DP2000/02

A comparison of the properties of NZM and FPS

Aaron Drew and Benjamin Hunt

March 2000

JEL classification: E10, E17, E63

Discussion Paper Series

Abstract[1]

The New Zealand Treasury and the Reserve Bank of New Zealand both maintain and use comprehensive macroeconomic models of the New Zealand economy: NZM and FPS respectively. In this paper, shocks are applied to the two models to illustrate and compare their dynamic properties. The most notable differences arise from their characterisations of the inflation process. In NZM, inflation is modelled as a cost-push phenomenon, whereas FPS models inflation as a demand pull process. Consequently, shocks arising from demand and cost sources often have quite different implications for monetary policy in the two models. In contrast, in general the long-run responses of the models to permanent shocks are quite similar, although the transition paths differ reflecting both the differing inflation processes and adjustment dynamics.

---

[1] The views expressed in this paper are those of the authors and may not represent the views of the New Zealand Treasury or the Reserve Bank of New Zealand. Ben Hunt is now an economist in the Research Department of the IMF. Our thanks to Kam Szeto and Paul Gardiner from the New Zealand Treasury for their assistance in implementing NZM into TROLL, and for comments on the paper. Any remaining errors and omissions are the responsibility of the authors.

1 Introduction

The Reserve Bank of New Zealand and the New Zealand Treasury both maintain comprehensive macroeconomic models of the New Zealand economy. The two models share some similar theoretical underpinnings, however, there are some notable differences in their structures and in the way their parameter values have been chosen. To develop a better understanding of the their differences and similarities, this paper presents a comparison of the two models.

Although both models are based on a neo-classical balanced-growth paradigm, there are a number of notable structural differences. One key difference is how the two models characterise the inflation process. In NZM, inflation is modelled as a cost-push phenomenon, whereas FPS models inflation as a demand pull process. Another notable difference is found on the supply side. NZM uses a multi-good production framework while FPS is based on a single good paradigm. In addition to structural differences, some of the parameter values that are used in the models equations have been chosen using a different approach. All the parameters that appear in the FPS equations have been chosen through a calibration process. As well as relying on calibration, NZM also contains some parameter values that have been estimated directly from the New Zealand data using standard econometric techniques.

In addition to structural and parameterisation differences, the two models also characterise the monetary and fiscal policy processes differently. Consequently, some modifications to the monetary and fiscal policy rules contained in the models were required to put the models on a comparable basis. To facilitate the comparison of model properties, NZM has been coded into the Troll software used with FPS at the Reserve Bank.

The comparison of the properties highlights some interesting differences. The most notable differences in properties arise from the differences in the characterisation of the inflation process in the two models. Because of this, shocks arising from different sources often have quite different implications for the required response of monetary policy in the two models. The fiscal shocks considered, however, yielded quite similar responses. In general, the long-run responses of the models to permanent shocks are quite similar, although the dynamic adjustment paths to that long run are at times quite different.

The remainder of the paper is structured as follows. Section 2 contains a brief discussion of the structure and parameterisation of the two models. In section 3, the changes to the policy rules that were required to put the two models on a comparable basis are outlined. Section 4 contains the responses of the two models to some stylised shock experiments designed to illustrate their macroeconomic properties. Section 5 concludes the paper.

2 The structures of FPS and NZM[2]

2.1 Overview of the models

NZM and FPS describe the interaction of five economic agents: households, firms, government, a foreign sector, and the monetary authority. Both models possess a two-tiered structure. The first tier is an underlying steady-state structure that determines the long-run equilibrium to which the models converge. The second tier is a dynamic adjustment structure that traces out how the economy converges towards the long-run equilibrium.

In both models the long-run equilibrium is characterised by a neoclassical balanced growth path, where labour, capital and productivity growth fuel economic growth. In FPS, the equilibrium path for consumption is derived from the consumer's utility maximisation problem. Households choose a marginal propensity to consumer out of total wealth that maximises the utility from their expected life-time consumption stream. In NZM, equilibrium consumption is determined by marginal propensities to consume out of labour income and non-human wealth. The marginal propensities are based on the shares of labour and property in national income. In both models, firms maximise profits and government achieves exogenously-specified targets for debt and expenditures. The foreign sector trades in goods and assets with the domestic economy. In FPS, the actions of these agents determine expenditure flows that support a set of stock equilibrium conditions for capital, government debt and net foreign assets that underlie the balanced growth path. In NZM, stock equilibrium conditions exist for capital and government debt, but not for the net foreign asset position.

In NZM, the dynamic adjustment to the economy's long-run equilibrium is largely modelled as an error-correction process. Agents respond to deviations between dynamic and equilibrium values by adjusting their behaviour to resolve the disequilibria as they move through time. Monetary and fiscal policy influence the adjustment process in order to achieve their respective objectives. Forward-looking, model-consistent expectations in key financial variables also play an important role in the dynamic adjustment.

In FPS, the dynamic adjustment process embodies both "expectational" and "intrinsic" dynamics. Expectational dynamics arise through the interaction of exogenous disturbances, policy actions and private agents' expectations. Intrinsic dynamics arise because adjustment is costly. The costs of adjustment are modelled using a polynomial adjustment cost framework[3]. In addition to expectational and intrinsic dynamics, the behaviour of both the monetary and fiscal authorities also contributes to the overall dynamic adjustment process. Overall, the differences between the dynamic adjustment processes in the two models are of form rather than function. Appeals to intrinsic and expectational dynamics are often used to motivate the dynamic processes in reduced-form error-correction models.

On the supply side, FPS is a single good model. The production technology is Cobb Douglas with labour and capital as the inputs. The resulting single good is differentiated in its use by a system of relative prices. In contrast, NZM has a production process for three different goods;

---

[2] For the original sources on the structures of the model's see Black et al. (1997) and Murphy (1998).

[3] See Tinsley (1993).

a consumption/investment/manufactured export good, rural exports, and housing. The production technology for the first two goods is given by constant elasticity of substitution/transformation functions. Imports as well as capital and labour are inputs into these production functions. The solution to the representative firm's profit maximisation problem yields both the long-run sustainable level of output as well as the desired price level given input costs. Production of the housing good is based on a Tobin-q model.

In FPS, inflation can potentially arise from many sources; however, it is fundamentally the difference between the economy's supply capacity and the demand for goods and services that determines inflation in domestic goods prices. Further, the relationship between goods markets disequilibrium and inflation is specified to be asymmetric. Excess demand generates more inflationary pressure than an identical amount of excess supply generates in deflationary pressure.[4] In NZM, the inflation process is characterised as a mark-up process. In the short run, if the level of market demand deviates from firms' profit-maximising level of output at current prices, then firms adjust prices over time until the first-order conditions from their maximisation problem are satisfied given technology and input prices.

2.1 Households

In FPS, there are two types of households: "rule-of-thumb" and "forward-looking." Forward-looking households save, on average, and hold all of the economy's financial assets. Rule-of-thumb households spend all their disposable income each period and hold no assets. The theoretical core of the household sector is the specification of the optimisation problem for forward-looking households.[5] In this framework, the forward-looking household chooses a path for consumption – and a path for savings – that maximises the expected present value of lifetime utility subject to a budget constraint and a fixed probability of death. This basic equilibrium structure is overlaid with polynomial adjustment costs, the influence of monetary policy, an asset disequilibrium term, and an income-cycle effect. Aggregate consumption is decomposed into its various components in a satellite model.[6]

In NZM, equilibrium consumption is given by a reduced-form consumption function. Consumption is a function of labour income and both financial and real assets. The propensities to consume out of which have been calibrated to reflect their relative shares in national income. Dynamics arise from an error-correction process, the deviation of the "ideal" price of consumption from inflation expectations, and anticipated changes in consumption taxes. The component of consumption corresponding to housing investment is modelled directly in NZM and is used to decompose consumption into two components.

---

4 Although the body of empirical evidence supporting asymmetry in the inflation process in both New Zealand and elsewhere is growing, the most convincing argument for using asymmetric policy models is the prudence argument present in Laxton, Rose and Tetlow (1994). The evidence for New Zealand is discussed in Black *et al* (1997).

5 The specification is based on the overlapping generations framework of Yaari (1965), Blanchard (1985), Weil (1989) and Buiter (1989), but in a discrete time form as in Frenkel and Razin (1992) and Black *et al* (1994).

6 See Breece and Cassino (1998).

In equilibrium, households supply labour inelastically with respect to the real wage in both models. However, NZM labour supply includes an "encouraged worker" effect based on the level of employment as well as a demographic effect arising from the age structure of the population of working age.

2.2 The representative firm

The firm is modelled very simply in FPS. Investment and capital formation are modelled from the perspective of a representative firm. This firm acts to maximise profits subject to the usual accumulation constraints. Firms are assumed to be perfectly competitive, with free entry and exit to markets. Firms produce output, pay wages for labour input, and make rental payments for capital input. Profit maximisation is sufficient to determine the level of output and the real wage. This simple framework is then extended to incorporate adjustment costs, a "time-to-build" constraint and cyclical fluctuations in the cost of capital.[7]

The equilibrium real wage is determined by labour's marginal product and employment is determined by households' exogenous supply of labour. Over the cycle, an Okun's Law relationship maps goods market disequilibrium into labour market disequilibrium and a wage Phillips curve describes the dynamic adjustment of wages.

The representative firm's profit maximisation problem in NZM assumes CES and CET production technologies. As is the case in FPS, the marginal product of capital condition from the firm's profit maximisation problem determines the desired level for the capital to output ratio. This in turn implies an equilibrium investment flow sufficient to maintain the ratio given growth and depreciation. Partial adjustment, a Tobin-q effect, and the gap between short- and long-term interest rates influence the dynamics of investment around that desired level. Firms' investments in inventories of rural and non-rural output are modelled directly in NZM.

Real wages are determined by a wage Phillips-curve. Firms take the real wage as given and the resulting labour demand determines employment in the long run in NZM. An error correction model that includes an impact from the level of domestic production relative to capital describes the dynamic adjustment path of employment.

2.3 The government

In NZM and FPS the fiscal sectors are very similar. Government has the power to collect taxes, raise debt, make transfer payments and purchase output. Both models exogenously impose clear objectives for government in the long run. The government's binding intertemporal budget constraint is used to solve for the labour income tax rate that supports the fiscal choices.

---

7 The time to build constraint implies that it takes time before new investment is utilised in the production process.

2.4 The foreign sector

In FPS, the foreign sector is treated as completely exogenous to the domestic economy. It supplies the domestic economy with imported goods and purchases the domestic economy's exports and thus completes the demand side of the model. Further, the foreign sector stands ready to purchase assets from or sell assets to domestic households depending on whether households choose to be net debtors or net creditors relative to the rest of the world. Several key prices affecting the domestic economy are also determined in the foreign sector. The foreign dollar prices of traded goods and the risk-free real interest rate are assumed to be determined in the foreign sector. FPS's foreign sector is a complete macroeconomic model on its own. It includes a monetary policy reaction function specified to stabilise inflation. Both foreign shocks and the foreign policymaker's response to them impact the domestic economy. In NZM, the foreign sector plays a very similar role to that in FPS with two notable exceptions. First, the determination of the price of New Zealand's exported manufactured goods is determined by domestic costs. Second, foreign monetary policy does not respond to a shock arising in the foreign sector.

