

DRAFT

The New Zealand Treasury Model (NZTM)

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1. Introduction

Various economic models are used for forecasting the macro-economy at the New Zealand Treasury. One of the models is NZM98, which is a macroeconometric model of the NZ economy that was developed by Chris Murphy in 1998. NZM98 is constructed in the style of the Murphy Model of Australia, but is modified to allow for differences in institutional structures, data availability and data properties between New Zealand and Australia.

As the development of the macroeconometric model is an on-going process to incorporate latest policy changes, structural shifts in the data, and the development of economic theory and modelling, Treasury has put in major efforts over recent years in the re-development of the core macroeconometric model. As a result, the new model has been called the New Zealand Treasury Model (NZTM) to distinguish it from NZM98.²

The structure of the New Zealand Treasury Model (NZTM) differs somewhat from that of the New Zealand Model (NZM) in three major areas:

- The relative price structure;
- Equilibrium real exchange rates; and
- Demand-pull framework on inflation;

Moreover, greater emphasis has been placed on using NZTM in aiding the Treasury's macroeconomic forecasting team to make its forecast for the New Zealand economy.

One of the drawbacks of NZM98 is that the monetary policy reaction function is a contemporaneous price-level-targeting rule. Since the core theoretical structure is

¹ I wish to thank Paul Gardiner and Nathan McLellan for their contribution to the NZTM through discussions and assistance with sections of this paper.

² NZM was the original model for the New Zealand economy built by Chris Murphy in 1995. In 1998 NZM was updated to NZM98 to allow for monetary policy operation under the Monetary Conditions Index (MCI) regime.

based on price levels, it is not possible to formulate the monetary rule as an inflation-targeting rule. Under a price-level target, following a shock to the prices, the price level needs to return to the target level at some future point after the shock. Therefore, a price-level targeting rule is “tougher”³ than an inflation-targeting rule.

This can be seen when comparing the dynamic response between two targeting rules. The variability of inflation and output is greater under price-level targeting than under inflation targeting, as base level drift is not accepted in the former case⁴.

As the core structure of NZM98 is based on price levels, the steady state model of NZM98 is simulated before running the dynamic version of the model in order to provide equilibrium values for forward-looking variables. Under a price-level targeting rule, all the price levels are well anchored in the long run. In this framework, the solution of the steady-state model on nominal exchange rates provides appropriate terminal conditions for the dynamic model.

In contrast, NZTM has a relative price structure that allows the monetary policy rule to be specified as an inflation target. Unlike NZM98, NZTM does not have a fixed end point on the nominal exchange rate. Instead, the steady-state version of the model generates an equilibrium path for the real exchange rate that provides key anchors for the dynamic structure of the model.

In NZM98, the production of the domestic good is demand-determined in the short-run, with firms gradually adjusting the price of the domestic good to a medium-term target, which can be interpreted as the marginal cost of producing domestic goods. In this framework, the pass-through from the wages and import prices into domestic inflation is strong. In NZTM, the pass-through from labour market into domestic inflation has been weakened somewhat. The production block of NZTM has been econometrically estimated (Szeto 2001). Hence, the steady-state version of the model provides an estimate of long-run potential output, which in turn provides a measure of the output gap for the dynamic model. The output gap plays a major role in determining inflation in NZTM.

³ Tougher means that the central bank needs to tighten/loosen harder and longer to achieve the target after a shock.

⁴ Svensson (1999) found that if the output persistence is, at least, moderate, price-level targeting naturally results in lower high-frequency inflation and output variability.

There is no single model to meet the requirements for both policy evaluation and forecasting. For policy simulation, more emphasis would be placed on the theoretical structure of the model. For forecasting, more emphasis would be focused on how well the specification of the model represents the data. It is also essential that the forecast model is able to clarify how judgements about the key model assumptions affect the forecast.

Furthermore, there is always a trade-off between complexity and simplicity. The main role of NZTM is to help the Treasury's forecasting team to make its forecasts for the economy. With that role in mind, the theoretical structure of NZTM is designed to be parsimony without affecting the forecast performance of the model.

For example, the estimates of the natural rate of unemployment (NAIRU) are exogenously determined in NZTM. In theory, there are many factors determining the level of the NAIRU and those factors are not immutable. According to the Shapiro-Stiglitz model, firms cannot monitor their worker's performance perfectly and they pay more than market-clearing wages to induce workers not to shirk. Furthermore, the no-shirking condition can be a function of income tax rates. Higher tax rates shift the no-shirking locus up, which in turn changes the level of NAIRU. Therefore, it is important to have a formal model on how the levels of NAIRU are determined for policy simulation. However, it is reasonable to assume that the levels of NAIRU are relatively constant over the medium-term forecast horizon.

In addition to providing the key anchor for the dynamic version of the model, the steady-state version of the model also strengthens the properties and analytic capabilities of the dynamic model. After a considerable number of time periods has elapsed following a shock, the path of the dynamic model should converge to a growth path consistent with the solution of the steady state model. Therefore, the steady state version of the model is used to study the equilibrium effects of permanent shocks and provides a quality assurance on the long run properties of the dynamic model.

The main purpose of this paper is to describe the structure of both the steady-state and dynamic versions of NZTM. Section 2 describes the formal theory that supports the steady-state model. Section 3 describes the calibration of the model and the numerical

steady state it attains. In Section 4, we describe a number of shocks to exogenous variables that help to illustrate the properties of the steady-state model. Section 5 outlines the dynamic structure of NZTM. Finally, Section 6 presents a series of shocks from the dynamic model.

2. The Model

The steady-state version of the NZTM is based on two blocks of estimated equations that are linked by a large number of identities. The first block relates to the supply side of model. Here, the domestic good (YD) and export supply (TEXPS) are modelled in a nested production function format. This production block has been estimated as a system using Full Information Maximum Likelihood (FIML). For more details on the production block and the estimation methodology see Szeto (2001).

Within the production block, for simplicity, technical progress is assumed to be labour augmenting, that is technical progress is assumed to be Harrod-neutral. When the production block was estimated, the data implied an estimate for labour augmented technical progress of around 2% per annum. This estimate is quite high for the NZ economy. Hence, the coefficient is subsequently imposed at 1.5% per annum, which is closer to the historical average for the New Zealand economy.

The second block is composed of two equations. The first one is related to the estimation of a long-run consumption equation, which is a key equation of the demand side of the model. The consumption equation describes how household spending is determined in the long-run. The estimation method uses the cointegration approach to test for a long run relationship between consumption (CON), real income (RINCOME) and real wealth (RWEALTH). A cointegration approach is employed as non-stationarity is observed in the relevant variables. This approach is similar to recent development work on consumption equations by Downing (2001). The second estimated equation describes how consumers allocate total consumption between housing services (CONH) and other consumption (CONO). In the long-run, consumption of housing services (CONH) and other consumption (CONO) is a function of the price of CONH relative to the price of CONO.

The model is divided into four sectors: the private business sector, the household sector, the external sector and the government sector.

- The private business sector determines the levels of inputs and outputs in the production sector. The business sector uses three inputs – labour, business fixed capital and imports – to produce two outputs the domestic good (YD) and export supply (TEXPS).
- The household sector models households' consumption decision based on their income and wealth. Households not only supply the labour input for the production process but business capital as well. Households are assumed to allocate their total consumption between housing services and other consumption by maximising their utility function.
- The external sector introduces the financial capital market to the model, which determines the level of the real exchange rate, the level of underlying capital flows and the level of net foreign debt.
- The government sector is a simple entity in the model. The government buys some output in the model, financing this expenditure through tax revenue or borrowing. All the spending decisions are set exogenously in the model, with the tax rate on labour income being endogenously adjusted to achieve a target public debt to GDP ratio.

The model contains 99 equations and therefore includes 99 endogenous variables. There are 43 exogenous variables in the model. A full description of all the variables is included in Appendix 1. Appendix 2 lists all the equations and identities of the model. The following sections provide a brief overview and relevant theories for each of the four sectors.

2.1 The Private Business Sector

At the heart of NZTM is a theoretical micro-framework on how firms decide how much and how the commodities are produced in the private sector. Decisions about the quantities of inputs employed and the quantities of outputs produced are based on an

optimising process in which firms maximise profits subject to a production function constraint.

The production block combines three inputs (capital KBF, labour N and imports IM⁵) in producing two outputs (domestic good (YD) and export supply (TEXPS)) and is composed of two constant elasticity of substitution (CES) functions and one constant elasticity of transformation (CET) function.

Those CES and CET functions⁶ are expressed as follows:

$$Y_t = ((A_1 e^{\lambda T} N_t)^\rho + (A_2 KBF_t)^\rho)^{1/\rho} \quad (1)$$

$$T_t = ((A_3 e^{\pi_1 T} IM_t)^\delta + (A_4 Y_t)^\delta)^{1/\delta} \quad (2)$$

$$T_t = ((A_5 e^{\pi_2 T} TEXPS_t)^\theta + (A_6 YD_t)^\theta)^{1/\theta} \quad (3)$$

where Y denotes primary factors for production, T total gross output, T is a time trend, λ is the rates of labour augmenting technical progress, ρ , δ and θ are the substitution related parameters, π_1 and π_2 are the trend growth rates to capture changes in import penetration and a more open economy.

Equation (1) and (2) form a nested CES function. Equation (1) represents the value of production contributed by capital and labour. Hence, Y can be interpreted as the value added. The value added (Y) is then combined with imports in another CES to yield gross output (T).

The standard assumption made in most macroeconomic models is that exports and the domestic good are perfectly transformable in production. As New Zealand's exports are based significantly on primary industries, the assumption of perfect transformation seems inappropriate. Thus, the domestic good (YD) and export supply (TEXPS) are combined in a transformation function described by equation (3).

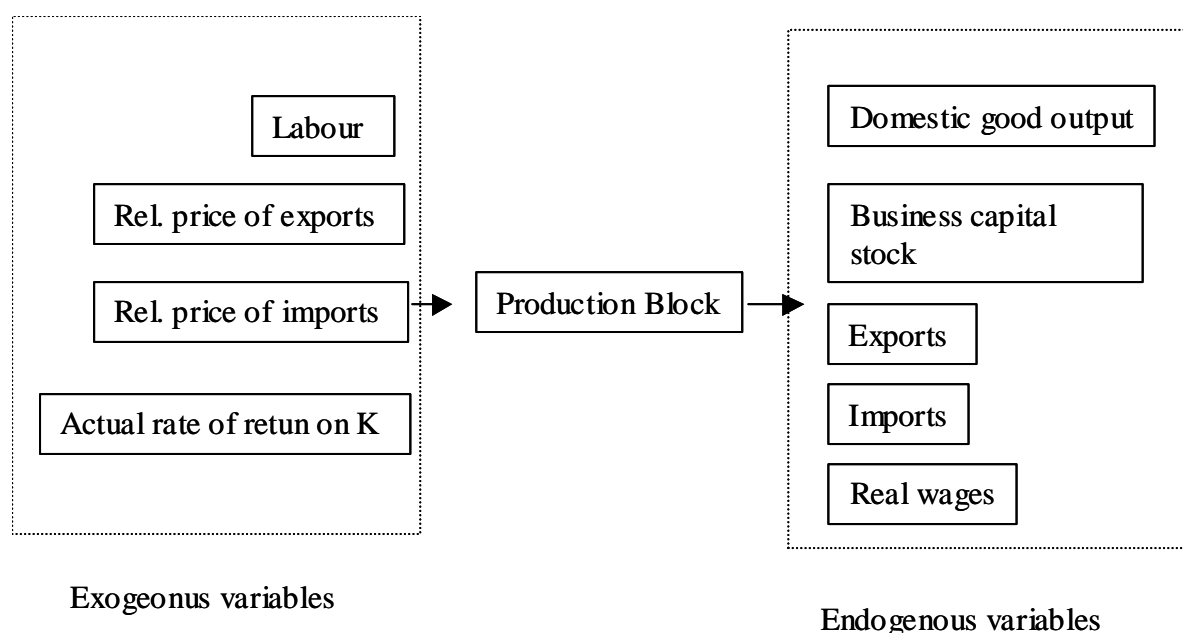
⁵ All imports are considered as intermediate materials.

⁶ Constant returns to scale is assumed in the production block.

In the short-run, the domestic good (YD) is demand-determined, the cost of inputs (wages and import prices) is fixed, and the capital stock (KBF) is considered a fixed inputs. With the fixed unit price of exports, firms maximise profits by adjusting employment, the price of the domestic good (PYD), and the levels of both export supply (TEXPS) and imports (IM).

In the long-run, employment becomes exogenous to the production block and is determined by the labour supply and wages become endogenous. Furthermore, the stock of business capital stock is no longer fixed in the long-run and is determined by the rate of return on business capital stock (AR) which in turn is a function of real interest rates, depreciation rates and the risk premium. Figure 1 shows a simple flow diagram of the production block in the steady-state version of the model.

Figure 1: A flow diagram of the production block in the steady state



2.2 The Household Sector

2.2.1 Private Final Consumption

Most theoretical models of consumption are based on the notion that individual's spending behaviour in a given period is related to their income in that period. The life-cycle hypothesis (Ando and Modiglianli 1963) suggests that consumer will spread any

existing resource to achieve a smooth consumption profile. Therefore, we can derive a consumption function of the form:

$$\text{CON} = f(\text{REAL INCOME}, \text{REAL WEALTH}) \quad (4)$$

Equation (4) states that private consumption (CON) depends upon real income and real non-human wealth, which generates a stream of future income.

There are two major problems encountered in estimating equation (4). The first problem is to find adequate measures for both income and wealth. The second problem is that the sample period of all the available data is not long enough to support a stable long-run relationship.

