frac{\alpha\beta(\lambda+\theta)}{1+\alpha(\beta\theta-1)}, \qquad \text{A.3}$$

into A.1, as well as substituting in A.2 for β into A.1, we get:

$$\text{Jump} = 1 + \frac{\theta}{\lambda}\left\{1 - \frac{\alpha\frac{x}{\theta}(\lambda+\theta)}{1+\alpha(x-1)}\right\}. \qquad \text{A.4}$$

This derivation is predicated on the assumption that at time t, we are in long run equilibrium, hence $fd_t = 0$ and the exchange rate is normalised at $s_t = 0$.

By multiplying the brackets through by $\frac{\theta}{\lambda}$ we get:

$$\text{Jump} = 1 + \frac{\theta}{\lambda} - \frac{\alpha x(1+\frac{\theta}{\lambda})}{1+\alpha(x-1)}. \qquad \text{A.5}$$

Multiply RHS by $\frac{\lambda}{\lambda}$ and create a common denominator leads to:

$$\text{Jump} = \frac{\lambda(1+\alpha(x-1))+\theta(1+\alpha(x-1))-\lambda\alpha x(1+\frac{\theta}{\lambda})}{\lambda(1+\alpha(x-1))}, \qquad \text{A.6}$$

$$\Rightarrow \qquad = \frac{\alpha\lambda+\alpha\lambda(x-1)+\theta+\theta\alpha(x-1)-\lambda\alpha x-\alpha x\theta}{\lambda(1+\alpha(x-1))},$$

$$\Rightarrow \qquad = \frac{\alpha(x-1)(\lambda+\theta)+(\lambda+\theta)-\lambda\alpha x-\alpha x\theta}{\lambda(1+\alpha(x-1))},$$

$$\Rightarrow \qquad = \frac{(\lambda+\theta)(1+\alpha(x-1))-\alpha x(\lambda+\theta)}{\lambda(1+\alpha(x-1))},$$

$$\Rightarrow \qquad = \frac{(\lambda+\theta)(1+\alpha(x-1)-\alpha x)}{\lambda(1+\alpha(x-1))},$$

$$\Rightarrow \qquad = \frac{(\lambda+\theta)}{\lambda}(1-\frac{\alpha x}{1+\alpha(x-1)}),$$

$$\Rightarrow \qquad = (1+\frac{\theta}{\lambda})(\frac{1-\alpha(x-1)-\alpha x}{1+\alpha(x-1)}),$$

$$\Rightarrow \qquad = (1+\frac{\theta}{\lambda})(\frac{1-\alpha}{1+\alpha(x-1)}). \qquad \text{A.7}$$

By rearranging A.7 we get:

$$\text{Jump} = (1+\frac{\theta}{\lambda})(\frac{\frac{1}{1+\alpha(x-1)}}{1-\alpha}),$$

$$\Rightarrow \qquad = (1+\frac{\theta}{\lambda})(\frac{1}{\frac{(1-\alpha)+\alpha x}{(1-\alpha)}})$$

$$\Rightarrow \qquad = (1+\frac{\theta}{\lambda})(\frac{1}{1+\frac{\alpha}{(1-\alpha)}x}) \qquad \text{A.8}$$

Remember that $x = \frac{1}{\kappa}-1$, hence A.8 becomes

$$\text{Jump} = (1+\frac{\theta}{\lambda})(\frac{1}{1+\frac{\alpha}{(1-\alpha)}(\frac{1}{\kappa}-1)}). \qquad \text{A.9}$$

Appendix B

The following provides details of the closure used for historical validation, compared with the default closure

Historical	Default
d80	d80
d813	d813
d841	d841
dcc	dcc
dmin	dmin
f_winf	f_winf
gmd	gmd
ige	ige
igg	igg
mpolres	mpolres
mtaz	mtaz
nap	nap
ndf	ndf
ngg	ngg
nh	nh
nhlr	nhlr
nim	nim
npop	npop
qrain	qrain
qs741	qs741
qtime	qtime

Historical	Default
qtimf	qtimf
rain	rain
rbiz	rbiz
rdkb	rdkb
rdkdw	rdkdw
rdkge	rdkge
rdkgg	rdkgg
rfi	rfi
rmarg	rmarg
rpfe	rpfe
rtcnr	rtcnr
rtcre	rtcre
rtgmd	rtgmd
rtib	rtib
rtidw	rtidw
rtmgs	rtmgs
rtprb	rtprb
rtprg	rtprg
rtxc	rtxc
rtxnc	rtxnc
shifter	shifter
wgtm	wgtm
wnpop	wnpop
wpgtm	wpgtm
wpmpe	wpmpe
wr90	wr90

Historical	Default
wrgl	wrgl
xrcre	xrcre
xrdgof	xrdgof
xrdgp	xrdgp
xrdisa	xrdisa
xrdisaz	xrdisaz
xrdogf	xrdogf
xrdpof	xrdpof
xreop	xreop
xrepo	xrepo
xrgdw	xrgdw
xrggk	xrggk
xrgrnec	xrgrnec
xriret	xriret
xritc	xritc
xrmtaz	xrmtaz
xrngg	xrngg
xrocb	xrocb
xrpgge	xrpgge
xrpggk	xrpggk
xrpksfm	xrpksfm
xrpksn	xrpksn
xrpsnn	xrpsnn
xrpxnc	xrpxnc
xrrtk	xrrtk
xrsfmz	xrsfmz

Historical	Default
xrspe	xrspe
xrubr	xrubr
xrwdgt	xrwdgt
xrwg	xrwg
xrwmz	xrwmz
xrwpxgs	xrwpxgs
xryge	xryge
xrymtcz	xrymtcz
xryotdz	xryotdz
xrytocz	xrytocz
xrytodz	xrytodz

The following endogenous variables were used as swaps for Equation Residuals to ascertain the accuracy of the estimated equations (i.e., to solve the model for the residuals).

con	u_con
gge	u_gge
ib	u_ib
idw	u_idw
ksfm	u_ksfm
ksn	u_ksn
mgs	u_mgs
nb	u_nb
nge	u_nge
nlf	u_nlf

pcnrf	u_pcnrf
pcre	u_pcre
pgmdf	u_pgmdf
pibf	u_pibf
pidwf	u_pidwf
piretf	u_piretf
pmgs	u_pmgs
pnc	u_pnc
pxc	u_pxc
r90	u_r90
rgl	u_rgl
rtn	u_rtn
wt	u_wt
xc	u_xc
xnc	u_xnc
bdgofz	u_bdgof
bdgpz	u_bdgp
bdogfz	u_bdogf
bdpofz	u_bdpof
beopz	u_beop
bepoz	u_bepo
wdgoaz	u_wdgoa
wdgofz	u_wdgof
wdgpz	u_wdgp
wdogfz	u_wdogf
wdpoaz	u_wdpoa
wdpofz	u_wdpof

weopz	u_weop
wepoz	u_wepo
ydgoz	u_ydgo
ydgpz	u_ydgp
ydogz	u_ydog
ydpoz	u_ydpo
yeopz	u_yeop
yepoz	u_yepo

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