The determination of the real exchange rate is also different in the two models. First, FPS contains an equilibrium exchange rate that is partially a function of households' decision regarding their long-run financial asset position. Given firms' desired level for the capital stock and the exogenously imposed target for the stock of government bonds, households' choice for their equilibrium financial asset position determines the equilibrium level for net foreign assets (liabilities in New Zealand's case). Combined with the terms of trade determined in the foreign sector the equilibrium net foreign asset position pins down the steady value for the real exchange rate. The exchange rate is the price that must adjust to ensure that the domestic economy can service its stock of net foreign liabilities given the terms of trade it faces. In NZM, the determination of the equilibrium path for the real exchange rate occurs in what is known as a 'simultaneous block'. This block includes many variables; consequently, it is difficult to ascertain what the key driver(s) of the equilibrium exchange rate is.

In terms of the dynamic adjustment of the exchange rate, both models rely primarily on uncovered interest parity. However, NZM uses an entirely model-consistent expectation of the forward exchange rate, while FPS relies on an expectation that is partially backward looking and partially model consistent. Because of this difference, the exchange rate in NZM is a pure jumper responding very quickly to new information, whereas the exchange rate in FPS exhibits greater persistence.

2.5 Inflation and the monetary authority

One of the key differences between NZM and FPS is their characterisation of the inflation process. In FPS, inflation is largely driven by the deviation between the demand for goods and services and the productive capacity of the economy. Such frameworks have often been described as "demand-pull" models of inflation. NZM on the other hand characterises the inflation process as been driven primarily by deviations between output prices and the cost of production - a "cost-push" model of inflation.

In FPS, deviations in aggregate demand from the economy's supply capacity cause inflation in the price of domestically produced and consumed goods to deviate from the target rate.

Inflation expectations have a backward-looking component as well as a forward-looking, model-consistent component. Deviations of demand from potential output have an asymmetric effect on inflation. Excess demand causes inflation to increase faster than an equivalent amount of excess supply causes it to decelerate. An exchange rate effect and changes in the foreign dollar price of imported consumption goods are then added to derive the CPI inflation that is targeted by the monetary authority.

In NZM, an increase in aggregate demand relative to the capital stock increases employment. Through the Phillips curve, this causes wage growth to accelerate. Increases in real wages beyond those justified by productivity growth increase firms' desired output price of the domestic good. Increases in the desired output price are transmitted into actual output prices via a partial adjustment mechanism. Because imports are an intermediate input, changes in import prices that arise from movements in the exchange rate or movements in the foreign dollar price of imports also enter the firm's desired price. Domestic goods prices are then combined with the price of housing services to derive the CPI index that is targeted by the monetary authority.

Another importance difference in the inflation processes in the two models is the role accorded inflation expectations. Given FPS was designed to answer monetary policy questions in which inflation expectations are viewed to be of critical importance, inflation expectations play a key role in inflation dynamics in FPS. These expectations are modelled as a partially backward-looking and partially forwarding-looking process with the bulk of the weight being given to recent lagged out turns and near future model-consistent forecasts. In contrast, NZM uses a ten-year moving average of model-consistent forecasts of inflation to proxy for inflation expectations. The implication of this is that under most monetary policy rules the NZM proxy for inflation expectations will be considerably less variable than the FPS proxy.

In both NZM and FPS the monetary authority effectively closes the model by enforcing a nominal anchor. However, there is an important difference in that the standard monetary policy rule in FPS specifies the nominal anchor in terms of a rate of inflation, while the NZM nominal anchor is specified in terms of a price level. In FPS the monetary authority's behaviour is modelled by a forward-looking reaction function that moves the short-term nominal interest rate in response to projected deviations of inflation from an exogenously specified target rate. In the standard version of NZM, the MCI is the policy instrument and it responds to the contemporaneous deviation of the price level from its target path. Given the MCI and the exchange rate, the interest rate is then determined using the MCI trade-off weight.

2.6 Specifying parameter values

The FPS model was parameterised using a process called calibration. Calibration relies on both the properties found in the macroeconomic data, often described as the "stylised facts", as well as economic theory to specify the parameter values for the model's equations. Where possible and sensible, parameter values are taken directly from econometric estimates. However, econometric evidence from both reduced-form equations and vector autoregressions are usually used as starting points to establish sensible ranges for parameter values. The actual parameters values are then narrowed down more precisely using simulation experiments designed to ensure that the broad macroeconomic properties of the model are consistent with what both the data and theory suggest.

Although some parameters in NZM are also calibrated, a large number are obtained directly from econometric estimation of reduced-form equations. Although limitations have been placed on the estimation because many New Zealand data series are quite short and the economy has undergone significant structural change, the parameter estimates in general appear to relatively stable (see Murphy 1998).

3 Policy rules

To sensibly compare NZM and FPS, they must have similar fiscal and monetary policy rules so that differences in properties can be attributed to differences in structure or parameterisation. In this section, the standard monetary and fiscal policy rules that are used in NZM and FPS are described. We then present re-specified monetary and fiscal policy rules. The common rules have been calibrated so that both models respond in a sensible way to an autonomous increase in aggregate demand.

3.1 The standard monetary policy reaction function in FPS

The generic monetary policy reaction function used in FPS is an inflation-forecast-based rule of the form:

$$rsl_t = rsl^* + \sum_{k=0}^{n} \rho_k (\pi_{t+k} - \pi^*) + \alpha \cdot \Delta rn_t$$

where rsl_t is the slope of the yield curve (i.e., the 90-day interest rate less the 5 year rate), rsl^* is the equilibrium slope, π_{t+k} is the projection for annual CPIX inflation at time t, k quarters into the future, and ρ_k is the strength with which policy responds to inflation deviations from the target forecasted k quarters ahead. The π^* appearing in the reaction function is the mid-point of the Reserve Bank of New Zealand’s current target band of 0 to 3 percent. The parameter α smooths the adjustment in *rn*. Finally, note that although the reaction function is written in terms of the yield spread, *rn* is the model’s policy instrument. By shifting the short-term rate, the monetary authority achieves a desired path for the slope of the yield curve. In the ‘standard’ version of FPS used in Bank projections, the numerical values for the above rule are: $\alpha = -0.5$, $\rho_6 = \rho_7 = \rho_8 = 1.4$ and all other ρ_i are set to zero.

3.2 The standard monetary policy reaction function in NZM

The monetary policy reaction function in NZM is a contemporaneous price-level-targeting rule of the form:

$$mci_t = \theta \log\left(p_t / p_t^*\right)$$

where mci_t is the real level of ‘monetary conditions’, p_t is the level of CPIX, and p_t^* is the equilibrium level of CPIX, which grows at 1.5 percent per annum. The coefficient θ is calibrated to the value of 10,000. This value implies that if the price level is 1 percent above target, real monetary conditions are increased by 100 basis points.

The formulation of this rule is different than the formulation of the monetary policy rule in FPS in several respects. First, the short-term nominal interest rate is viewed to be the policy instrument rather than the MCI.[8] Second, the FPS rule is forward looking. A common finding in the literature is that because of the lags between policy actions and inflation outcomes, better macroeconomic performance can be achieved under a monetary policy rule that is forward looking.[9] Finally, the NZM rule is based on a price-level target rather than the inflation target used in FPS.

3.3 A common monetary policy rule

Specifying the policy reaction function as a forward-looking short-term interest rate rule with explicit instrument smoothing is a relatively easily task. However, as outlined in section 2, the theoretical structure of NZM is based on price levels. The implication of this is that an inflation-targeting rule cannot be implemented without fundamentally adjusting the core structure of the model. Rather than undertake such a re-formulation of NZM, we specify a price-level targeting rule that is used in both models in the simulations presented in the next section.

The rule is as follows:

$$rsl_t = rsl^* + \sum_{k=10}^{12} \sigma_k (p_{t+k} - p^*_{t+k}) + \alpha \cdot \Delta rn_t$$

where $\sigma_{10} = \sigma_{11} = \sigma_{12} = 0.3$, $\alpha = -0.5$

In this rule, the policy instrument responds to the deviation of the price level from its target level 10-, 11- and 12-quarters ahead.

In general terms, a price-level targeting rule is tougher than an inflation-targeting rule. This reflects the fact that under a price-level target, inflation needs to be returned to target and the price-level drift that arises from the inflation deviations need to be unwound. To mitigate the relative toughness of a price-level rule, the rule above is made even more forward-looking than the standard FPS rule. This lengthening of the response horizon allows the monetary authority more time to unwind the price level drift that occurs when inflation deviates from target. The implications for the properties of both models under the common monetary policy rule are illustrated in appendix 1.

---

8 For a discussion of the role of the MCI in monetary policy in New Zealand, see Hunt and Orr (1999). Recent work by the Treasury has also involved changing the policy instrument to the nominal short-term interest rate.

9 For a discussion of the properties of forward-looking inflation targeting rules, see Drew and Hunt (2000).

3.4 The fiscal policy reaction function in FPS

The fiscal policy reaction function used in FPS is:

$$td_t = \sum_{i=1}^{4} \alpha_i td_{t-i} + (1 - \sum_{i=1}^{4} \alpha_i td_{t-i})(td_t^* + \beta(gb_{t-1} - gb_{t-1}^*) - \chi \cdot \Delta gb_t^*),$$

where td is the rate of tax on labour income, td^* is the equilibrium path, gb is the actual level of government debt relative to potential output and gb^* is the equilibrium government debt-to-output ratio. The sum of α_1 to α_4 equals 0.65, leaving a weight of 0.35 is on the term in brackets.

Following any permanent change to the long-run government debt-to-output ratio, equilibrium paths as well as non-equilibrium paths undergo adjustment. The final term in the reaction function is designed to capture the sort of additional adjustment that may be required in labour income tax rates in response to a change to the long-run debt-to-output ratio. In contrast, the term $\beta(gb_{t-1} - gb_{t-1}^*)$ adjusts taxes both when cyclical pressures cause government debt to move away from equilibrium, and when there are changes to the equilibrium path.

3.5 The fiscal policy reaction function in NZM

The fiscal reaction function in NZM is given by:

$$td_t = td_{t-1} + \beta(gb_t - gb_t^*) + \chi \cdot \Delta(gb_t - gb_t^*),$$

where the definitions of the variables are similar to that in FPS, except that government debt is normalised relative to actual as opposed to potential output. The second term in the reaction function is identical to the second term enclosed in brackets in the FPS reaction function, and the effective response coefficient is also of a similar magnitude being under 0.2. The third term in the reaction function adjusts taxes according to the change in the government debt to output ratio. The weight on this term is greater than one.[10] The implication of this is that, starting from equilibrium, any disturbance that causes output or government debt to move will cause an immediate adjustment in taxes that is close to the magnitude of the deviation of actual debt from the target. In appendix 2 some simulations are presented that illustrate the properties of the NZM and FPS standard fiscal reaction functions.

3.6 A common fiscal policy reaction function

The fiscal policy reaction functions in NZM and FPS are very similar. The tax rate on labour income is adjusted in both models to achieve a target ratio of government debt-to-GDP. In both models, this target is set exogenously. There are, however, some differences in the dynamic properties of the two rules. The primary reason for the difference is that in FPS there is explicit modelling of equilibrium fiscal policy, which provides an anchor for labour income

---

[10] The weight needs to be greater than one to ensure that convergence to the steady state occurs over a ‘reasonable’ horizon following any sizeable permanent change in the debt target.

taxes. Consequently, under their standard fiscal rules, tax rates do not adjust as much in FPS as they do in NZM following a temporary disturbance. This is illustrated in appendix 2.