As it is difficult to find a stable long-run relationship for consumption (see Downing 2001), the choice of income and wealth measures is based on previous work by **Murphy (1998)**. Household income is calculated as the sum of real after-tax labour income and transfers, while non-human wealth includes both financial and real assets. Labour income is preferred to household disposable income in estimating consumption equation because the use of household disposable income can lead to double-counting of property income (Rae 1996). Rae further suggests that disposable income should not be used because it includes the highly volatile entrepreneurial income component. In this model, nominal household income is defined as:

$$\text{Household Income} = (1 - \text{POL1}) * W * \text{NT} + \text{TRPUPR} + \text{TROSPR} \quad (5)$$

where POL1 is the rate of tax on labour income, W is the nominal wage, NT is total employment, TRPUPR is the nominal transfer from the public sector to the private sector and TROSPR is the nominal transfer from overseas to the private sector.

As households own all the business capital stock in the model, they can borrow from overseas to fund their business investment. Therefore, a theoretically preferred measure of net wealth includes business capital stock (KBF) and housing stock (KH) as real assets. The nominal net wealth is defined as follows:

$$\text{Net Wealth} = (\text{B} - \text{ZPA} - \text{ZP}/\text{E}) + \text{PYD} * (\text{KBF} + \text{KH}) \quad (6)$$

where B denotes the private sector holdings of public sector bonds, E is the nominal exchange rate, ZPA and ZP are the private sector debt to foreigners contracted in NZ currency and in foreign currency respectively, and PYD is the price of domestic good. The first three terms of equation (6) are classified as financial assets in the model.

Both nominal measures of income and net wealth are then deflated by PYD to derive the real measures of household income and net wealth. To ensure convergence to a balanced growth path, the consumption equation is linear homogenous in real income (RINCOME) and real wealth (RWEALTH). The long-run equilibrium consumption function in real terms is expressed as follows:

$$\begin{aligned} \text{Log}(\text{CON}) = & C101 + C102 * \text{Log}(\text{RINCOME}) \\ & + (1 - C102) * \text{Log}(\text{RWEALTH}) - \text{Log}(\text{PCON} / \text{PYD}) \end{aligned} \quad (7)$$

where PCON is the consumption price index and the last term in equation (7) implies that the higher the relative price of consumption good, the lower is the level of consumption.

The level of household real income (RINCOME) and real wealth (RWEALTH) are graphed against the level of consumption in Figures 2 and 3. It appears that the consumption boom around 1995-1997 is associated with slower growth in real wealth for the following period. The rapid rise in private debt to foreigners allowed consumption to grow rapidly during this period. The data might suggest that consumption and real net wealth could be simultaneously determined in the medium run. It could explain why previous research found that the coefficient on the wealth variable is inconsistent with life cycle theory.

Figure 2: The logarithm of real household income and consumption

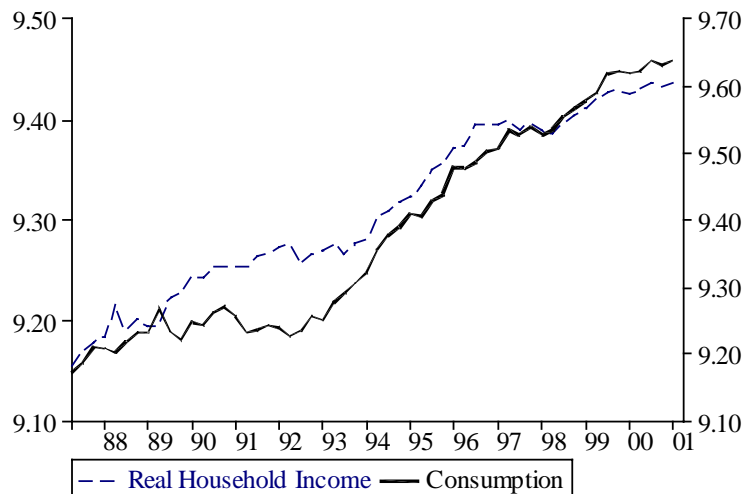
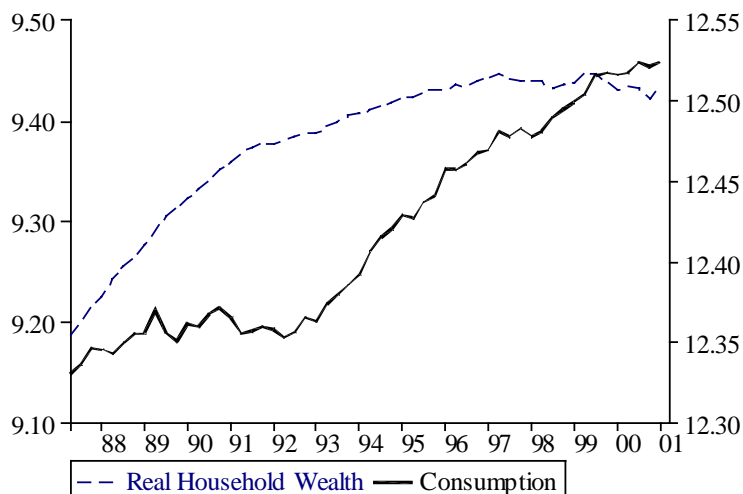


Figure 3: The logarithm of real household wealth and consumption



The results of the unit root tests of all the relevant variables are reported in Appendix 3a. The results suggest that all the variables are $I(1)$, except the real wealth (RWEALTH) variable which is $I(2)$. Using OLS, equation (7) is estimated over the period 1987q2 to 2001q1.

The coefficients from the estimation are presented in Appendix 3b. The results suggest that that income elasticity is 0.98.⁷ This point estimate is higher than was expected.

⁷ The empirical literature often refers to the income elasticity as the marginal propensity to

The results of the cointegration test do not support a long-run equilibrium consumption function. This finding is consistent with those found by Downing (2001). As mentioned before, it could be due to the problem of small sample size. It is interesting to note that when the wealth variable is excluded in the estimation, there is evidence of cointegration.

Another interesting finding from estimating equation (7) is that the income elasticity is estimated to be 0.64 if the equation is estimated to be over a shorter period from 1987q2 to 1995q4. It is clear that the estimates are not very stable and are sensitive to the estimation period. As a result, equation (7) is calibrated in the model and a coefficient of 0.66 is imposed on conceptual and practical grounds.

2.2.2 Demand for Housing Services

In this model, the household is assumed to maximize utility by choosing an allocation of consumption between housing services (CONH) and other consumption (CONO). The optimal split between consumption of housing services (CONH) and other consumption (CONO) is determined by the ratio of the equilibrium housing services price (PCONH) to the equilibrium price for other consumption. That is, the behavioural equation to be estimated is:

$$\text{Log}(\text{PCONH}/(\text{PYD}*(1+\text{POL4}))) = \text{C400} + \text{C401}*\text{TREND} + \text{C402}*\text{Log}(\text{CONH}/\text{CONO}) \quad (8)$$

The time trend variable has been included in this long-run equation to capture changes in consumers' preference and changes in the demographic profile of the population. The elasticity of substitution (σ) between housing services (CONH) and other consumption (CONO) items can be derived from the following equation:

$$\sigma = -1 * \frac{1}{\text{C402}} \quad (9)$$

consume (MPC).

Figure 4: The ratio of CONH/CONO and its relative price

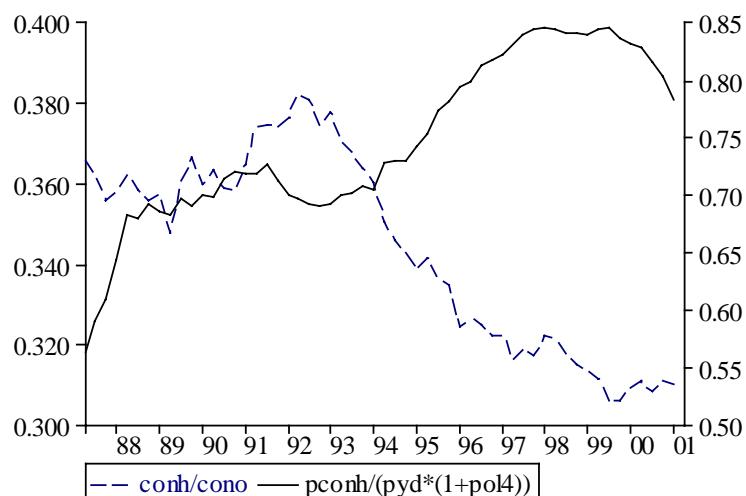


Figure 4 shows that the demand for housing services is inversely related to its own relative price. The large increase in the relative price of housing services in the second half of the 1990s coincided with a large decrease in the ratio of the demand for housing services to the demand for other consumption items.

The results of the unit root test suggest that both series are nonstationary. Estimation of (8) by OLS yields an estimate of the elasticity of substitution of 3.3, which is relatively high. Figure 4 shows that there is a sharp increase in the relative price of housing services at the beginning of the sample period, which could be attributed to the introduction of GST. Therefore, we re-estimated the equation over the period of 1991q1 to 2001q1 and the elasticity of substitution is then estimated to be 0.79. The detail of the estimation results is presented in Appendix 4.

2.2.3 Labour Supply

In the steady-state, the labour market is in equilibrium. The unemployment rate is equal to the NAIRU at which expectations of firms and workers as to the behaviour of wages and prices are correct. The NAIRU and the participation rate are set exogenously in the steady-state model.

2.3 The External Sector

Edwards (1987) and (1989) developed an intertemporal framework to investigate how both policy induced disturbances and exogenous shocks affect the path of equilibrium relative prices in an economy. The equilibrium exchange rate is reached when the economy attains both internal and external equilibrium. Internal equilibrium means that the non-tradable goods market clears in all periods. External equilibrium means that current account balances are consistent with long-run sustainable capital flows.

The theoretical structure of the New Zealand Treasury Model (NZTM) is similar to the general equilibrium intertemporal model described by Edwards (1989). The key differences between these two models are that in NZTM imports are included as an intermediate input and factor price equalization holds. When there is significant variability in the terms of trade, it is not appropriate to treat tradables as a single composite good and the real exchange rate should be defined as the relative price of importables to non-tradables (RPM) or the relative price of exportables to non-tradables (RPTEX). For more discussion on the theoretical framework on the real exchange rate, refer to Szeto and Gardiner (2001).

The key structure of the external sector can be represented by the following equations:

$$\mathbf{FRWEALTH} = \mathbf{PAGDPR} * \mathbf{RGDP} \quad (10)$$

$$\mathbf{RFDEBT} = \mathbf{RPFDEBT} + \mathbf{RGFDEBT} \quad (11)$$

$$\mathbf{DGDPR} = \mathbf{FRDEBT} / \mathbf{RGDP} \quad (12)$$

Equation (10) simply states that the level of the net real household financial wealth (FRWEALTH) is determined by a ratio of net household financial wealth to real GDP (PAGDPR). The private financial wealth variable is composed of domestic bonds and foreign assets (RPFDEBT). The steady state solution of government foreign debt (RGFDEBT) is set exogenously in the model. Equation (11) states that the net foreign debt is a sum of household foreign debt and government foreign debt. Therefore, the steady state solution of the net foreign debt to GDP ratio (DGDPR) is determined simultaneously by the above equations.

$$\mathbf{RDOS} = \mathbf{RFDEBT} * \mathbf{GR_1} \quad (12)$$

At the steady state, the level of underlying capital inflows (RDOS) is equivalent to a proportion of net foreign debt (RFDEBT) as specified by Equation (12). The proportion is determined by the natural growth rate of the economy (GR_1).

The following equation is the balance of payments equation:

$$\begin{aligned} \mathbf{RDOS} = & -1 * (\mathbf{RPTEX} * \mathbf{TEXP} - (\mathbf{RPM} / (1 + \mathbf{POL5})) * \mathbf{IM} \\ & + \mathbf{RTROSPR} - \mathbf{RTRPUOS} + \mathbf{RYOSPR} + \mathbf{RYOSPU}) \end{aligned} \quad (13)$$

where RTROSPR denotes real transfers from overseas to the private sector, RTRPUOS real transfers from the public sector to overseas, RYOSPR net real investment income from overseas to the private sector and RYOSPU net real investment income from overseas to the public sector.

Equation (13) states that the underlying capital inflow is equal to the current account and the equilibrium real exchange rate (RPM or RPTEX) is defined as the rate at which equation (13) holds.

2.4 The Government Sector

The government sector is composed of a set of accounting identities. The role of the government is to provide public services such as health and education and provide a safety net for those who are in need. The government's activity consists of purchasing goods and services and making transfer payments. Government spending can be financed in two ways: taxing and borrowing from the private sector.

In NZTM, five major tax flows are modelled. They are as follows:

- Income tax;
- Consumption tax on non-housing;
- Consumption tax on housing;
- Import tax and;
- Lump sum tax.

The NZTM covers a range of transfer payments, including superannuation, unemployment benefits, and other benefits.

In the steady-state, both the real public liability to RGDP ratio and government expenditure are set exogenously. The tax rate on labour income is then endogenously adjusted to achieve a fiscal balance.

3. The Steady State

In the previous chapter, we have mentioned that the steady-state version of the model comprises 43 exogenous variables, which together determine the steady-state solution of the model. In order to remove the short-term volatility of the data, the Hodrick-Prescott (HP) filter is used to decompose the exogenous variables into trend and cyclical components. The parameter λ of the HP filter is set equal to 1600. The trend variables are then used to solve for the steady solution over the historical period.