The common rule addresses the difference between the two reaction functions. The rule is identical to the NZM rule, except that the debt-to-income ratio is based on trend or potential output rather than actual output. Hence the common fiscal policy rule used in the simulations to follow is given by:

$$td_t = td_{t-1} + \beta(gb_t - gb_t^*) + \chi \cdot \Delta(gb_t - gb_t^*),$$

where the level of debt is expressed relative to trend output in NZM and relative to potential output in FPS. In appendix 2 simulations are presented that illustrate the properties of the common rule relative to the standard rules used in NZM and FPS.

4.0 Model properties

In this section, the properties of the models are illustrated by examining their dynamic responses to stylised shocks. The shock experiments we consider can be broken down into two groups: shocks that have only temporary influences and shocks that lead to a permanent change in the economy. Under the temporary shocks there are no changes to the long-run equilibrium, hence the model's dynamics and the actions of the monetary and fiscal authorities drive the dynamic adjustment paths. The permanent shocks illustrate how the economy's equilibrium changes given the disturbance, and the dynamic adjustment that the economy has to undergo to reach that new equilibrium.

The results of the shock experiments are seen in figures one to eight. In all figures, the solid lines shown the NZM model outcomes, while the dashed lines show the FPS model outcomes. Variables are expressed as percentage or percentage point deviations from the original control solutions.

4.1 A temporary increase in domestic aggregate demand

In this experiment, an autonomous increase in the demand for both investment and consumption goods causes aggregate demand to increase by roughly 3 percent above control for one year. The results are seen in figure one. The magnitude and timing of the impulses have been calibrated to have roughly the same impact in both models over the first year. Beyond that horizon, it is the interaction of policy and the models' dynamics that determines the adjustment paths. One of the most interesting aspects that this experiment illustrates is the differing role accorded to expectation in the two models.

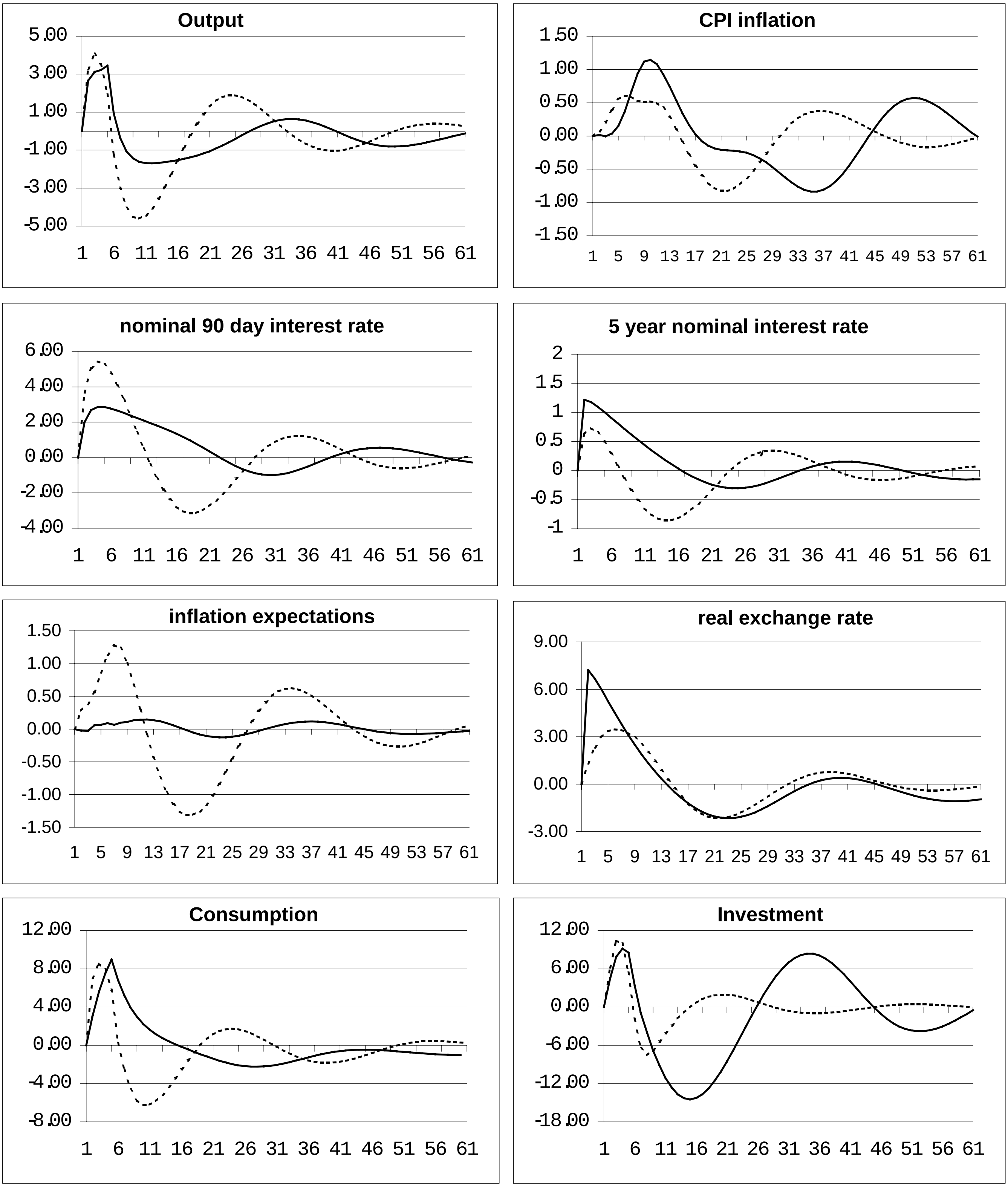
While the initial period of excess demand is similar in the two models, the outcomes for inflation are different. In FPS, inflation responds relatively quickly to the excess demand. This primarily reflects the speed that inflation expectations adjust given the future path for inflation. Expected inflation exceeds the target by just over one percentage point in the first year of the shock. In NZM, inflation expectations are very stable and, consequently, inflation responds much more slowly. First the excess demand in the goods market feeds into wages, then into firms' desired price and then into actual goods prices.

The initially stronger response of monetary policy in FPS reflects the more prominent role that inflation expectations are playing. The short-term interest rate rises by roughly 5 percentage points above control in the first year compared to an increase of just over 2 percentage points in NZM. To achieve the price level target in FPS, the policymaker must first check the initial acceleration in inflation expectations and then reverse it. In the face of the asymmetric Phillips curve in FPS, this requires a sustained period of excess supply. The sharp tightening in policy eventually reduces consumption and investment demand as well as net export demand. Net exports decline because the higher domestic short-term interest rate results in an appreciating currency making exports more expensive and imports cheaper. Once policy has generated the required response of expectations, it must ease quickly to prevent deflation from becoming entrenched. Output and policy continue to experience some mild cycling until the price level has firmly locked in at the target.

Although the tightening in policy and the period of excess supply are milder in NZM than in FPS, they are more prolonged. The short-term interest rate stays above control for the first 5 years of the experiment. The effect of the policy tightening is reflected primarily in investment, as interest rates do not explicitly affect consumption behaviour. Furthermore, investment in NZM is more interest rate sensitive than investment in FPS. The milder yet more prolonged cycling in NZM reflects that a symmetric inflation process is easier to control, and that inflation dynamics are not driven to the same extent by inflation expectations. In NZM, both the exchange rate and the long-term interest rate respond to the policy tightening by much more than they do in FPS. Again this reflects a key difference in the relevant expectations structures of the two models. In NZM, the long-term interest rate and the exchange rate are based purely on model consistent forward expectations. In FPS, foreign long-term rates provide an anchor for domestic long rates, hence the long-term interest rate is only partially based on the expectations theorem. Further, the expected exchange rate in FPS uses lags that serve to anchor it more than its NZM counterpart.

The different expectations structures in the two models result in a notable difference in macroeconomic variability under an identical monetary policy rule. Because inflation is more firmly anchored in NZM, policy and consequently real output are less variable and inflation is actually allowed to be more variable. To achieve the price-level target, the monetary authority in NZM correctly perceives that milder dislocations of the real economy are required. Further, because of the difference in expectations structures in long-term interest rates and the exchange rate, they turn out to be more variable in NZM even with notably less variability in the short-term interest rate.

Figure 1: A temporary increase in domestic aggregate demand
(Shock-minus-control, NZM solid, FPS dashed)



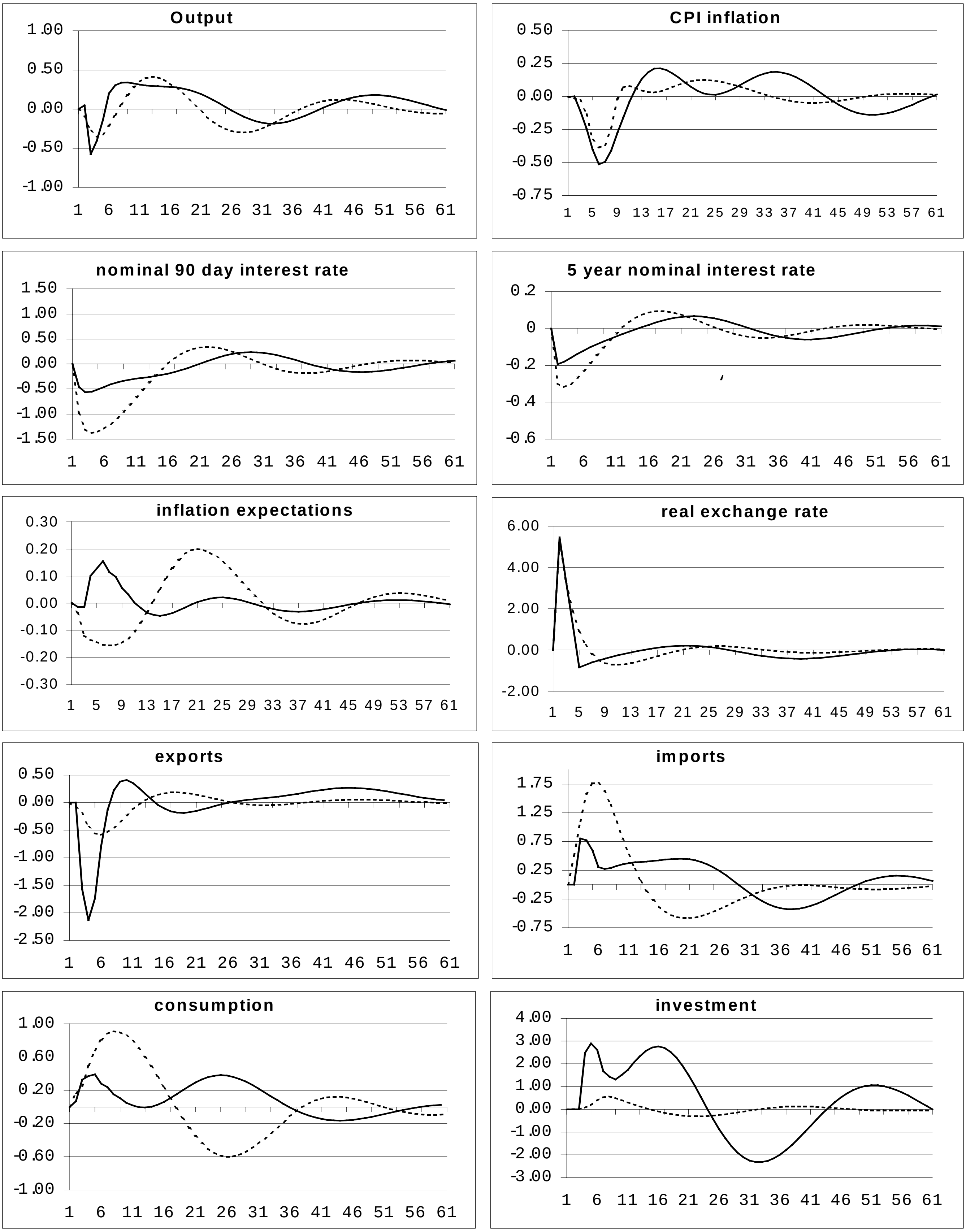
4.2 A temporary appreciation in the exchange rate

In this experiment a temporary increase in the real exchange rate is induced. The shock can be interpreted as a temporary decline in the risk premium on New Zealand assets that is demanded by foreign investors. Again, the shock itself has been calibrated to get a similar exchange rate response over the first year in both models. The interesting aspect that this experiment illustrates is the different response of the tradeables sector to the exchange rate in the two models.

In terms of the interaction of inflation, interest rates and real output this shock illustrates the same key properties as those demonstrated in the demand shock. Interest rates and output are more variable in FPS and inflation is more variable in NZM. The differences, however, are not as pronounced because the magnitude of the shocks effect on output and inflation are considerably smaller. Consequently, the dynamic effect of the interacting between the asymmetric inflation process and expectations in FPS is more muted than in the demand shock. Again, consumption is effected relatively more by monetary policy in FPS, while investment is far more interest rate sensitive in NZM.

The interesting difference that this shock highlights is the response of the components of trade to the real exchange rate. In NZM, the initial decline in exports is much sharper than in FPS, while the increase in imports is much smaller. Although the overall response of domestic demand is quite similar in the two models it appears that import penetration ratios are more price sensitive in FPS and consequently imports are more price sensitive. Exports on the other hand are more price sensitive in NZM than they are in FPS. As a result, net exports behave almost identically in the two and the overall behaviour of aggregate demand is initially quite similar.

Figure 2: A temporary appreciation in the exchange rate
(Shock-minus-control, NZM solid, FPS dashed)



4.3 A temporary increase in nominal wages

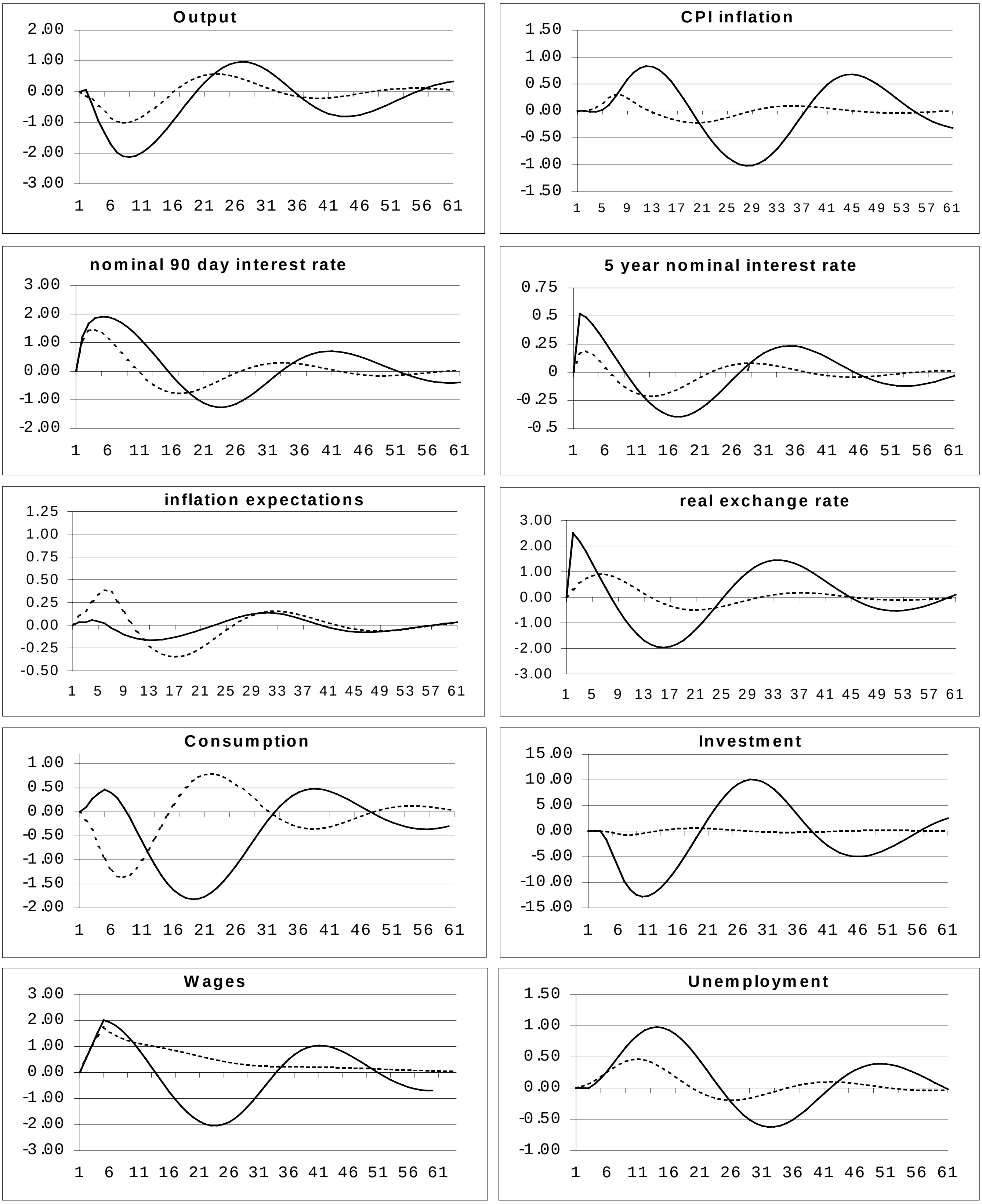
In this experiment the level of nominal wages is increased by approximately 2 percent over the first year. This experiment illustrates the implications of the different inflation process in the two models.

In NZM, the increase in nominal wages causes production costs to rise. Increased production costs lead to an increase in the firm's desired output price and market prices start to increase above control. After roughly two years, CPI inflation is almost one percentage point above control. To maintain the price level target the short-term interest rate rises 2 percentage points above control and stays above control for roughly three years. The tightening in monetary policy reduces aggregate demand (primarily investment and net exports) and output falls below control four roughly five years. Nominal wages themselves cycle below control by about two percent after five years. After this horizon, the macro aggregates all experience some mild cycling before the price level is re-anchored.

In FPS, the macro implications of this shock are considerably milder. Inflation increases by roughly a quarter of a percentage point above control. Nominal interest rates increase by just over one percentage point, generating a mild decline in aggregate demand sufficient to re-anchor the price level. Nominal wages themselves gradually return to control from above.

The different macroeconomic pictures arising from the two models reflect their different characterisations of the inflation process. Viewed as a cost-push process, nominal wage disturbances are very inflationary and a strong policy response is required to maintain the price-level target. However, the demand-pull framework in FPS implies there is relatively little impact of nominal wage increases on prices. Consequently, the policy response in FPS is considerably milder.

Figure 3: A temporary increase in nominal wages
(Shock-minus-control, NZM solid, FPS dashed)



4.4 A temporary increase in foreign demand

In this experiment foreign demand increases by roughly one percentage point for a period of one year. This is an important experiment for any model of a small open economy like New Zealand. Disturbances arising in the rest of the world are of significant importance to the properties of the business cycles experienced by small open economies. This shock illustrates the implications of the more complete modelling of the foreign economy in FPS.[11]

In FPS, the increase in foreign demand causes foreign inflation to accelerate. The increase in foreign prices is more pronounced in commodities than in general manufactured consumption goods consistent with historical experience. Given the acceleration in inflation, foreign short-term interest rates increase to stabilise inflation. The increase in short-term rates flows into long-term rates through forward expectations. The tightening in foreign monetary policy eventually generates a period of excess supply in the foreign sector and inflation is subsequently re-anchored at its target rate. These developments in the foreign sector impact the domestic economy through four channels. The increase in foreign demand flows through to exports. Foreign long-term interest rates influence domestic long-term rates. Foreign short-term interest rates influence the exchange rate via the UIP condition and foreign price movements alter the terms of trade faced by the domestic economy.

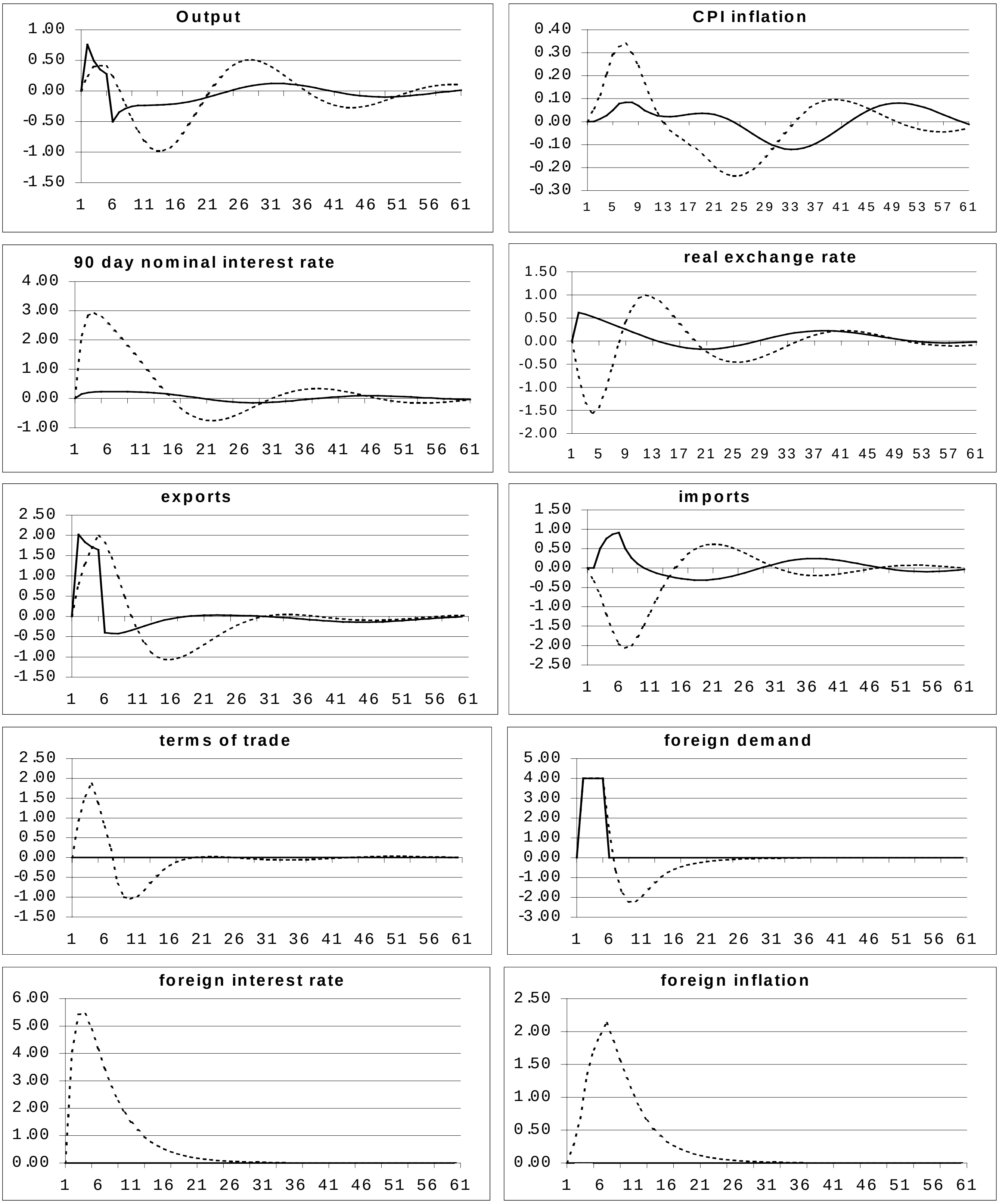
In FPS, output expands as increased foreign demand increases exports. CPI inflation starts to accelerate from both the increase in aggregate demand and the increase in the price of imported consumption goods. The domestic dollar price of imported consumption goods rises even faster than the foreign dollar price because the New Zealand dollar depreciates. Policy responds to the increase in inflation and short-term interest rates rise. However, because the impact of the shock on the domestic economy is smaller than the impact on the foreign sector, foreign short-term interest rates increase by more leading to the initial depreciation in the currency. Eventually the tightening in domestic interest rates generates a period of excess supply that results in the deflation necessary to achieve the price-level target. With CPI inflation eventually going negative, the exchange market perceives that domestic real interest rates will be above foreign rates and the currency appreciates, further dampening demand pressures in the domestic economy. The foreign tightening also contributes to easing the domestic demand pressure. As the foreign sector goes in to excess supply, export demand declines. After the initially period of excess supply, the domestic economy experiences some mild cycling as the price level is re-anchored at the target.