In Section 3.1, we present graphs of the key exogenous variables. Finally, we compare the steady solution with the actual value for some of the endogenous variables in Section 3.2

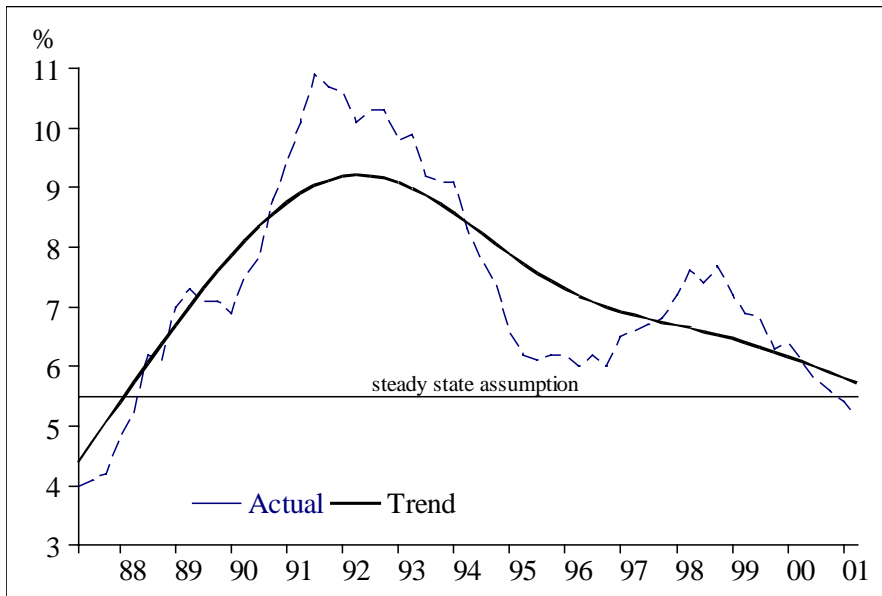
3.1 The Exogenous Variables

3.1.1 NAIRU

Figure 5 shows both the unemployment rate and its trend value. The historical trend value of the unemployment rate is used as a proxy for the Non-Accelerating Inflation Rate of Unemployment (NAIRU). As can be seen from Figure 5 below, while the NAIRU rose in the late 1980s and early 1990s, since around 1993 it has fallen to around 5.5% in 2001. This may reflect labour market reform in the early 1990s.

In NZTM's forecast environment, the steady-state assumption for the NAIRU is 5.5%.

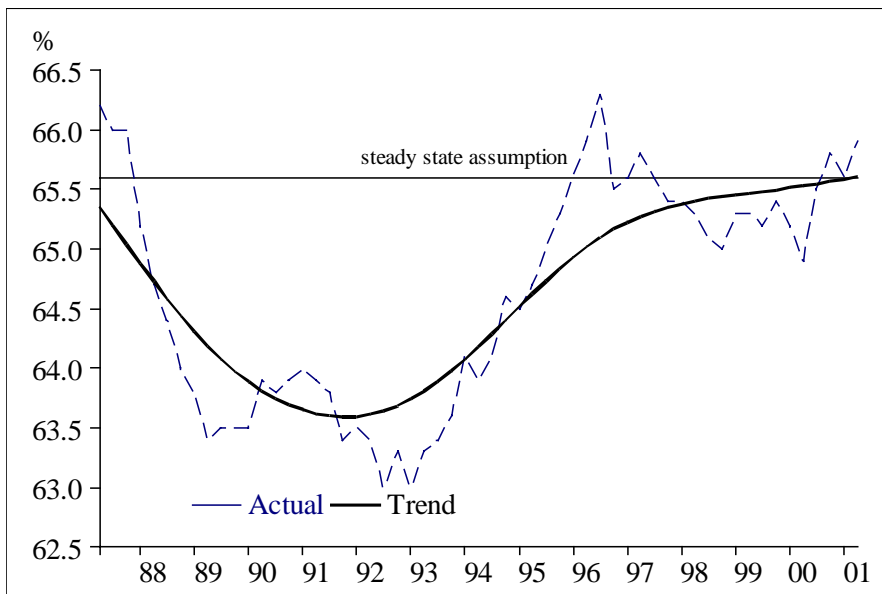
Figure 5: Unemployment rate



3.1.2 Participation Rate

Figure 6 shows both the actual and trend participation rates. In NZTM's forecast environment, the steady-state assumption for the participation rate is 65.6%. This assumption is based on a long historical average for the participation rate.

Figure 6: Participation Rate



3.1.3 Net Real Household Financial Asset to Real GDP ratio

The steady-state assumption for the net real household financial assets to GDP ratio is a key determinant for the steady-state solution for the net foreign debt to GDP ratio. As can be seen from Figure 7, there is a decreasing trend in the net real household financial assets to GDP ratio between 1987 and 2001. The consequence of the declining trend is that the net foreign debt to GDP ratio has been on an upward trend between 1987 and 2001, reflecting the fact that the New Zealand economy has run current account deficits over this entire period (see Figure 8). Haugh (2001) has argued that the increase in the current account deficit from 1997-2000 was due to households undertaking residential investment, hence the increase in the trend net foreign debt to GDP ratio after 1997.

In NZTM's forecast environment, the steady-state assumption for the net real household financial assets to GDP ratio is set at -1.2 . This assumption leads to a level of current account deficits of 3.8% that are consistent with underlying capital inflows over the 1990s. This steady-state assumption also implies further falls in the net foreign debt to GDP ratios from its current level.

Figure 7 Net Real Household Financial Assets to GDP ratio

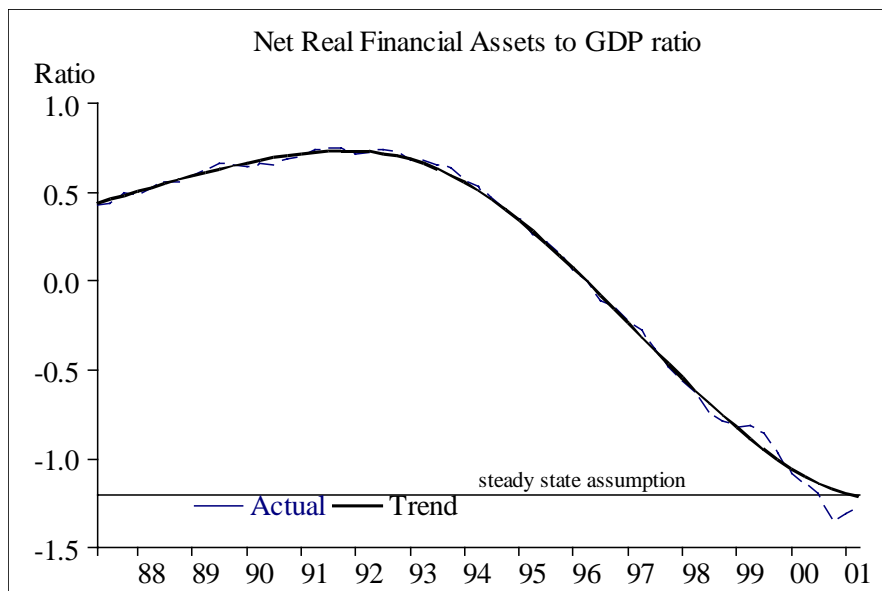
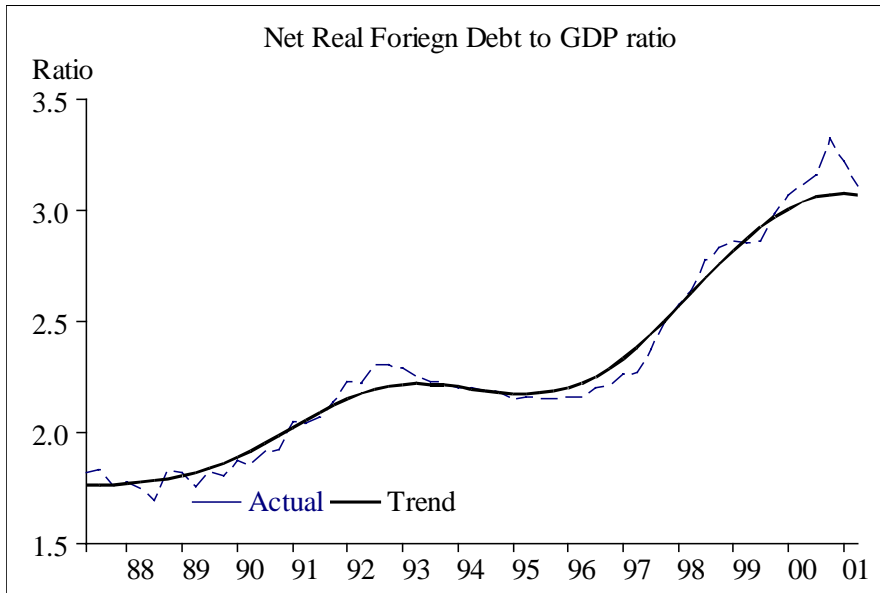


Figure 8 Net Real Foreign Debt to GDP ratio

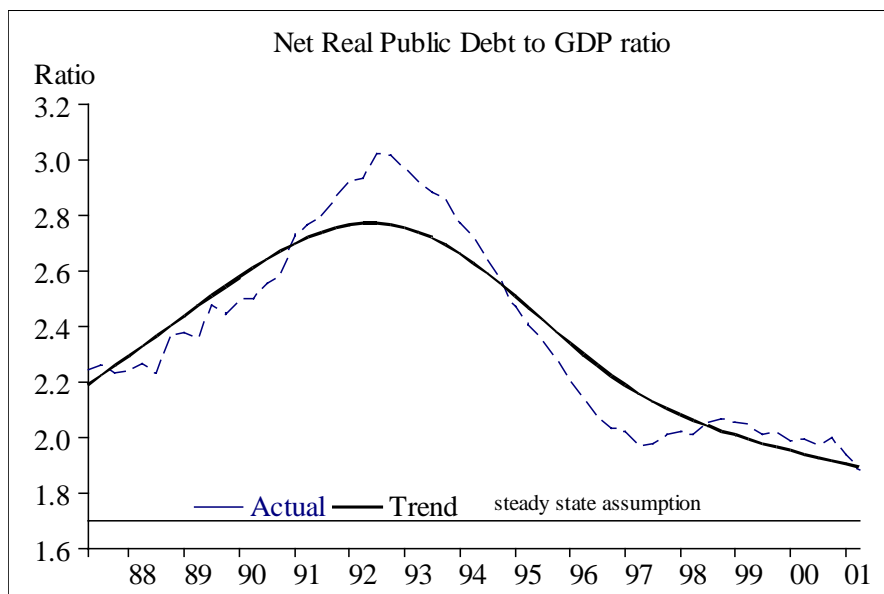


3.1.4 Net Real Public Debt to Real GDP ratio

As can be seen from Figure 9, while the net public debt to GDP ratio rose during the late 1980s and early 1990s, between 1993 and 2001 we have seen significant declines. The falling trend between 1993 and 2001 probably reflects fiscal consolidation over the 1990s.

The steady-state assumption for the net public debt to GDP ratio in the forecast environment is 1.7%. This is set to reflect the government's gross debt target.

Figure 9 Net Real Public Debt to Real GDP ratio



3.1.5 Foreign Prices

As shown in Figure (10) and Figure (11), both foreign export and import prices did not exhibit a long-term trend over the data period chosen. Over the same period, the price of the domestic good has been trending upwards. The difference in productivity between the traded and non-traded sector might explain the divergence price movement between traded and non-traded goods. The values of π_1 and π_2 are estimated to be negative, reflecting the increasing openness of the New Zealand economy. In the forecasting horizon, π_1 and π_2 are set to be -0.006 . Allowing for a constant expenditure share of traded goods, the trend growth rates for both export and import prices are set equal to 0.9% per annum.

Figure 10 Foreign Import Prices

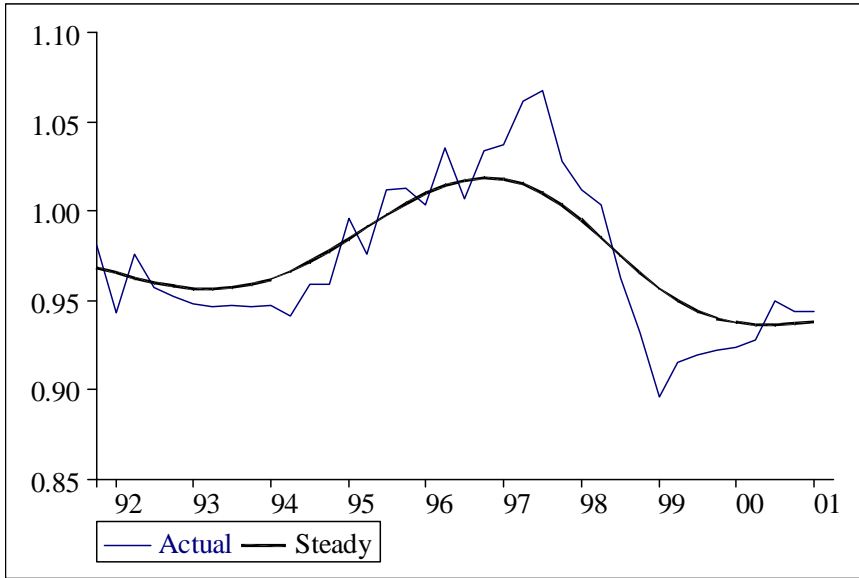
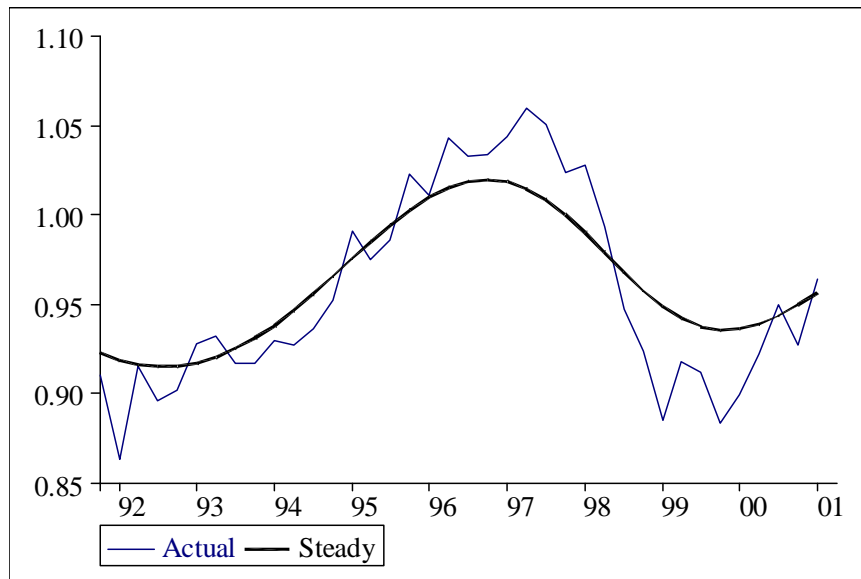


Figure 11 Foreign Export Prices



3.2 The Steady-state Solution

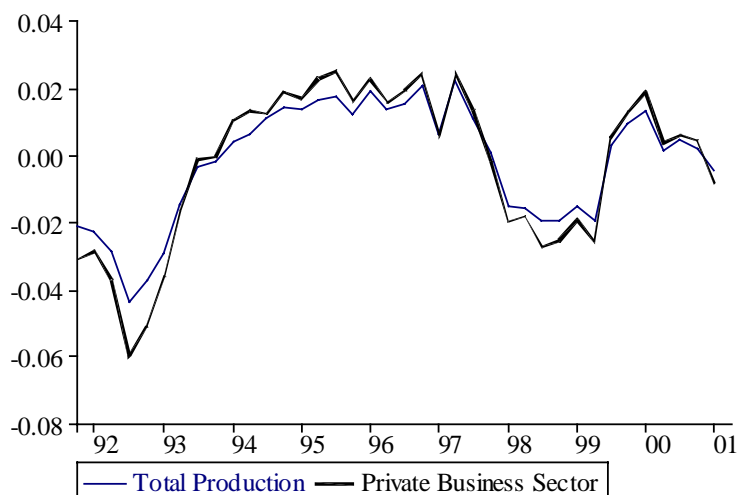
Like the fit of a regression model, the steady-state solution gives us an indication of how well the data fits the model. In practice, the steady-state solution should not be too far away from the actual data, otherwise, convergence problems may arise when using the dynamic version of the model for forecasting. Furthermore, the difference between the actual value and the steady-state value can be interpreted as the measure of disequilibrium. In this section, we first focus on two key endogenous variables, namely output and real exchange rates and then present graphs of other endogenous variables in Appendix 5.