In NZM, the increase in foreign demand increases exports and, consequently, domestic aggregate demand to roughly the same extent as it does in FPS. However, because the shock does not change the firm's desired output price to any great extent, there are only very mild inflationary pressures and short-term interest rates increase considerably less than in FPS. With foreign interest rates unchanged, the small increase in domestic short-term interest rates leads to mild appreciation in the currency. Cheaper imports result in import demand increasing compared to the fall that occurs in FPS. Beyond the initial surge in exports and aggregate demand, the domestic economy experiences very little dislocation from the foreign demand disturbance.

---

[11] Although NZM does not have an endogenous foreign sector, in principle the channels may be accounted for during a projection by applying judgement to the relevant equations of the model.

Figure 4: A temporary increase in foreign demand
(Shock-minus-control, NZM solid, FPS dashed)



4.5 A permanent increase in total factor productivity

In this experiment, total factor productivity is permanently increased by one percentage point. The shock illustrates the many similarities that exist between the underlying steady state frameworks of FPS and NZM. It also illustrates some interesting difference in how the two models describe the dynamic adjustment towards the new steady state.

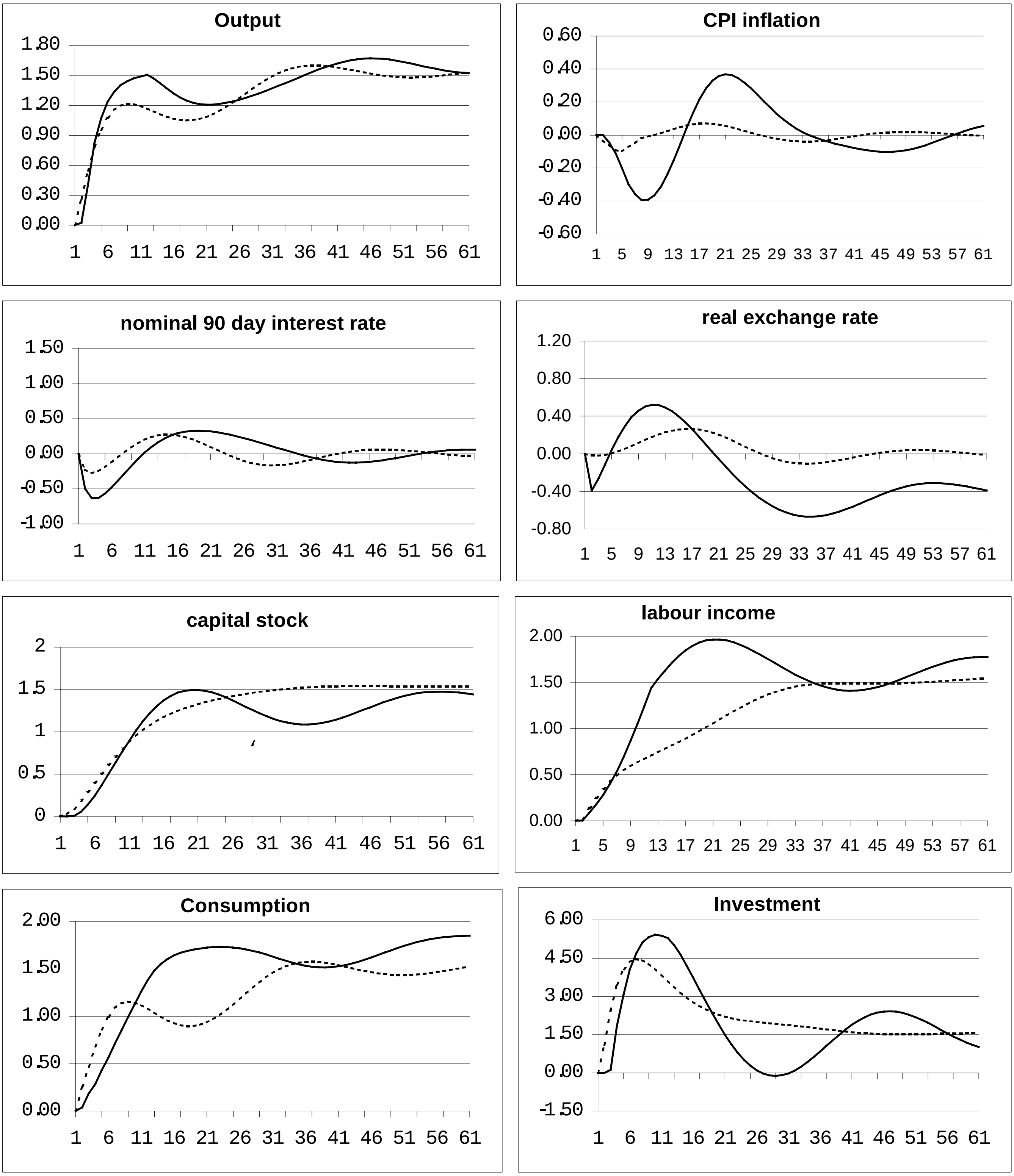
The long-run impact of this shock is virtually identical for all key macroeconomic variables except the real exchange rate. Real output increases by 1.5 percentage points (0.5 percentage points more than the increase in productivity) in both models owing to the permanent increase in the desired capital stock. This occurs because the representative firm increases capital until its marginal return equals its cost. Labour income increases by the full amount of the increase in real output, as under the neo classical framework underlying the models, all the returns from increased productivity accrue to labour. All components of demand maintain their original shares of output and increase by 1.5 percentage points.

The real exchange rate behaves differently in the two models. In FPS, the ratio of net foreign assets to output does not change in this shock thus there is no reason that trade as a proportion of output needs to change. Consequently, there is no requirement for the real exchange rate to adjust. In NZM, there is a permanent depreciation of the real exchange rate. Because there is no explicit framework for the determination of the real exchange rate in NZM, it is difficult to tell exactly why it appears to be stabilising below its initial level. However, theory suggests that for a large or almost small open economy that faces a downward sloping demand curve, a depreciation of the exchange rate is required to increase export volumes.

The dynamic adjustment in FPS occurs relatively smoothly with little role for monetary policy. The minor inflationary pressures that do emerge are the result of demand responding a little faster than supply because of the time-to-built constraint faced by the representative firm. On balance, policy needs to tighten only slightly to maintain the target price level. The intrinsic dynamics in FPS ensures that the bulk of the dynamic adjustment occurs relatively smoothly. All components of demand rise smoothly to their new equilibrium except investment. However, investment must initially rise considerably above its new long-run value to build the capital stock to its new long-run level.

In NZM, the shock generates some deflationary pressures that require a slightly stronger policy response than is required in FPS. The improvement in productivity reduces the firm's desired output price and inflation declines below control. The resulting policy easing generates a slightly more cyclical response of investment, labour income and output in NZM than occurs in FPS. However, given the magnitude of the change in real output, these differences in the dynamic adjustment paths of the two models are relatively small.

Figure 5: A permanent increase in total factor productivity
(Shock-minus-control, NZM solid, FPS dashed)



4.6 A permanent decrease in the government debt-to-output ratio

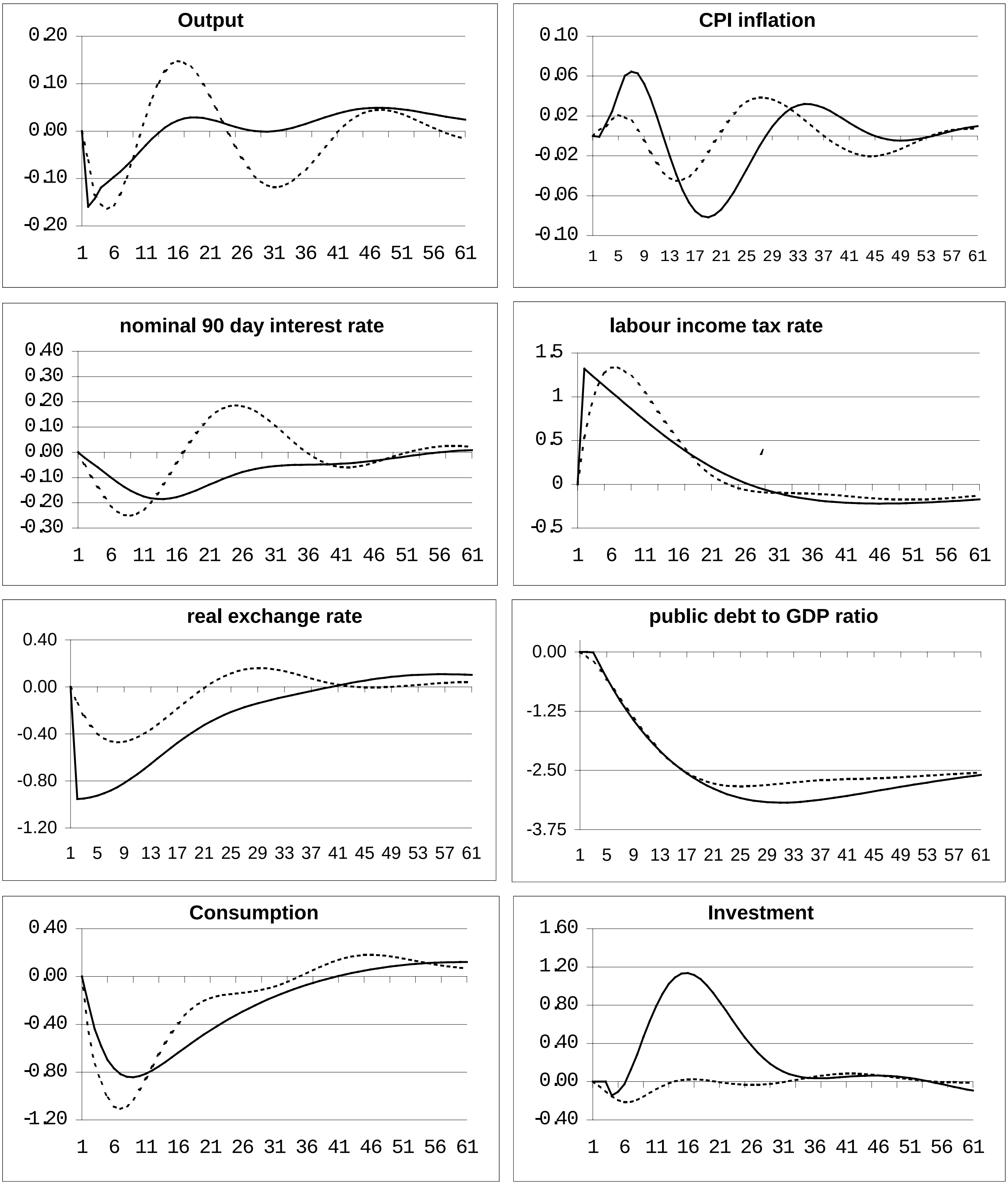
This experiment consists of a permanent reduction in the government's target debt-to-income ratio of 2.5 percentage points. The experiment illustrates that the two models respond fairly similarly to fiscal policy initiatives of this type.

First consider what happens in FPS in the long run. With fewer government liabilities to service, labour income tax rates are lower. Given that households' desired wealth position has not changed, they need to replace the government debt removed from their portfolios with net foreign assets, consequently the long-run net foreign asset-to-income ratio improves by the amount of the reduction in the government debt-to-income ratio. With fewer net foreign liabilities to service, less domestic production needs to be exported, hence the real exchange rate appreciates. The increase in the real exchange rate reduces the cost of imported investment goods and firms' desire capital stock increases, which in turn leads to greater productive capacity. Greater productive capacity, lower import prices and more resources available for domestic uses leads to an increase in consumption.

The dynamic adjustment path looks different than the long-run equilibrium. To improve the fiscal balance sufficiently to reduce debt, the government must increase labour income taxes. Lower disposable income and a desire to improve their net foreign liability position induces households to reduce consumption. The reduction in aggregate demand results in a slight decline in inflation prompting an easing in short-term interest rates. This causes the exchange rate to depreciate via UIP, stimulating exports and curtailing imports. The improved trade balance cumulates into the desired improvement in the net foreign asset position. Once the government has achieved it new debt target, income taxes fall to their new equilibrium. Once the new desired net foreign liabilities position has been achieved the real exchange rate, exports and consumption all converge to their new equilibrium levels. Investment and productive capacity lock in at their new long-run levels once firms have built the capital stock to its new equilibrium.

The new long-run equilibrium in NZM looks identical to that in FPS. Labour income tax rates are lower. The real exchange rate is higher and exports lower. Consumption, investment and output are all higher. As is the case in FPS, the impact of this shock on inflation is relatively minor and, consequently, the monetary policy response is quite mild. In general, monetary policy needs to be slightly more accommodating to offset the impact of the temporary fiscal tightening. The dynamic adjustment of the labour income tax rate in both models is very similar. The only difference is that the tax rate adjustment in FPS is slightly smoother owing to the influence of a more smoothly adjusting equilibrium debt-to-income target.

Figure 6: A permanent reduction in the government debt-to-output ratio
(Shock-minus-control, NZM solid, FPS dashed)



4.7 A permanent improvement in the terms of trade

This experiment is done in two ways to clearly illustrate the forces at work. First we consider a permanent improvement in exogenous world price of New Zealand exports. Then we examine a permanent reduction in the world price of imports.

The responses to the permanent increase in export prices are graphed in figure 7. In FPS, in the long run there is a permanent increase in productive capacity. This arises because firms' increase the capital stock in response to the cost of capital falling. This fall occurs as the real exchange rate appreciates, leading to a fall in the relative price of imported investment. In turn, the real exchange rate appreciation arises because the increase in the value of exports implies fewer real resources need to be exported to service net foreign liabilities. Although the volume of exports increases, imports increase by more resulting in a reduction in the real trade balance. The greater productive capacity, and the larger share of it that is available for domestic use, is allocated to increased investment and consumption.

In NZM the long-run picture is slightly different. First the permanent improvement in output is smaller. The currency does not appreciate as much in the long run and so the permanent improvement in the domestic dollar terms of trade is also smaller than occurs in FPS. Exports themselves are slightly lower in the new equilibrium, as the increase in rural exports is more than offset by a decline in manufactured exports.[12] The overall net export position declines, but only by about a third of the decline that occurs in FPS.

The dynamic adjustment is also slightly different in the two models as monetary policy initially responds in opposite directions. In FPS, demand initially increases faster than supply. Firms increase investment to build the capital stock and households start to consume part of their permanent increase in income. Demand pressures more than offset the downward pressure on inflation from the appreciating currency and the short-term interest rate initially rises to maintain the price-level target. In NZM, inflation initially declines because of the direct effect of the appreciating currency on the CPI and the indirect effect on import prices and thus on firms' desired price. Firms willingly increase the supply of rural exports and no inflation pressures emerge initially. The easing in the short-term interest rate eventually stimulates sufficient investment demand that the firms' desired output price increase and the price level is returned to target.

The models' responses to the permanent reduction in the price of imports are graphed in figure 8. Many of the long-run affects of this terms-of-trade shock in FPS are similar to those that arise from the increase in export prices. Productive capacity increases because the decline in the cost of imported investment goods stimulates an increase in the capital stock. Both imports and exports increase with the net trade balance falling. The real exchange rate, however, must depreciate to generate the increase in export volumes required to service the net foreign asset position given the increased demand for imports resulting from the price decline.

---

[12] The Treasury has been working on changing the structure of NZM so that all export goods are produced under a single production technology that assumes the output price is exogenous. This modification should result in total exports increasing under a permanent positive increase in their world price.

In NZM, the equilibrium structure of the model generates long-run effects that are identical to FPS, although their magnitudes differ somewhat. The increases in output, imports and exports are all smaller. The real exchange rate depreciates by roughly the same amount (the dynamic path has not converged to the long-run equilibrium by the end of the 15-year horizon presented in the graphs).

The difference in the dynamic adjustment paths of the two models is very similar to that which occurs under the positive export price shock. In FPS, the initial impact of the shock is predominantly inflationary and interest rates increase. This arises because demand initially rises faster than supply and eventually more than offsets the initial decline in inflation arising from the direct effect of the fall in import prices. In NZM, the initial impact of the shock is deflationary as both the direct price effect and the second round effects off the decline in input costs cause inflation to fall. Monetary policy therefore eases to maintain the price level target.

Figure 7: A permanent increase in the price of exports
(Shock-minus-control, NZM solid, FPS dashed)

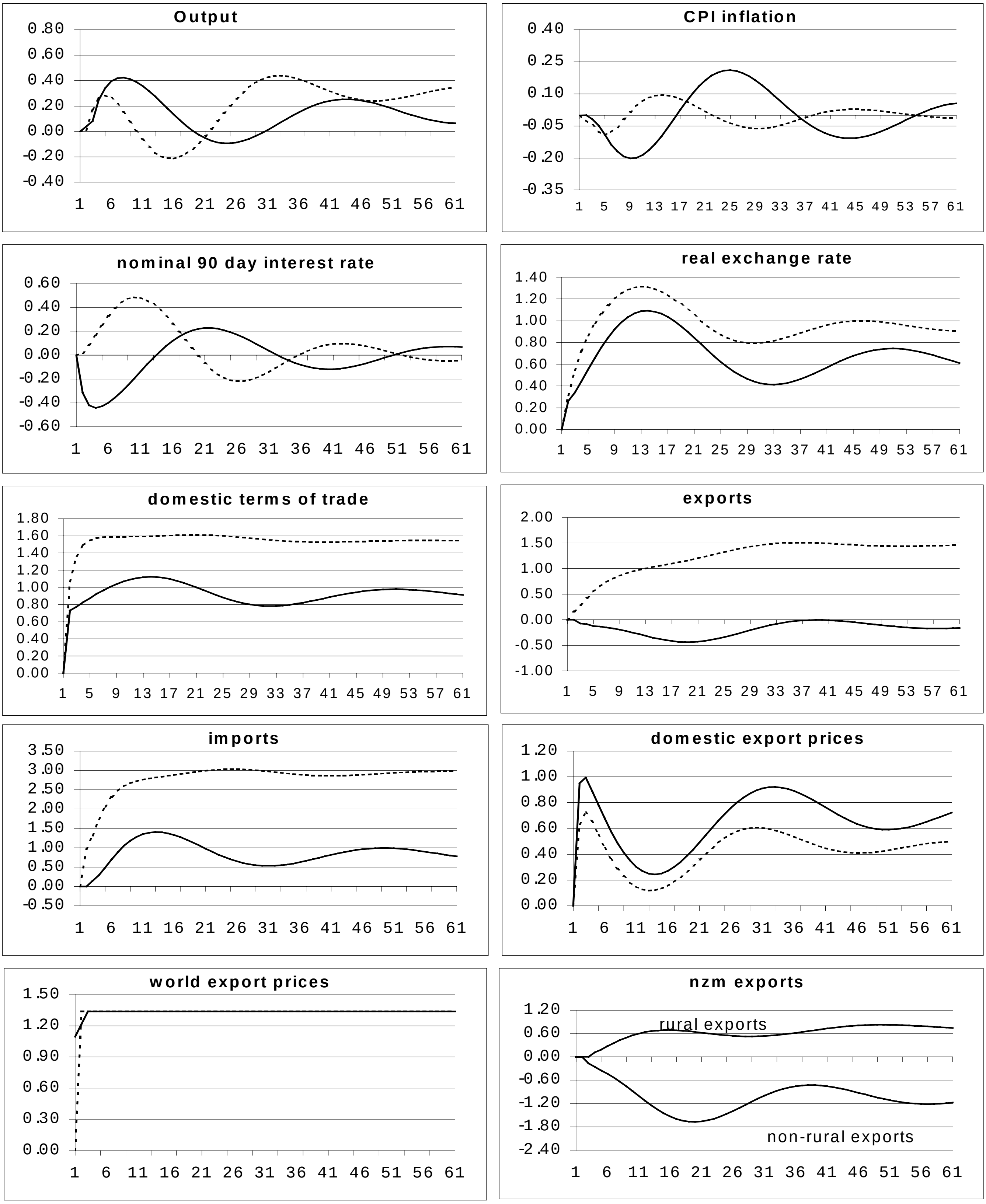
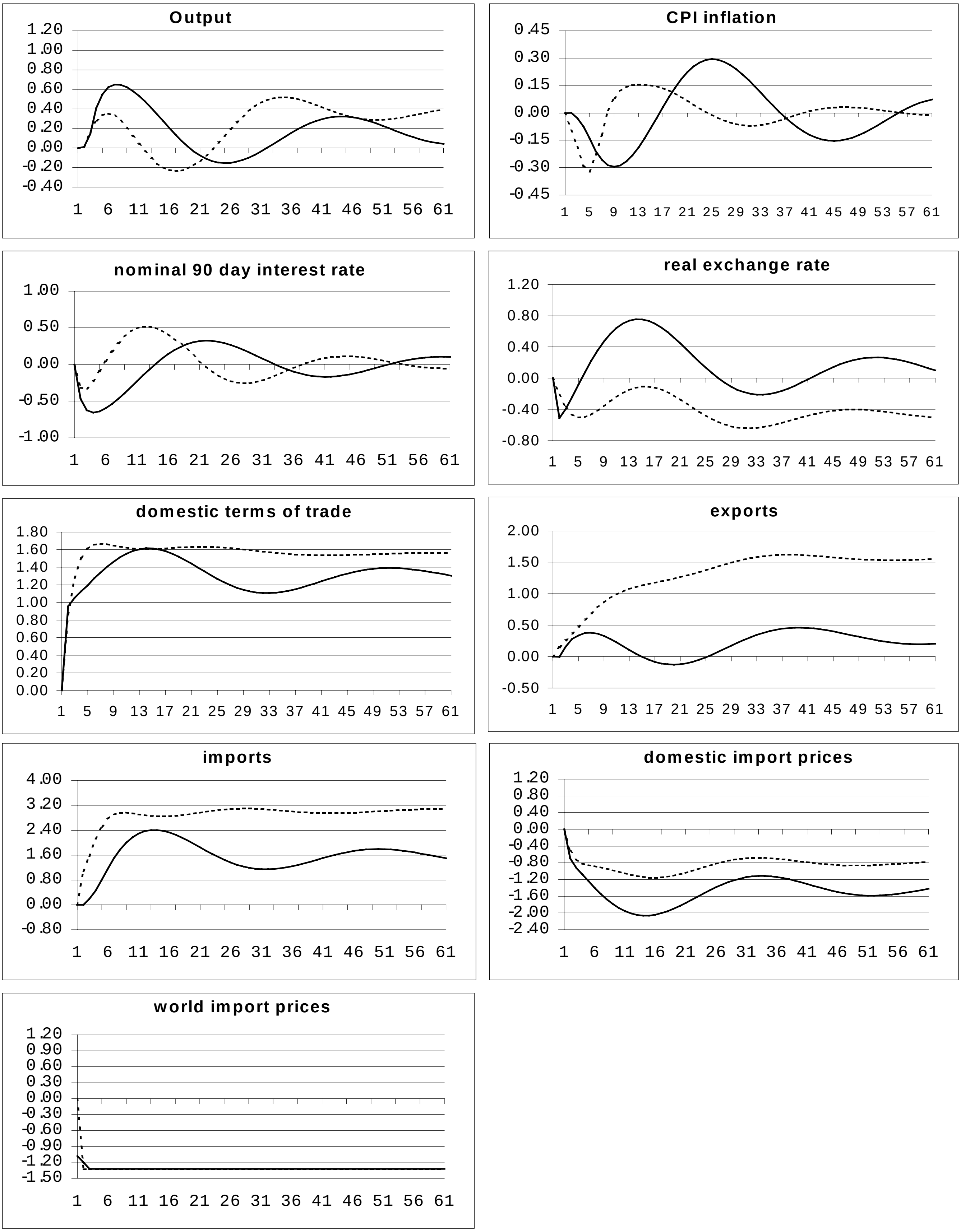