3.2.1 Potential Output

In recent years, many central banks have favoured the demand-pull framework in modelling inflation. Usually, some measures of the output gap are used to measure future inflationary pressures. The output gap is the difference between actual output and potential output. The production block of the model provides a measure of potential output of the private business sector.

Although the private sector production (PNA10) accounts for about 68% of the total production, almost all the variability in total production can be attributed to PNA10. The following figure shows the output gaps of GDP (NA10) and private sector production (PNA10). Both measures of potential output are estimated using the HP filter with $\lambda=1600$.

Figure 12: Measures of the output gap - total production and private sector



The other components of GDP (NA10) are housing consumption (CONH), government employment (C5000*NGG) and consumption tax (C5001*CONO). The following identity defines NA10 as:

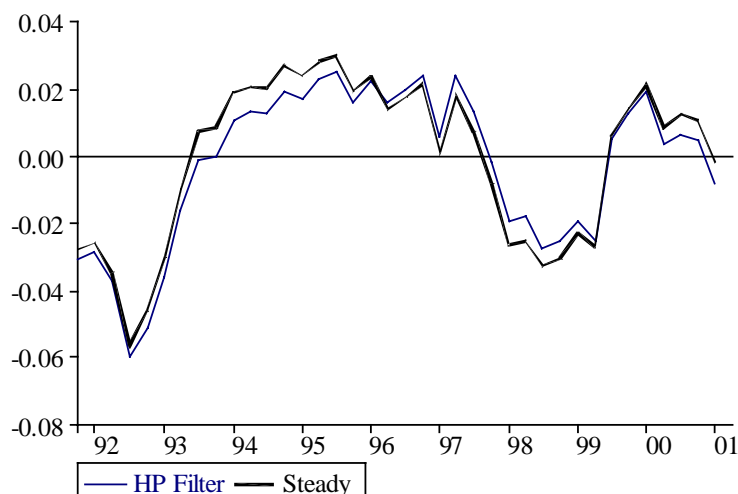
$$NA10 = PNA10 + C5000 * NGG + CONH + C5001 * CONO$$

where $PNA10 = YD + TEXPS - IM$.

In NZTM, the output gap measure is based on the private business sector production rather than total production. The main reason for using the private business sector production is that the output gap is used to determine the inflation rate of the domestic good but not the general inflation rate in the dynamic model. Therefore, it is more appropriate to use the private sector output gap. Figure 13 compares the output gap derived from the model with the output gap estimated from the HP filter. Although the steady-state solution is very similar to the potential output estimated from the HP filter over the estimation period, the advantage of using the production function approach is

that one can analyze the impact of changes in the economic structure on potential output.

Figure 13. A comparison of two different measures of output gap



3.2.1 Real Exchange Rate

Given the importance of the real exchange rate, many studies have attempted to quantify the level of the long-run equilibrium real exchange rate. Like potential output, the level of the long-run equilibrium real exchange rate is unobservable and various techniques have been developed to estimate it.

In this model, the steady-state solution of the real exchange rate is the level at which both internal and external balance is simultaneously attained. External equilibrium is attained when the current account balances are compatible with the underlying capital inflows. Internal equilibrium means that the market for the domestic good and the factors of the production are in equilibrium. The resultant estimates of the real exchange rate from the steady-state model are, therefore, consistent with the definition of the long-run equilibrium exchange rate developed by Williamson (1985).

As mentioned above, the real exchange rate is defined as the relative price of importables to non-tradables (RPM) or the relative price of exportables to non-tradables (RPTEX). An appreciation of the real exchange rate is represented by a decrease of RPM or RPTEX. Figure 14 charts the inverse of the steady-state solution of RPM with that of the actual RPM. The extent of real exchange rate misalignment is plotted in Figure 15. The results show that the real exchange rate did indeed overshoot its long-run equilibrium level over the period 1996 to 2000.

Although the nominal exchange rate has dropped sharply since 1997, the real exchange rate remained overvalued over a long period of time after the initial fall in the nominal exchange rate. Our results suggest that the fall in the nominal exchange rate has been offset by a sharp fall in the world prices during the Asian crisis. The real exchange rate misalignments peaked at the beginning of 1999 and the real exchange was substantially overvalued by 10%.

Currently, the real exchange rate is undervalued by about 6% following a sharp fall in real exchange rates at the end of 1999. At the beginning of 2001, the nominal exchange rate was at 49.6 on a TWI basis. Assuming all else being equal, the equilibrium value for the NZD was around 53 on a TWI basis.

Figure14: New Zealand's equilibrium real exchange rate: the inverse of RPM

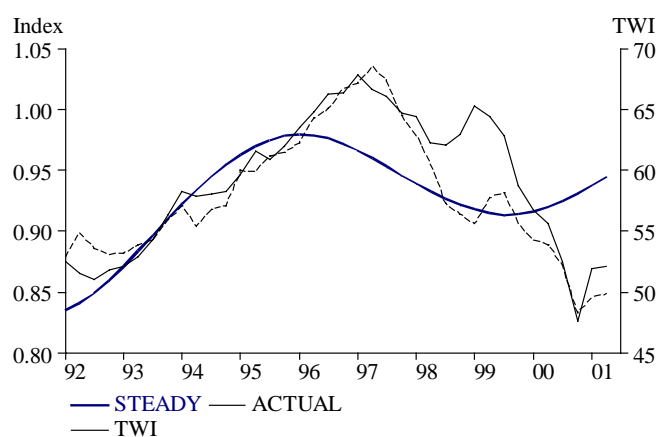
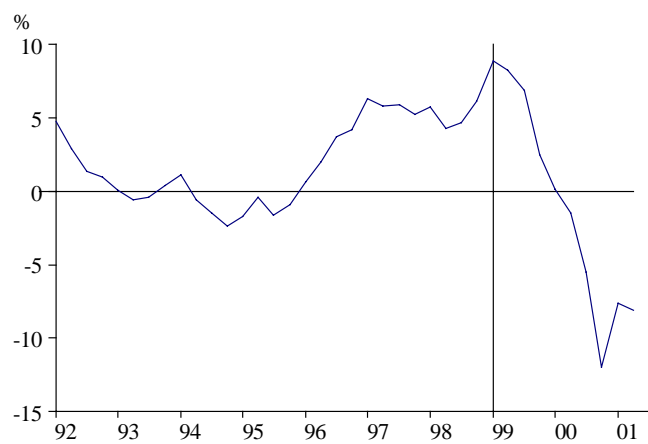


Figure 15: New Zealand real exchange rate misalignments



4. Simulations

In this section, we examine some of the properties of the model by simulation analysis. The illustrative simulations presented here identify the new steady-state solution of the model following a shock.

4.1 A permanent increase in world export price by 1%

In this experiment, we consider a permanent improvement in the terms of trade by raising the world price of New Zealand exports. This permanent shock raises the purchasing power of New Zealand exports and consequently more imports are allowed in equilibrium to attain the external equilibrium. As a result, consumers benefit from this higher purchasing power and a larger share of domestic production becomes available for consumers. Higher domestic demand leads to an appreciation in the real exchange rate. Overall, the domestic productive capacity is increased slightly by 0.12%.

Simulation 1: a permanent 1% increase in world export price

Percentage differences from base unless specified as percentage points (pp) from base or as differences (df) from the base

	1 quarter	2 years	10 years
RER- rptex	-0.88	-0.88	-0.88
RER-rpm	-1.87	-1.87	-1.87
Exports -texp	0.06	0.06	0.06
Imports - im	0.95	0.95	0.95
Consumption -con	0.73	0.73	0.73
Business investment -ibf	0.30	0.30	0.30
Residential investment -ih	0.90	0.90	0.90
Private sector output - pna10	0.09	0.09	0.07
Current account - curb (pp)	0.01	0.01	0.01
Income tax rate- poll (df)	-0.001	-0.001	-0.001

4.2 A permanent 1% increase in the level of productivity

The section describes an experiment where the level of productivity is increased by 1%. This shock has no impact on the relative prices of the model and the only long-term consequence is some upward shift in the productive capacity by 1%.

Simulation 2: a permanent 1% increase in the level of productivity

Percentage differences from base unless specified as percentage points (pp) from base

or as differences (df) from the base

	1 quarter	2 years	10 years
RER- rptex	0.00	0.00	0.00
RER-rpm	0.00	0.00	0.00
Exports -texp	1.00	1.00	1.00
Imports - im	1.00	1.00	1.00
Consumption -con	1.00	1.00	1.00
Business investment -ibf	1.00	1.00	1.00
Residential investment -ih	1.00	1.00	1.00
Private sector output - pna10	1.00	1.00	1.00
Current account (pp)	0.0	0.0	0.0
Income tax rate (df)	0.0	0.0	0.0

4.3 A permanent change in productivity growth

In the previous experiment, the growth rate of productivity returns to its initial value after the shock. The simulation presented here is to illustrate the response of a permanent increase in productivity from 1.5% per annum to 2.0% per annum. There are three key results in this experiment:

- First, higher productivity growth lowers consumption initially because more of the domestic good is required to meet higher investment in the new equilibrium. However, in the long-run consumption is higher because the economy is on a higher growth path.
- Second, there is an effect on the real exchange rates. For a given foreign debt to GDP ratio, the higher growth rate allows the current account deficit to increase in the new equilibrium. To support this new equilibrium, the real exchange rate appreciates.
- Third, there is a negligible change in the income tax rate because government expenditure is set exogenously and grows at the same rate as the private productive sector.

Simulation 3: a permanent change in productivity from 1.5% per annum to 2.0% per annum

Percentage differences from base unless specified as percentage points (pp) from base

or as differences (df) from the base

	1 quarter	2 years	10 years
RER- rptex	-1.72	-1.72	-1.72
RER-rpm	-1.72	-1.72	-1.72
Exports -texp	-0.15	0.48	4.48
Imports - im	0.87	1.50	5.50
Consumption -con	-2.89	-2.26	1.74
Business investment -ibf	6.42	7.05	11.05
Residential investment -ih	4.20	4.82	8.82
Private sector output - pna10	0.26	0.88	4.86
Current account - curb (pp)	-0.38	-0.38	-0.38
Income tax rate- pol1 (df)	0.002	0.002	0.002

4.4 Lowering the real household financial assets to GDP ratio

In this experiment, the long-run real household financial asset to GDP ratio is decreased from -1.2 to -1.5 . As a result, the foreign debt to GDP ratio is increased from 2.9 to 3.2 . The increase in foreign liabilities means a higher debt-servicing burden. Hence, the real exchange rate is required to depreciate, leading to an increase in exports and a fall in imports. In the long run, the shock has a negligible impact on the private sector output but the consumption's share of output is lower in the new equilibrium.

Simulation 4: Lowering the real household financial assets to GDP ratio

Percentage differences from base unless specified as percentage points (pp) from base or as differences (df) from the base

	1 quarter	2 years	10 years
RER- rptex	1.14	1.14	1.14
RER-rpm	1.14	1.14	1.14
Exports -texp	0.26	0.26	0.26
Imports - im	-0.41	-0.41	-0.41
Consumption -con	-0.36	-0.36	-0.36
Business investment -ibf	0.03	0.03	0.03
Residential investment -ih	0.95	0.95	0.95
Private sector output - pna10	-0.01	-0.01	0.01
Current account - curb (pp)	-0.19	-0.19	-0.19
Income tax rate- pol1 (df)	0.001	0.001	0.001
Public liabilities - pubder	-0.16	-0.16	-0.16

4.5 Reducing the public liability to GDP ratio

In this experiment, the government reduces its public liability to GDP ratio from 1.74 to 1.64 . In NZTM, the public liability comprises borrowings, pension liability, currency issued liability and payable and provisions liabilities. Currently, borrowing accounts for about 69% of the total liability and the government debt target is based on either gross or net borrowings. Furthermore, the denominator used in calculating the government debt target ratio is annual GDP. Hence, the public liability to GDP ratio of 1.74 and 1.64 in NZTM is equivalent to a government gross debt target of 30% and 28%, respectively.

As government spending remains unchanged, a lower debt to GDP ratio implies a lower level of government debt and a lower debt-serving burden, which in turn leads to a lower income tax rate in the new equilibrium.

Since consumers must hold the lower level of government bonds, households then raise their desired level of real assets to compensate for the decrease in their level of financial wealth. The impact of higher household disposable income leads to higher consumption. The other adjustment comes through the consumption deflator. In the new equilibrium, the consumption deflator is lower.

Simulation 5: reducing the public liability to GDP ratio

Percentage differences from base unless specified as percentage points (pp) from base or as differences (df) from the base

	1 quarter	2 years	10 years
RER- rptex	-0.38	-0.38	-0.38
RER-rpm	-0.38	-0.38	-0.38
Exports -texp	-0.09	-0.09	-0.09
Imports - im	0.14	0.14	0.14
Consumption -con	0.18	0.18	0.18
Business investment -ibf	-0.01	-0.01	-0.01
Residential investment -ih	0.25	0.25	0.25
Private sector output - pna10	-0.00	-0.00	-0.00
Current account - curb (pp)	-0.06	-0.06	-0.06
Income tax rate- pol1 (df)	-0.002	-0.002	-0.002

4.6 An increase in government consumption and investment by 10%

This simulation illustrates the effects in NZTM of a 10% increase in government consumption and investment. Given that we hold the government debt to GDP ratio constant, the increase in spending is financed by an increase in income tax. As the output of the domestic good remains relatively unchanged, fiscal expansion crowds out private consumption of the domestic good.

The reduction in demand for consumption goods is induced through two channels. The first channel is through higher taxes lowering disposable income, and hence

consumption. The second adjustment comes through lower real assets. With lower consumption of housing services, the housing stock must be lower in the new equilibrium.

Although private sector output remains unchanged, the shock affects total GDP through its impact on the consumption of housing services. As a result, there is a small appreciation of real exchange rate in response to a lower level of foreign debt in the new equilibrium.

Simulation 6: An increase in government consumption and investment by 10%

Percentage differences from base unless specified as percentage points (pp) from base or as differences (df) from the base

	1 quarter	2 years	10 years
RER- rptex	-0.05	-0.05	-0.05
RER-rpm	-0.05	-0.05	-0.05
Exports -texp	-0.01	-0.01	-0.01
Imports - im	0.02	0.02	0.02
Consumption -con	-2.81	-2.81	-2.81
Business investment -ibf	-0.00	-0.00	-0.00
Residential investment -ih	-4.00	-4.00	-4.00
Private sector output - pna10	0.00	0.00	-0.00
Current account - curb (pp)	-0.01	-0.01	-0.01
Income tax rate- poll (df)	0.020	0.020	0.020

5. Dynamic Structure

The previous chapters discussed the structure of the steady state version of NZTM. In this chapter we discuss the dynamic structure. The dynamic structure of the model “fits” around the steady state structure and attempts to replicate the cycles in economic data. While the steady-state version of the model is particularly important in determining the steady-state values for the key endogenous variables, the dynamic model also has an important role in shaping the path of the economy following a shock. The specification of the dynamic model is therefore key in determining an economic forecast.

While parts of the model have been estimated, one example is the production block, the dynamic model has been calibrated⁸. A good example of a calibrated model is the FPS developed by the Reserve Bank of New Zealand. The motivation for calibrating the dynamic structure has evolved from the properties of the data and the estimation results obtained for a number of dynamic equations. The results from this estimation work are used to inform the calibration of the model.

The dynamic structure of the model has been purposely kept as parsimonious as possible without losing the ability to replicate the dynamics of the data. One of the major motivations for this parsimonious specification is the ability to trace back and understand what is driving a model forecast as an example. Applying over specified dynamic models to actual data, which in New Zealand’s case is normally quite volatile, can lead to model forecasts that are difficult to understand.

Dynamic equations are specified to capture both short-term data movements and partial adjustment to equilibrium steady-state values.

This chapter reviews each sector of the components of GDP as well as discussing the inflation process and the monetary and fiscal rules.

⁸ This is an area of ongoing development as the model is “fine tuned.”

5.1 Private Consumption

Many models of consumption are based on individual optimisation of utility, where an individual makes consumption decisions over some period, based upon their earnings and wealth, and preferences for present and future consumption. The Friedman permanent income hypothesis and the Modigliani and Brumberg life cycle model are two influential examples of such models.

The structure of the private consumption sector has been detailed in the previous chapter. The dynamic specification of private consumption is as follows:

$$\text{LOG(CON)} = \text{C0401} * \text{LOG(COND)} + (1 - \text{C0401}) * \text{LOG(CON}(-1) * \text{GR)} - \text{C0402} * (\text{YCURVE}(-2)) + \text{Z_CON}$$

Private consumption is modelled in a partial adjustment specification as a function of the equilibrium level (COND), which is determined by labour income and wealth, and the yield curve.

The yield curve reflects the fact that households will decrease (increase) consumption when interest rates rise (fall) as the return on savings increases (decreases).

5.2 Residential Investment

A Tobin-q style model of housing investment is used in which the rate of investment is above or below a benchmark rate, according to whether the actual rate of return on housing investment is above or below a required rate of return. This requires measures of the benchmark rate of housing investment and of the actual and required rates of return on housing investment.

In the long run, the stock of housing will increase in line with the natural rate of growth of the economy, GR-1. Thus the benchmark rate of housing investment needs to cover both natural growth in the stock of housing and depreciation of 1% per quarter.

$$\text{IH} = (\text{GR} - 1 + \text{DRRB_EQ}) * \text{KH}$$

The required rate of return on housing includes depreciation, the equilibrium real interest rate, RI_{eq} , and a risk premium, RP , where each of these is expressed as a proportionate rate per quarter.

$$DRRB_EQ + RI_{eq} + RP$$

In the final equation, the rate of housing investment adjusts partially to the benchmark rate, and is influenced by the q-effect (the difference between the actual and required rates of return) lagged one quarter. The slope of the yield curve, $YCURVE$, also appears as a second interest rate effect on housing investment.

$$IH/KH = C0501 * (IH(-1)/KH(-1)) + (1 - C0501) * (GR + DRRB_EQ - 1) + C0502 * (KSRATIO * (RCONH(-1) - POL7_EQ(-1)) - (DRRB_EQ + RI(1) + RP)) + C0503 * YCURVE(-2) + C0504 * YCURVE(-3) + Z_IH,$$

The housing stock is calculated through a perpetual inventories approach where housing investment, net of depreciation, adds to the housing stock, which is carried over to the next quarter.

$$KH1 = (1 - DRRB_EQ) * KH + IH$$

$$KH = KH1(-1)$$

5.3 Business Investment

A Tobin-q style model is used for private business investment, the same approach that was used for housing investment. Thus the rate of investment is above or below a benchmark rate, according to whether the actual rate of return on business investment is above or below a required rate of return. This incorporates the main factors commonly believed to influence business investment. In this approach, higher real wages reduce business investment by reducing the actual rate of return, while higher real interest rates reduce business investment by increasing the required rate of return.

In the long run, the stock of business capital will increase in line with the natural rate of growth of the economy, $GR-1$. Thus the benchmark rate of housing investment needs to cover both natural growth in the stock of business capital and depreciation.

$$IBF = (GR - 1 + (DR_EQ)).KBF$$

The required rate of return on business investment includes depreciation, the real interest rate, RI_eq, and a risk premium, RP1, where each is expressed as a proportionate rate per quarter.

$$DR_EQ + RI_eq + RP1$$

In the final equation, business investment adjusts partially to the benchmark rate, and is influenced by the q-effect (the difference between the actual and required rates of return) lagged one quarter. The yield curve slope, YCURVE, appears as a second interest rate effect.

In the investment equation the ratio of business investment to capital is driven by its own lag, prospective profitability and the tightness of monetary policy. Profitability is measured through the gap between actual and required rates of return. The required rate of return on investment includes the depreciation rate, the real interest rate and a risk premium. The actual rates of return on capital is increased through higher prices for outputs and lowered through higher prices for inputs. Although the dynamic structure is calibrated the parameter values for the equation are close to that of their estimated values.

$$IBF/KBF=C1303*(IBF(-1)/KBF(-1))+C1301*(GR+DR_EQ-1)+C1302*(AR(-1)-(DR_EQ+RI_eq+RP1))+C1304*YCURVE(-2)+C1305*YCURVE(-3)+Z_IBF,$$

Net business investment adds to the business capital stock carried over to the next quarter.

$$KBF1 = (1 - DR_EQ).KBF + IBF$$

$$KBF = KBF1(-1)$$

5.4 Inventories

There are two types of inventories in the model: those for domestic consumption (IINR) and those for export (IIE). The specifications for the two types of inventories are very simple.

Domestic inventories are modelled as a function of YD and a deviation of the level of inventories from their equilibrium value.

$$IINR = \text{EXP}(\text{LOG}(YD * \text{SSRATIO_EQ}) - \text{LOG}(KINR(-1)/EKINR(-1))) + Z_IINR,$$

Export inventories are modelled as the difference between the supply of exports (TEXPS) and the demand for exports (TEXP).

5.5 Exports

In a small country like New Zealand, it is reasonable to assume that New Zealand is a price-taker in the markets for our exports. Export volumes respond to a change in world growth through an indirect effect of the foreign price for exports. The other factors that affect the supply of exports are wages and import prices. Export supply increases in response to lower wages and imports, which are both inputs into the production block.

From the production block the model generates a path of medium-run equilibrium solution for export supply. These medium-run solutions represent the optimising or neoclassical solution from the production block. Total exports adjust in a first order dynamics where GR-1 is the natural rate of growth of the economy. BETA1 is the trend growth rate to capture changes in import penetration and a more open economy.

Total export supply (TEXRS) adjusts to equilibrium supply (EXRSR) in a partial adjustment model.

$$\text{LOG}(\text{TEXPS}) = C1101 * \text{LOG}(\text{GR} * \text{EXP}(-1 * \text{BETA1}/4) * \text{EXRSR}(-1)) + (1 - C1101) * \text{LOG}(\text{GR} * \text{EXP}(-1 * \text{BETA1}/4) * \text{TEXPS}(-1)) + Z_TEXPS,$$

5.6 Imports

The dynamic structure of the import equation is also formulated as a partial adjustment model. The production block also determines the equilibrium imports in the dynamic model. In the production block, imports are considered as an intermediate input. Therefore higher wages leads to an increase in imports as firms substitute labour with imports.

Actual imports (IM) adjust to equilibrium imports (IMSR) in a partial adjustment model.

$$\text{LOG(IM)} = \text{C0902} * \text{LOG}(\text{GR} * \text{EXP}(-1 * \text{BETA2}/4) * \text{IMSR}(-1)) + (1 - \text{C0902}) * \text{LOG}(\text{GR} * \text{EXP}(-1 * \text{BETA2}/4) * \text{IM}(-1)) + \text{Z_IM},$$

5.7 Labour Market

5.7.1 Employment

Actual business sector employment (NT-NGG_A) adjusts to equilibrium employment (NSR) which is derived from the production block in a partial adjustment model. The speed of adjustment to equilibrium is calibrated at 0.15 which is marginally lower than recent empirical estimates, Gardiner (2001), but fits with the interactions with the other variables.

$$\text{LOG(NT-NGG_A)} = (\text{C1001} * \text{LOG}((\text{NSR}(-1)) * \text{EXP}(\text{POPGR_EQ}))) + (1 - \text{C1001}) * \text{LOG}((\text{NT}(-1) - \text{NGG_A}(-1)) * \text{EXP}(\text{POPGR_EQ}))) + \text{Z_NT},$$

Having modelled business employment (NT-NGG_A), total employment is obtained by adding general government employment (NGG_A), which is treated as an exogenous policy lever.

5.7.2 Labour Force

NZTM models the labour force participation rate calculated as the ratio of the labour force to the population aged 15 years and over.

$$\text{PARTT} = \text{C0201} * \text{PARTT}(-1) + \text{C0202} * (\text{PARTT_EQ}) + \text{C0203} * (\text{NAIRU}(-1) - \text{URT}(-1)),$$

For the purposes of the participation rate equation, the population aged 15 years and over is measured using demographic data sources. This is for consistency with the age-specific population effects appearing in the rest of the model. However, official data for the participation rate (PARTT) uses a different measure of the population aged 15 years and over. To match this official definition, an equation for PARTT is included in which the appropriate scaling factor (RPOP3) is applied to correct the demographic sources estimate of the population aged 15 years and over.

$$\text{PARTT} = 100 * \text{NTS} / (\text{RPOP3} * (\text{POP3} + \text{POP4}))$$

A further equation appears for the smoothed growth rate of the working age population, POPGR. In the long run, the participation rate will stabilise, so growth in the working age population will determine growth in the labour force which in turn is part of the sustainable growth rate of real output, GR-1. Thus POPGR appears later in an equation for GR.

$$\text{POPGR} = \Delta \text{LOG}(\text{POP3_eq} + \text{POP4_eq})$$

Using total employment (NT), and the labour force (NTS), which is derived from the above specification of the participation rate (PARTT), unemployment (NUN) and the unemployment rate (URT) and can be calculated.

$$\text{NUN} = \text{NTS} - \text{NT}$$

$$\text{URT} = 100 * (1 - \text{NT} / \text{NTS})$$

5.7.3 Wages

Wage setting arrangements have varied in New Zealand. In the early 1980s wage and prices controls were applied. In 1991, the Employment Contracts Act was introduced which has been replaced recently with the Employment Relations Act.

The wage equation is an inflation expectations augmented Phillips Curve.

$$(1+\text{INF_WA})=\text{EXP}(\text{INFE}(-1))*(\text{C0304}*\text{A1}(-1)/\text{A1}(-2)+\text{C0305}*\text{A1}(-2)/\text{A1}(-3))- \\ \text{C0306}*(\text{URT}(-1)-\text{NAIRU})+\text{C0307}*\text{LOG}(\text{ERWA}(-1)/\text{RWA}(-1))+\text{C0308}*\text{LOG}(\text{RPYDMR}(- \\ 1))+\text{Z_W},$$

Where wage inflation is determined by backward looking expectations of inflation, lagged productivity growth and excess demand pressures in the labour market measured through deviations of the actual unemployment rate from its equilibrium value. The equation also includes the medium-run variable, RPYDMR which proxys the profitability of the firm. Finally, the equilibrium real wage (ERWA) derived from the production block provides a long-run anchor for the equation.