Figure 8: A permanent reduction in the price of imports
(Shock-minus-control, NZM solid, FPS dashed)



5 Summary

In this paper we have compared the macroeconomic models used at the New Zealand Treasury and the Reserve Bank of New Zealand. A brief overview of the core and dynamic structures of the two models is presented focussing primarily on their differences. Common policy rules are developed for use in both models to allow for a comparison of their dynamic responses to a set of stylised shock experiments. That comparison illustrates some interesting differences between the two models.

The most notable differences in the dynamic responses of the two models arise from their different characterisation of the inflation process. In FPS, inflation is characterised as a demand-pull process that accords an important role to inflation expectations. Inflation expectations in turn are highly depended on current and future inflation outcomes and, consequently, monetary policy must work hard to achieve its objective. In NZM, the cost-push characterisation of inflation incorporates inflation expectations that are very well anchored. This means that inflation is at times a much easier process to control for the monetary authority. Because of the different characterisations, shocks that are inflationary in FPS can often be either much less inflationary or actually deflationary in NZM. On the other hand, shocks to input prices that are relatively inflationary in NZM are much less so in FPS. In general, one could say that in response to demand shocks, FPS trades off more variability in output and interest rates for less variability in inflation. In NZM, however, with inflation being well anchored and driven primarily by production costs, output and interest rates tend to be less variable, while inflation is actually more variable. The reverse appears to be true of supply shocks that affect input costs.

One other point regarding the dynamic adjustment differences between the two models is related to how long the models take to converge to equilibrium. The adjustment-cost framework used in FPS appears to result in faster convergence to the long-run equilibrium. The error-correction process used in NZM results in much slower convergence. This reflects the fact that error-correction processes only ensure asymptotic convergence.

In terms of their long-run equilibrium responses to permanent disturbances, the two models appear to be quite similar. The differences that do arise reflect primarily the different production processes for rural and manufactured exports in NZM. However, recent Treasury work on this sector of NZM could go a long way towards reconciling these differences.

References

Black, R, V Cassino, A Drew, E Hansen, B Hunt, D Rose and A Scott (1997), "The Forecasting and Policy System: the core model", *Reserve Bank of New Zealand Research Paper* No 43, Wellington.

Black, R, D Laxton, D Rose and R Tetlow (1994), "The steady-state model: SSQPM." The Bank of Canada's New Quarterly Projection Model, Part 1, Technical Report Number No 72, Ottawa: Bank of Canada.

Blanchard, O J (1985), "Debt, deficits and finite lives", *Journal of Political Economy* 93, 223–47.

Buiter, W H (1988), "Death, birth, productivity growth and debt neutrality," *The Economic Journal* 98 (June), 279-93.

Drew, A and B Hunt (2000), "Efficient policy rules and the implications of potential output uncertainty," *Journal of Economics and Business* Special edition on Money and Monetary Policy in a Changing World, 52, no1/2.

Frenkel, J A and A Razin (1992), *Fiscal Policies and the World Economy*, Cambridge: MIT Press.

Hunt, B, and A Orr (1999) "Inter-forecast monetary policy implementation: responding to unexpected exchange rate developments" *Reserve Bank of New Zealand Bulletin* 62, 1, 62-74.

Laxton, D, D Rose and R Tetlow (1994), "Monetary policy, uncertainty and the presumption of linearity," *Bank of Canada Technical Report*, 63.

Murphy, C (1998), "New Zealand Model 1998 (NZM98)," Report of September 1998 by Econtech, Commissioned by the New Zealand Treasury

Tinsley, P A (1993), "Fitting both data and theories: polynomial adjustment costs and error-correction decision rules," Unpublished paper. Division of Statistics and Research, Board of Governors of the Federal Reserve System, Washington.

Weil, P (1989), "Overlapping families of infinitely-lived agents," *Journal of Public Economics* 38:183-98.

Yaari, M E (1965), "Uncertain lifetimes, life insurance, and the theory of the consumer," *The Review of Economic Studies* 32, 137-50.

Appendix 1

A comparison of inflation- and price-level-targeting rules in FPS

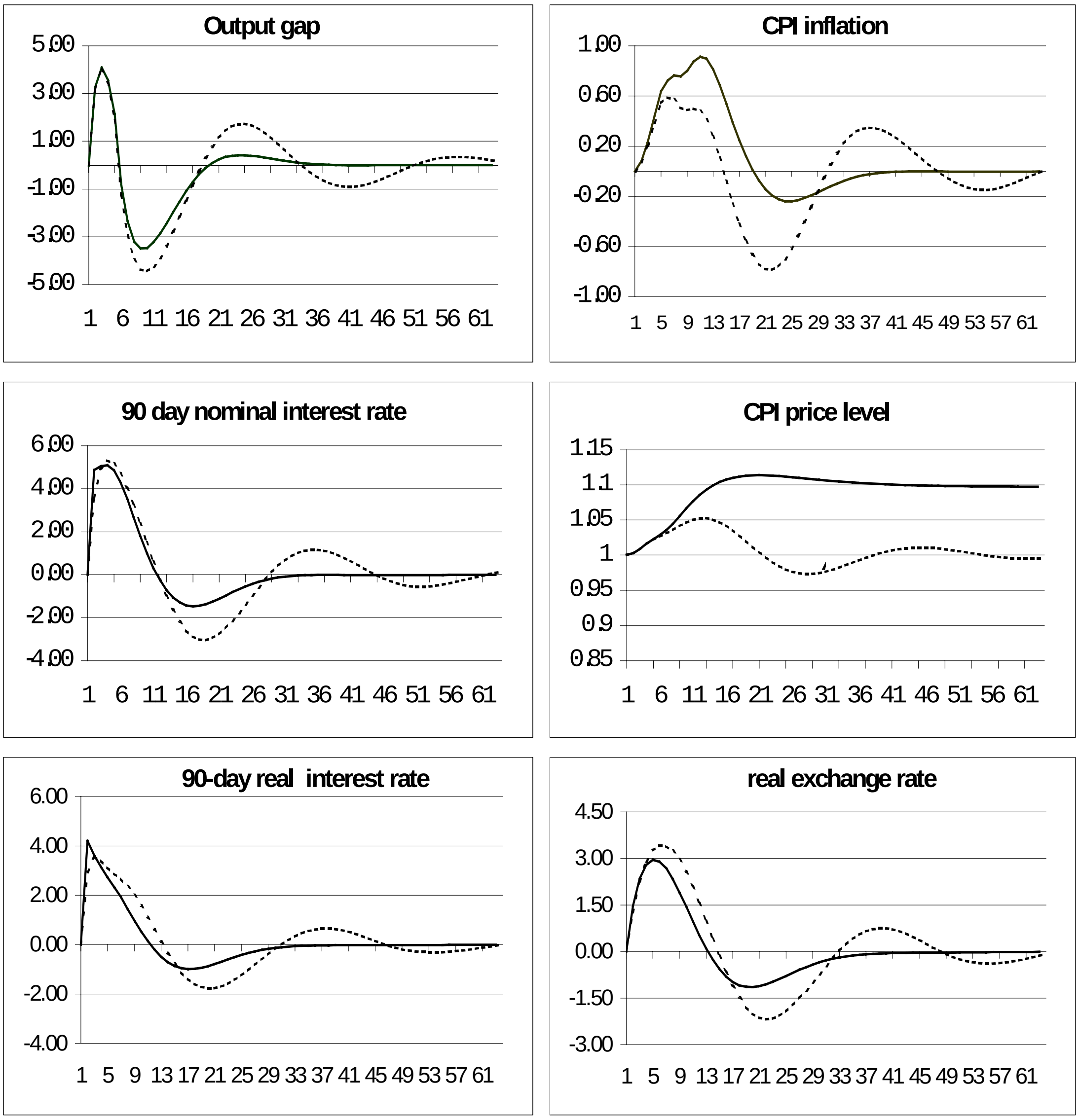
Figure I compares the dynamic response of FPS to a demand shock under both a price-level targeting rule and an inflation-targeting rule. The solid lines traces out the outcomes under the standard inflation-targeting rule used in FPS, while the dashed lines traces the outcome using the price-level-targeting rule specified in section 3.2.