5.8 Inflation

In the model inflation diverges from the target rate of 1.5% per annum through three channels. The first channel concerns the degree of excess demand in relation to the economy's ability to supply. This is the measure of the output gap, which has become a popular way to model inflationary pressures. In this framework, inflation will deviate from the monetary authorities target rate when demand pressures deviate from the economies potential to supply.

Potential output is unobservable and therefore we need to calculate this. Over history potential output is derived from the production block in the steady state model. Over the forecast period we use the Hodrick Prescott filter estimate of potential and assume that this adjusts to the steady state estimate through the following partial adjustment framework.

$$\text{PO_EQ} = \text{PO_EQ}(-1)*(0.5*\text{PGR}(-1)+0.5*\text{PGR}(-2)) + 0.2*(\text{EPO}(-1)-\text{PO_EQ}(-1))$$

The graph in the steady-state discussion highlights that over history the two approaches to estimating the output gap line up fairly well. In the steady state we assume that the rate of potential growth of the economy is 2.8% per annum. This growth rate is composed of population growth of 1.25% per annum, labour productivity growth of

1.5% per annum and other technological change parameters of the production block. Of course if our view changes around one or both of these drivers of growth then the assumptions can be changed to reflect that revised view. The section on shocks examines the consequences of changing our view on the labour productivity growth assumption.

The second channel through which inflation can deviate from its target rate is through inflation expectations. Inflation expectations are formed as a mixture of both forward and contemporaneous inflation rates with more weight assigned to the forward looking expectations.

The third channel is the mark-up view of inflation. The coefficient of RPYDMR is relatively small so that less weight is placed on this channel in the model.

The autoregressive specification recognises the persistence of inflation.

$$(INF_PYD-INF_TAR)=C1204*(C1205*(INFE(-1)-INF_TAR)+(1-C1205)*(INF_PYD(-1)-INF_TAR))+(1-C1204)*(C1206*LGAP(-1)+C1207*LGAP(-2)+C1208*LGAP(-3)+C1209*RPYDMR(-1)),$$

The measure of inflation targeted by the monetary authority is CPI, which is generated by the following equation:

$$INF=((1-(SHARE/(1+SHARE))))*(INF_PYD)+(SHARE/(1+SHARE))*(INF_PCONH))$$

Where INF_PCONH is the inflation of housing services and share is the ratio of housing services expenditure to other consumption.

5.9 Monetary Policy

In the model, the central bank adjusts short-term interest rates to achieve an inflation target of 1.5% per annum. The reaction function is forward looking with the monetary authority targeting deviations of annual inflation from the target rate over a 5 to 7 quarter horizon. Equal weight is placed on these target quarters.

$$RCS = (C5001*(INF_CPIX(5)-CPI_TAR)+C5002*(INF_CPIX(6)-CPI_TAR)+C5003*(INF_CPIX(7)-CPI_TAR)-C5004*(RCS-RCS(-1))+RL),$$

5.10 Fiscal Policy

The fiscal authority rule is set so that the authority targets both the level of public debt to nominal GDP and the rate of change.

The standard policy closure for fiscal policy is simple and passive. It is designed only to ensure that fiscal policy is sustainable in the long run in the sense that public debt does not follow an explosive path.

In the standard fiscal policy closure, the authorities have a target for public debt relative to GDP, which is pursued through adjustments in the rate of labour income tax. The fiscal policy rule like the monetary policy rule is forward looking.

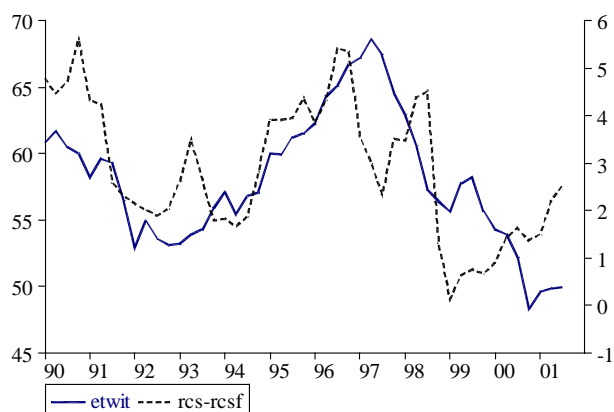
$$POL1 = POL1(-1) + C8001*(PUBDER(8)/ERGDP(8) - PUBDE_EQ(8)) + C8002*(PUBDER(9)/ERGDP(9) - RPUBDE_EQ(9) - (PUBDER(8)/ERGDP(8) - RPUBDE_EQ(8))) + C8003*(RPUBDE_EQ - RPUBDE_EQ(-1)),$$

5.11 Financial Markets

5.11.1 Exchange Rate

The determination of the equilibrium real exchange rate has been discussed in section 2.3 of the steady state structure. Past specifications of the exchange rate dynamics have focussed on using some form of uncovered interest rate parity in explaining exchange rate deviations from the equilibrium value. However, recent experience with applying such a model to the exchange rate have proved unsuccessful in explaining recent (as in the last few years) developments of the New Zealand Dollar. The graph highlights that such a situation would imply a significant appreciation in the New Zealand dollar. Of course we have not seen such an appreciation over the last few years.

Figure 16 TWI and Interest Rate Differential



The steady state model generates an equilibrium path for the real exchange rate index (ERE) for a given set of real variables such as world prices and technology. The medium-run equilibrium real exchange rate index (RE) is driven by the future deviation between the target and actual foreign debt to GDP ratio and can deviate from its steady value in medium term.

$$RE = (((0.25*ERE+0.25*ERE(-1))*EXP(INF_TAR) + 0.25*ERE(-2)*EXP(INF_TAR*2)+0.25*ERE(-3)*EXP(INF_TAR*0.25*3)) - 1.2* LDGDPR(2)-1.2*LDGDPR(3)+ 0.00*(RCS-RCSF)) ,$$

The following equation represents that the actual real exchange rate index (RER) is assumed to adjust towards its equilibrium. The assumption of uncovered interest parity continues to hold if partial adjustment coefficient (C1600) is set at 1.

$$RER= (1-C1600)*RER(-1)*EXP(INF_TAR)+C1600*RE*(1+RCS/400-INF) / (1+(RCSFB+RPRCS)/400-INFW)$$

RCS is the 90-day bill rate and RCSFB is the foreign bill rate. In other words, after adjusting for both domestic (INF) and foreign inflation (INFW) and risk premium (RP), the expected return from both 90-day bill is equal. However, the assumption of uncovered interest parity is not imposed in the model.

5.11.2 Bond Market

The bond market is modelled using the expectations theory of the term structure. This sets the yield on a 10-year bond equal to the expected yield from holding a continuous sequence of 3-month commercial bills over the same 10-year period. This would involve a sequence of 40 commercial bills, which would add 39 expected future commercial bill rates to the model. To avoid this unnecessary complexity, it is assumed that the 10-year bond rate equals a geometrically declining weighted average of expected future commercial bill rates, rather than a simple five-year average. This approximation allows a transformation to be applied which results in the 10-year bond rate, RL, equalling a weighted average of the one quarter-ahead forecast for the 10-year bond rate, RL(1), and the current 3-month bill rate.

$$RL = (1 - 0.95).RCS + 0.95.RL(1)$$

Once again, rational expectations are assumed. Thus new information changes the model forecast for RL(1), causing RL to jump to a new level.

The objections and counter-arguments for this approach are the same as for uncovered interest parity.

Thus a 10-year expected inflation rate, INFE, is needed to convert RL to a real rate. For consistency, the relationship of INFE to the annualised quarterly inflation rate, INF, is the same as the relationship of RL to RCS.

$$INFE = (1 - 0.95).INF + 0.95.INFE(1)$$

6. The Dynamic Properties of NZTM

In this section, we describe the dynamic properties of the model by presenting the results of seven shocks. The first three shocks describe the mechanism through which changes in world prices affect the economy. These experiments demonstrate that the dynamic path of the external export price shock is quite different from that of the import price shock. This illustrates that in a three-sector economy, it is important to determine how the terms of trade shocks are formed. The fourth shock is intended to illustrate how the economy responds to higher nominal wage inflation. We consider a temporary reduction in aggregate demand in the fifth experiment. The final two shocks, which lead to a permanent change in the economy, are raising the level of productivity and lowering the government liability to GDP ratio.

The results of the simulation experiments are presented in Figures one to seven. The responses are expressed either as per cent or percentage point deviations. The units on the horizontal axis are years.

6.1 A Temporary World Export Price Shock

The first shock is a temporary decrease in the world export price. The shock is introduced as a 3 percentage point decrease in the world export price. The shock lasts for 3 quarters.

The price shock results in an immediate deterioration in the current account, which leads to an increase in foreign debt. The real exchange rate depreciates instantly, responding to the future deviation between the target and actual foreign debt to GDP ratio.

Exports are lower initially in response to lower export prices but increase gradually as the real exchange rate depreciates. Demand for imports remains below control until the real exchange rate returns below the equilibrium.

The depreciation in real exchange rates first leads to an increase in inflation. The initial excess supply then reduces inflation to control. Finally the excess demand owing to

higher net exports results in a stronger inflationary pressure. Notice how the forward-looking monetary authority looks through the initial volatility and begins to tighten the monetary conditions three quarters after the shock.

Note that the demand for the domestic good declines initially due to the initial monetary tightening and lower household disposable income arising from higher unemployment. The demand for domestic goods then begins to increase in response to the subsequent easing in monetary conditions.

6.2 A Temporary World Import Price Shock

In this experiment, a 3 percentage point increase in the world import price is introduced. The size and the duration of the terms of trade shock are similar to the previous experiment.

As in the previous shock, worsening the terms of trade induces a real exchange rate depreciation. Unlike the previous shock, the initial fall in exports is much smaller and the initial decrease in the demand for imports is much larger. Consequently, it results in excess demand, which kicks off an inflation and monetary policy response. The monetary authority raises rates sharply after the shock.

Note the initial increase in employment. As the cost of imports increases, firms substitute labour for imports in the production. Firms continue to take on workers while the real exchange rate remains above control.

6.3 A Permanent Increase in World Export Prices

In this experiment, we investigate the dynamic path of a permanent improvement in the terms of trade. The impact of the permanent shock leads to a new long-run equilibrium path. The long-run properties of the steady state model with a permanent shock to the world export prices have been discussed in detail in the previous Chapter.

Given that the desired foreign debt ratio has not changed, the real exchange rate must appreciate to achieve the desired target in the long-run equilibrium, which reduces the

cost of imports and make more resources available for the domestic goods sector. The welfare gain of the permanent increase in world export prices can be estimated roughly by the amount of increased demand for domestic goods.

Initially, the dynamic adjustment path is similar to that of the temporary world price shock. The shock affects the current account balance first through rising world prices and hence the foreign debt position is lower than the desired level. Consequently, the real exchange rate appreciates and overshoots the new equilibrium level.

The impact of higher world export prices on export volumes is fully offset by the real exchange rate appreciation by the end of the first year. Combined with the increase in imports, lower foreign demand for exports generate a decline in aggregate demand.

As a result, there is a downward pressure on inflation and the level of unemployment is above the control. The forwarding-looking monetary authority projects that inflation will fall below the target and therefore loosens monetary conditions. The easing in the monetary conditions helps to stimulate domestic demand and the demand for the domestic goods gradually converges to its new equilibrium.

After seven years, the real exchange rate returns to its new equilibrium as the desired foreign debt to GDP ratio is achieved.

6.4 A Temporary Increase in Nominal Wages

This shock reports the results of a temporary increase in nominal wages, which raise the real wages by close to a percentage point. The mechanics of the shock is straightforward. The increase in real wages stimulates consumption demand, which in turn causes inflation to rise. Monetary policy tightens to prevent inflation rising. On the supply side, firms take on fewer workers and more imports in response to higher real wages. Higher input costs also make the export sector less competitive internationally. As a result, the level of current account deficit is above control and hence leads to higher foreign debt.

In order to attain the external balance, the real exchange rate depreciation must be employed. The real wage is gradually restored to its equilibrium as price inflation picks up and rising unemployment begins to dampen nominal wages growth.

6.5 A Temporary Demand Shock

This shock is intended to illustrate how a temporary increase in aggregate demand is transmitted through the economy. Consumption increases by 0.5 per cent and both business and residential investment increase by 1 per cent. The shock lasts for one quarter.

The increase in demand leads to an increase in inflation and the monetary authority tightens monetary conditions instantly to prevent inflation expectation from rising. Strengthening domestic demand fuel import growth. Exports increase on the back of stronger investment growth. However, the net exports are below control, which cause the current account deficit to rise. This sets off the real exchange rate to depreciate. Note that it takes about two years for inflation expectation returning to control.

6.6 A Permanent Increase in the Level of Productivity

In this shock, the level of productivity increases permanently by 0.5 per cent. The dynamic path of the shock is very similar to that of a permanent increase in world export prices. Both shocks permanently raise the level of the living standard by increasing private consumption and investment in the long run. The initial negative output gap reflects the higher productivity of the firm and hence the deflationary impact of the shock.

Consequently, the monetary authority needs to loosen monetary conditions to stimulate aggregate demand. In response to monetary easing, the firms increase the capital stock to its new long-run level as higher productivity raises the marginal return of capital. The benefit arising from higher productivity gradually passes to households by raising real wages. The increase in disposable income raises consumption slowly to its new equilibrium.

Initially, the adjustment to the new steady state also requires the real exchange rate to appreciate initially, as the desired level of foreign debt is higher than its initial equilibrium. However, it is important to note that the desired ratio of foreign debt to GDP ratio remains unchanged and the real exchange rate rises smoothly back to its original long-run level. In response to the initial real exchange rate appreciation, firms

reduce their export supply. On the back of the real exchange rate depreciation, exports begin to rise until it reaches its new equilibrium. Both imports and exports are higher in the new equilibrium by 0.5 per cent. In this respect, it is interesting to contrast this shock with the permanent increase in the world export prices. In the price shock, there is a permanent appreciation of the real exchange rate and exports stabilise just above their initial level.

6.7 Reducing the Public Liability to GDP Ratio

In this shock, the government lowers the government's target debt to GDP from 30% to 28%. In order to pay off debt faster, the government has to raise the personal income tax rate sharply. Consequently, consumption falls by over 2 per cent, relative to control, which in turn leads to a reduction in aggregate demand. As a negative output gap emerges, the monetary authority must loosen monetary conditions in order to offset the impact of the shock.

The decline in government debt implies that there are fewer financial assets available for households' wealth. To maintain the same level of financial wealth as before, households substitute foreign assets for domestic assets. Consequently, the new desired foreign debt to GDP ratio must fall, which set off the real exchange depreciation. Combined with the easing in monetary conditions, the real exchange rate depreciation raises aggregate demand above supply just one year after the shock.

Figure 16 A temporary decrease in world export prices

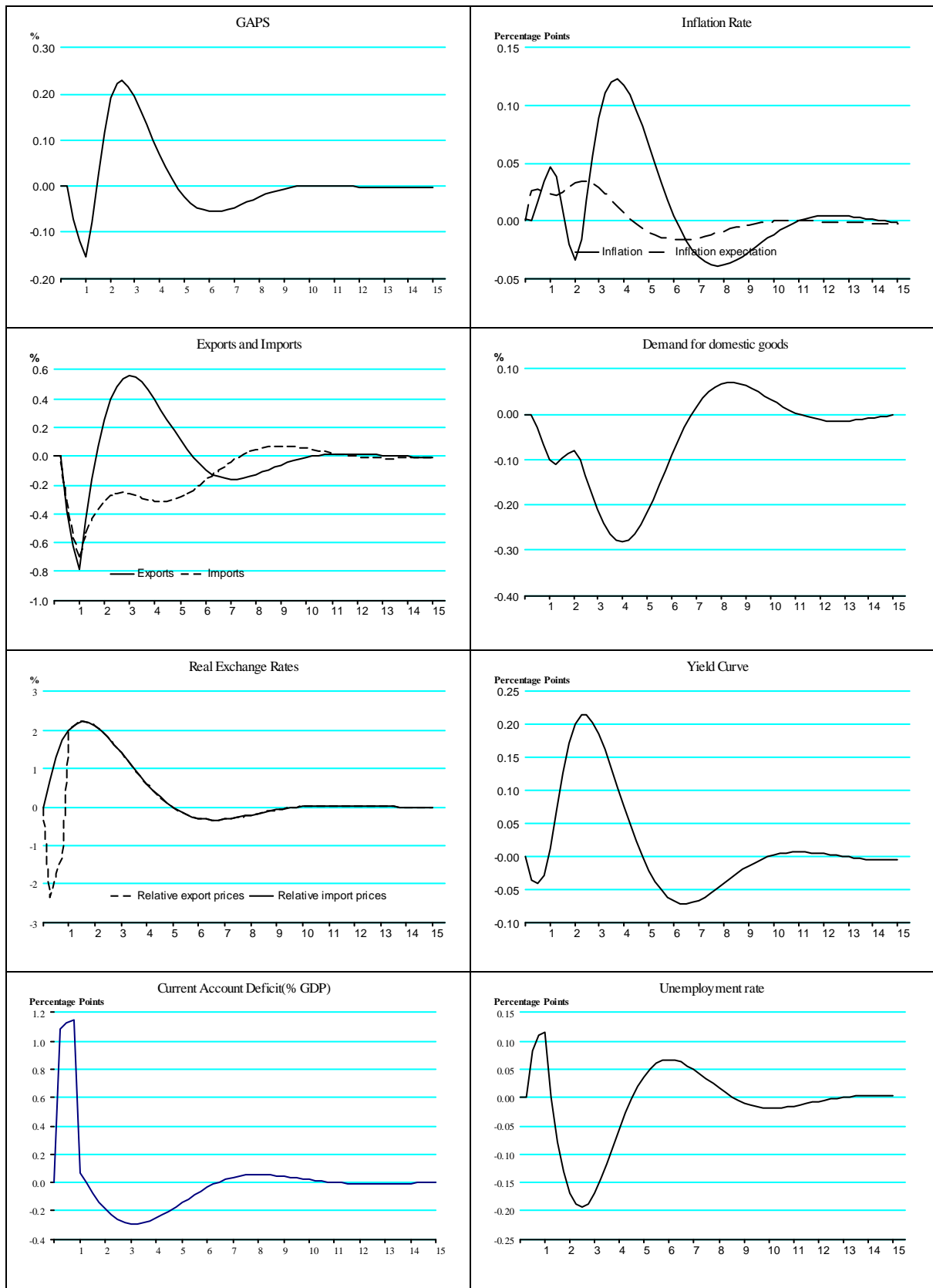


Figure 17 A temporary increase in world import prices

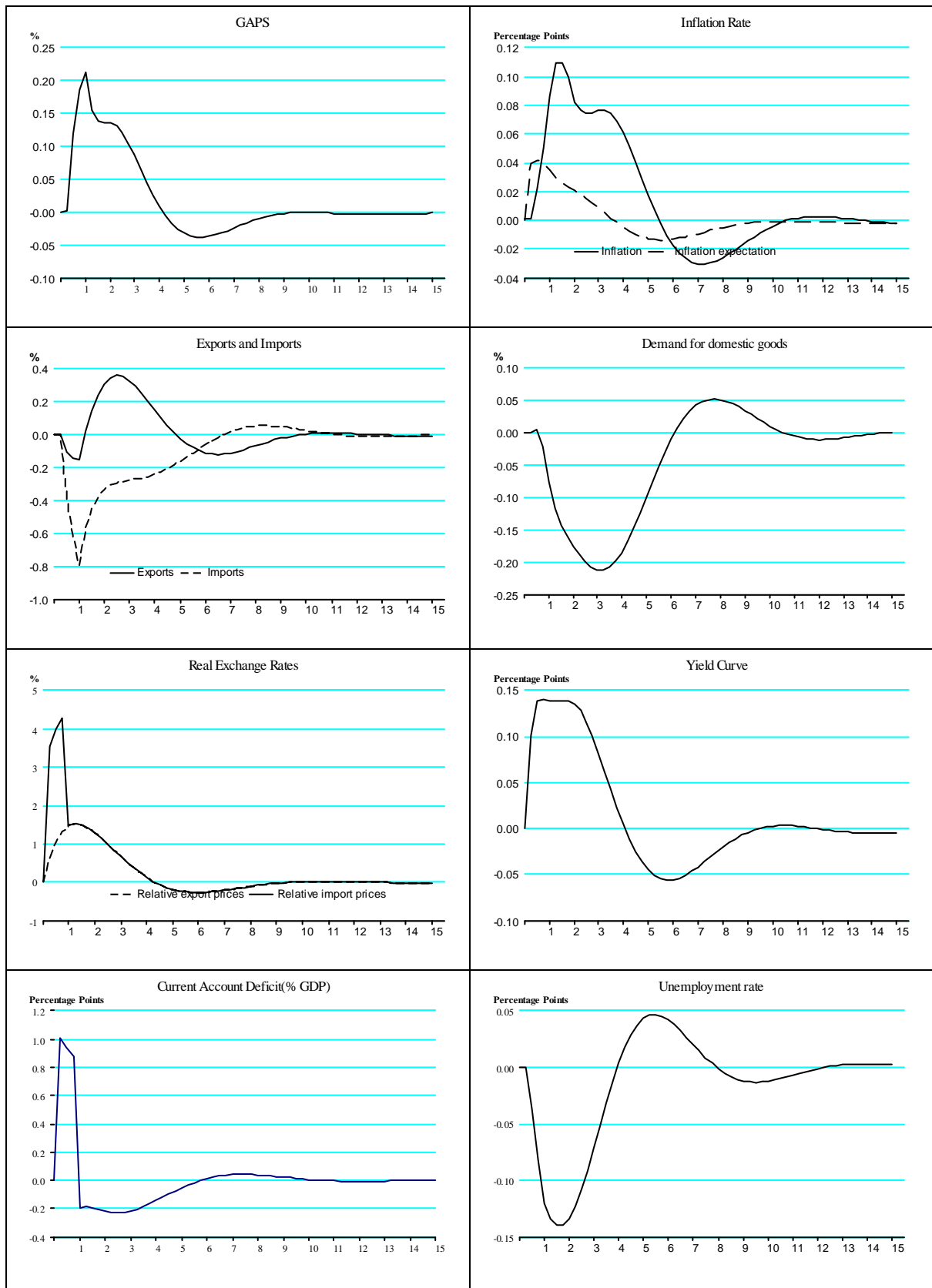


Figure 18 A permanent increase in world export prices

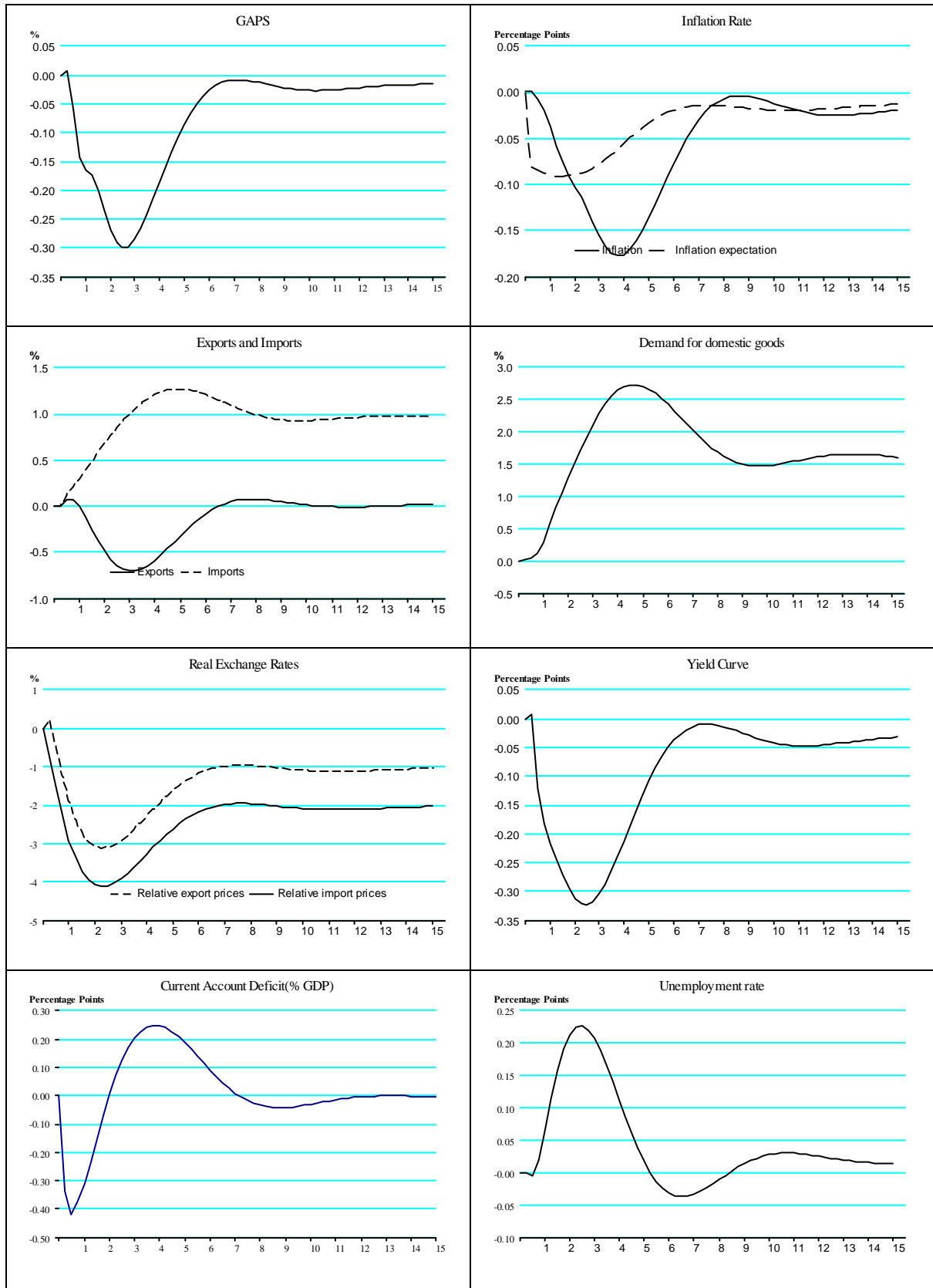


Figure 19 An increase in nominal wage demands

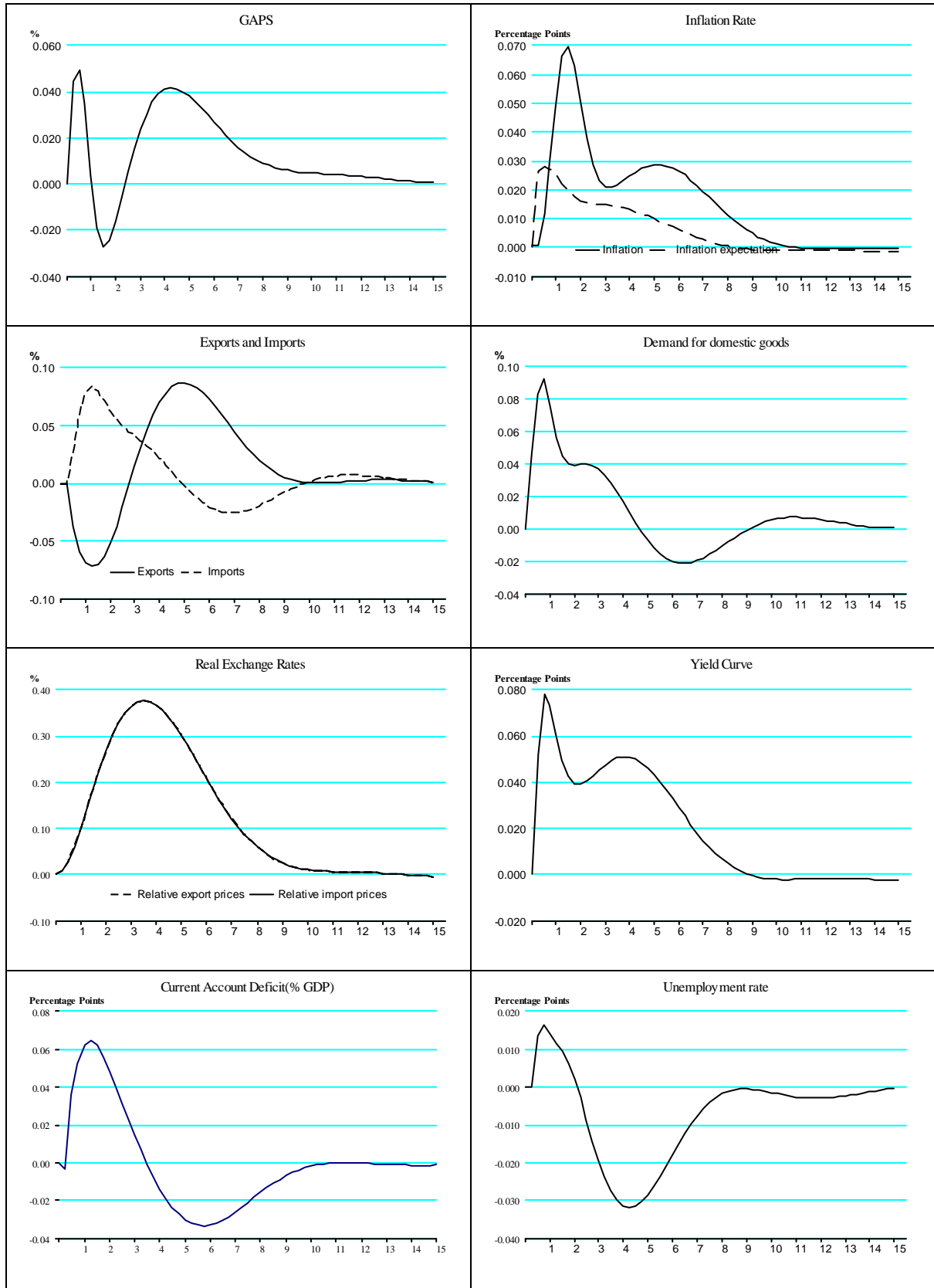


Figure 20. A temporary demand shock

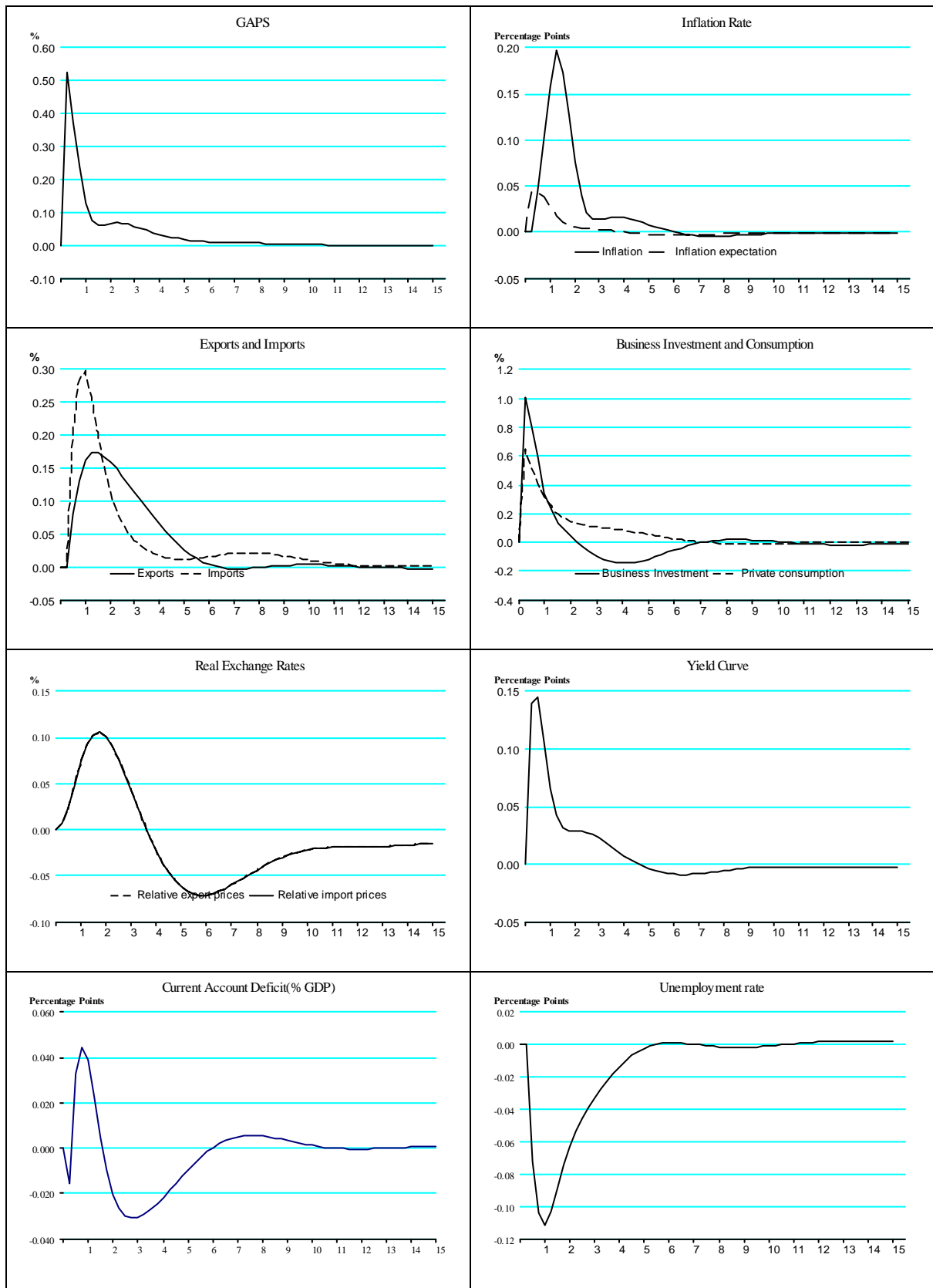


Figure 21 A permanent increase in the level of productivity

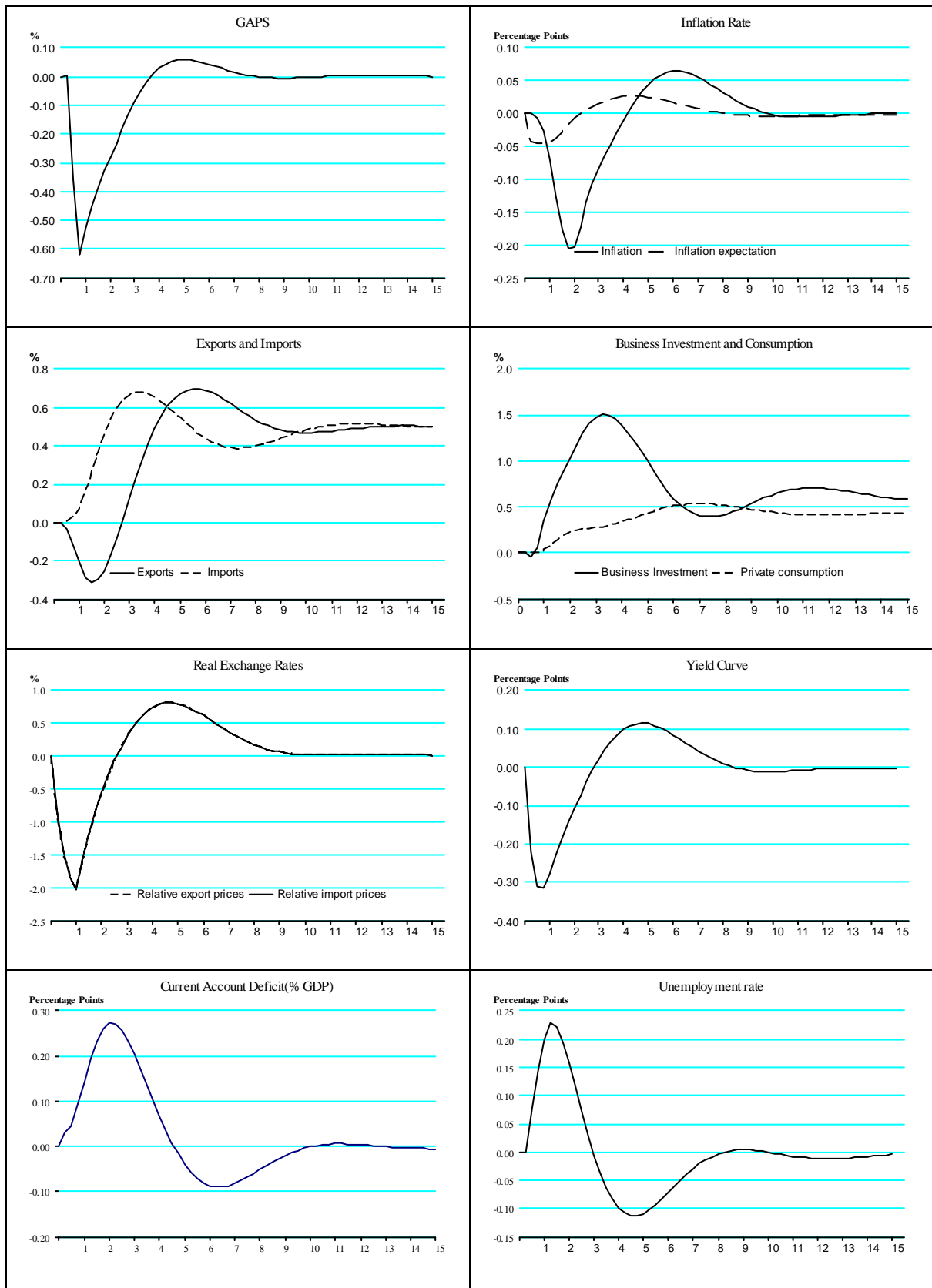
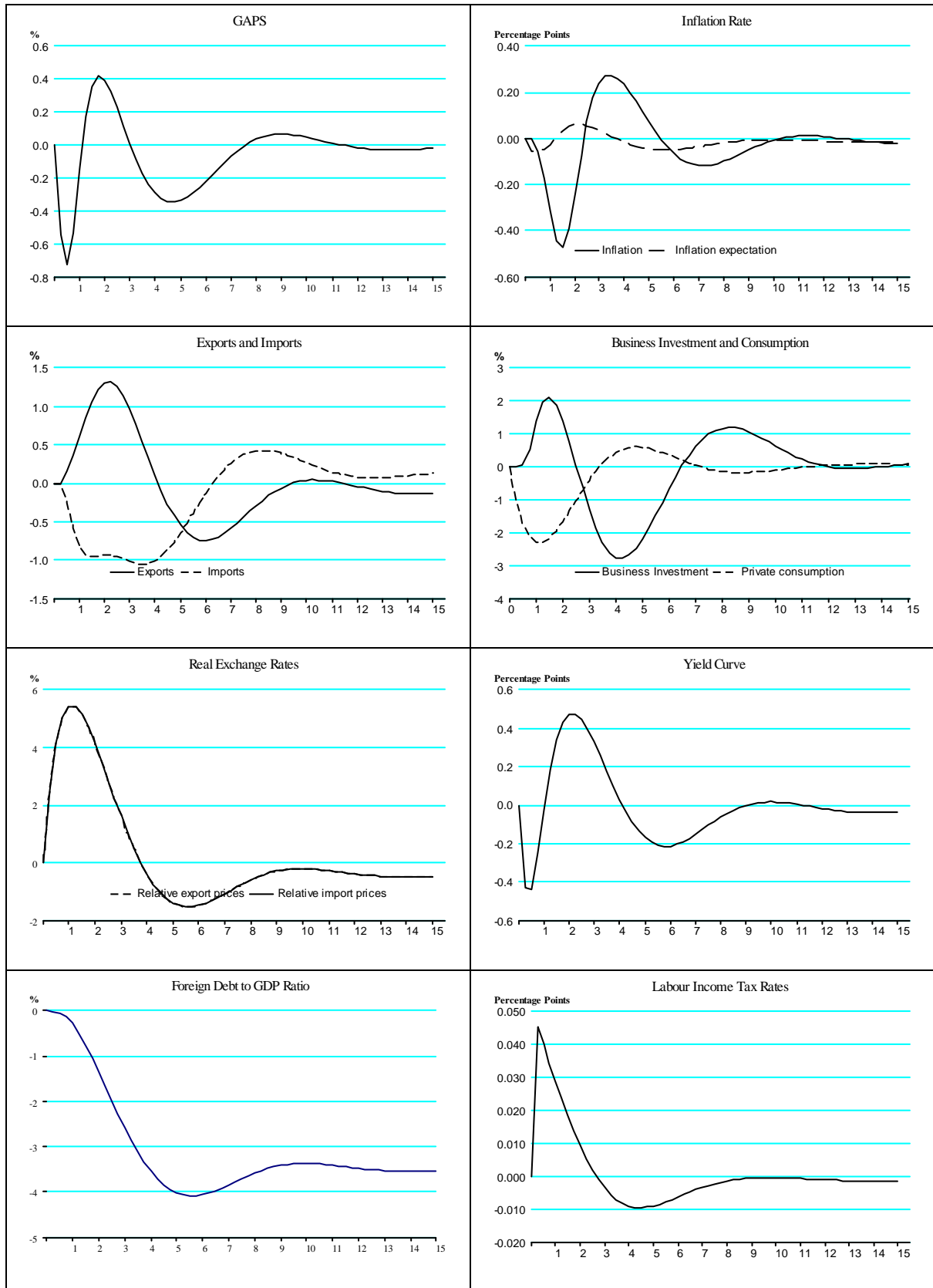


Figure 22 Reducing the public liability to GDP ratio



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