Over the first year of the simulation period, which corresponds to the period that the shock itself is impacting, the outcomes for all macro variables are broadly similar. Over the second year, differences begin to appear reflecting the different policy rules. Under the price-level rule, the monetary authority's concern is to return the price level back to its trend path. To achieve this, policy needs to be tighter for longer relative to the inflation-targeting rule. This is reflected in the profiles for the real interest rate and real exchange rate, particularly over the second and third years of the simulation. The result of the tighter policy is that the monetary authority is able to achieve lower CPI inflation at two years ahead, due both to the slightly tighter policy over the second year, and more importantly, the impact on inflation expectations arising from the relatively tighter policy beyond that point. However, the lower inflation comes at the expense of the real economy, with output about one percentage point lower than that under the inflation-targeting rule two years after the impact of the shock.

Under both policy rules, the initial policy tightening causes CPI inflation to go below the target. To re-anchor inflation expectations at target, policy is required to go below neutral for some time. In the case of the inflation-targeting rule, this causes CPI inflation to gradually lock-in at the inflation target. With the price-level rule, however, a further cycle is set-up as the loosening causes the price level to overshoot the price level target, requiring a tightening in policy further out.[13]

[13] The extra cycling observed using the price-level target is a common finding in the literature. A large reason of why this occurs in the simulation presented here is that inflation-expectations are a function of inflation. Proponents of price-level targeting would argue that the expectations process itself would alter under price-level targeting to be a function of the price level - thereby reducing or eliminating the need for further cycling.

Figure I: Inflation-targeting rule and the price-level rule



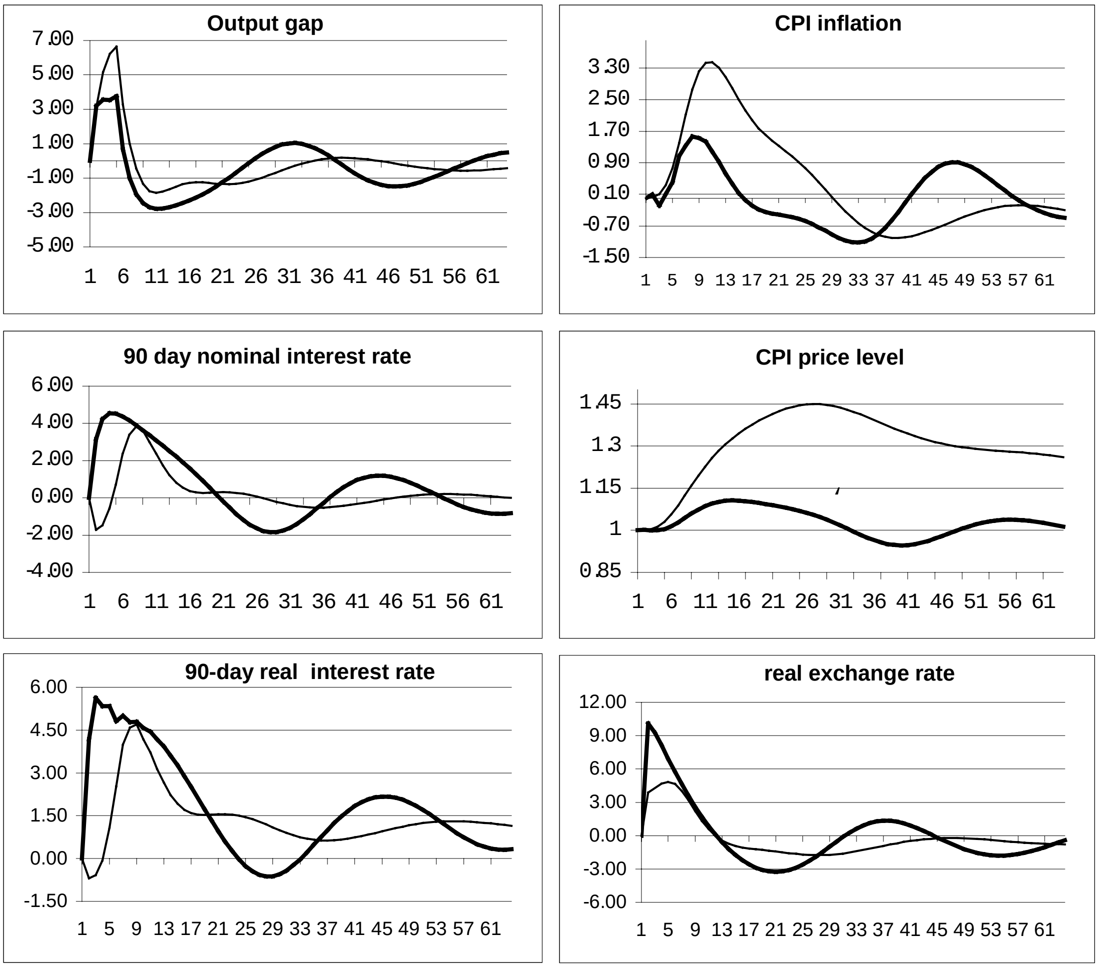
A comparison of the contemporaneous MCI rule and the forward-looking interest rate rule in NZM

To illustrate the implications of the common policy rule in NZM, the model is subjected to a demand shock of a similar magnitude to that applied to FPS. The outcomes from using two alternative policy rules are rules are traced out in figure II. The heavy solid lines are the outcomes using the forward-looking interest rate rule, while the light solid lines are the outcomes using the contemporaneous MCI rule.

Under the forward-looking interest rate rule, the monetary authority's ability to stabilise the price level appears to be superior relative to the MCI rule. Under the MCI rule, the price level has drifted from the base level by almost 30 percent after fifteen years. Under the forward-looking interest rate rule, the monetary authority is able to return the price level close to the target path after fifteen years. A key reason for the difference is the initial responses of the short-term interest rate under the MCI rule. Because the exchange rate is a 'jumper' in NZM, it increases substantially in anticipation of the future increase in short-term interest rates. Consequently, the short-term interest rate must initially decline below neutral for almost 6 quarters to achieve the path for the MCI given by the policy rule. This exacerbates the size of the initial cycle in output, leading to higher inflation over the medium term. In contrast, the short-term interest rate increases immediately using the forward-looking interest rate rule. This quick response of interest rates effectively halves both the magnitude of the price level deviation from the target, and the time that the price level is away from the target.

Nominal and real interest rates are higher under the forward-looking interest rate rule for almost five years. The exchange rate is substantially higher over the first two years of the experiment, and does not go below the exchange rate path produced using the contemporaneous MCI rule until into the third year. The tighter monetary conditions reduce inflation substantially, however, without a significantly more deleterious impact on real output. In the fifth year of the experiment, real output is higher under the forward-looking interest rate rule.

Figure II: Standard NZM rule and the price level rule



Appendix 2

Properties of the standard fiscal rules

To illustrate the properties of the two fiscal reaction functions, two shocks are considered:

1 A permanent reduction in the government debt-to-GDP ratio of 2.5 percentage points.

2 A temporary demand shock (ie the same shock as the one used to illustrate the properties of the monetary reaction function).

The percentage point change in labour income taxes required in NZM and FPS are shown in figures III and IV below. The solid lines represent the NZM paths, while the dashed lines show the FPS paths. Finally note that monetary policy is described in both models by the common forward-looking interest rate rule outlined in section 3.2.

Figure III: A permanent reduction in debt

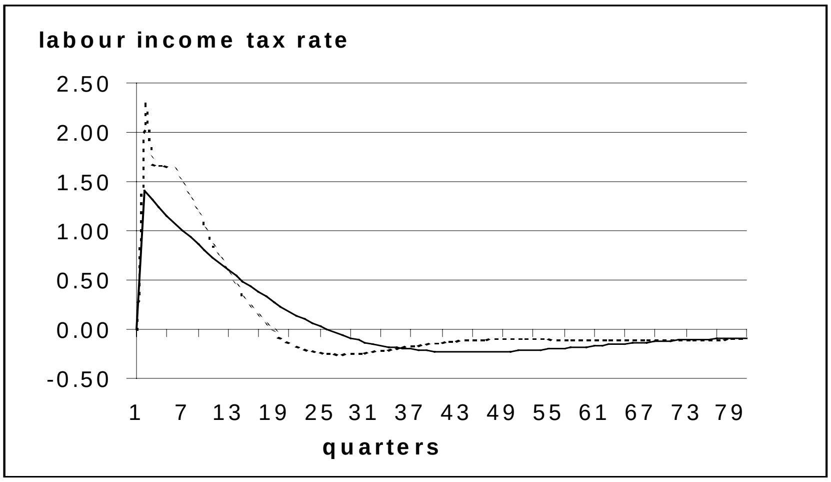
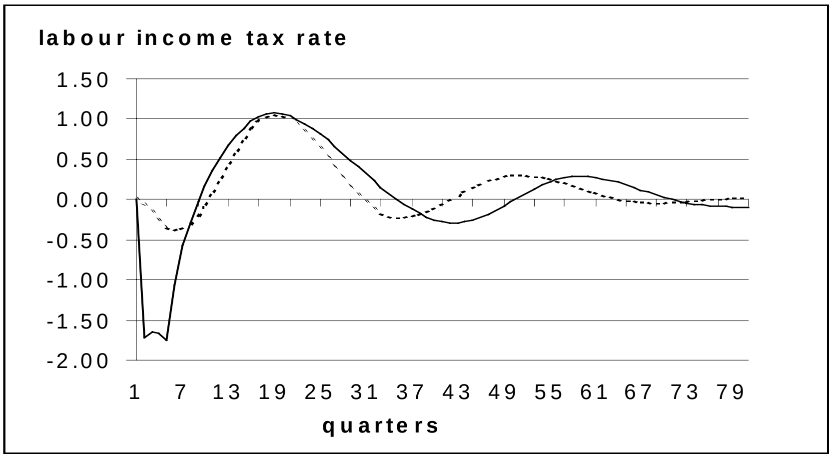


Figure IV: A shock to demand



Following a permanent reduction in the desired government debt-to-output ratio, labour income taxes in NZM and FPS increase above control to generate revenues used to retire debt. Although the adjustment of taxes in FPS is more 'aggressive' in that the initial increase in that tax rate is higher and taxes return more quickly to control, the cumulative adjustment of taxes required in both models is roughly similar. There appears to be little difference between the two models in the behaviour of taxes in following a permanent reduction in debt.

Following a positive impulse to aggregate demand, the rate of tax on labour income in both models initially *decreases*. In FPS, the decline is attributable to the level of debt falling as taxation revenues rise and transfers decline. In NZM, the decline is magnified because tax rates are not anchored to an equilibrium rate and because the debt-to-output ratio also declines as output increases. The greater pro-cyclical response of tax rates in NZM initially exacerbates the business cycle.

In figure V below the impact of making trend output the argument in the fiscal reaction function in NZM is illustrated. NZM and FPS are shocked with the same impulse to demand as above. The heavy solid line is the outcome using trend output, the light line shows the path using actual output, and the FPS solution is dashed. What is clear from this simulation is that taxes in NZM are significantly less cyclically influenced once the reaction function is written in terms of trend output. In particular, the initial fall in taxes is smaller with taxes falling by a similar order of magnitude as in FPS.

Figure V: An alternative rule under a demand shock