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The Forecasting and Policy System: Demand-side Satellite Models

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Abstract

This paper presents three satellite models for the Forecasting and Policy System (FPS). Satellite models are used to disaggregate the projections generated by the core model into a more detailed profile. The household expenditure, exports, and business investment satellite models dis-aggregate the relevant macroeconomic variables by modelling the shares of each aggregate allocated to each expenditure item. The models are assessed by examining their dynamic properties in response to artificial shocks and their ability to track historical data.

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JEL Classification: C53, E27

1. Introduction

This paper presents the demand-side satellite models for the Forecasting and Policy System (FPS). The models presented here are the first in a series of satellite models that will be used to prepare the Bank's quarterly projections. They are used to disaggregate the highly aggregated projection profiles generated by the FPS core model into more detailed components.

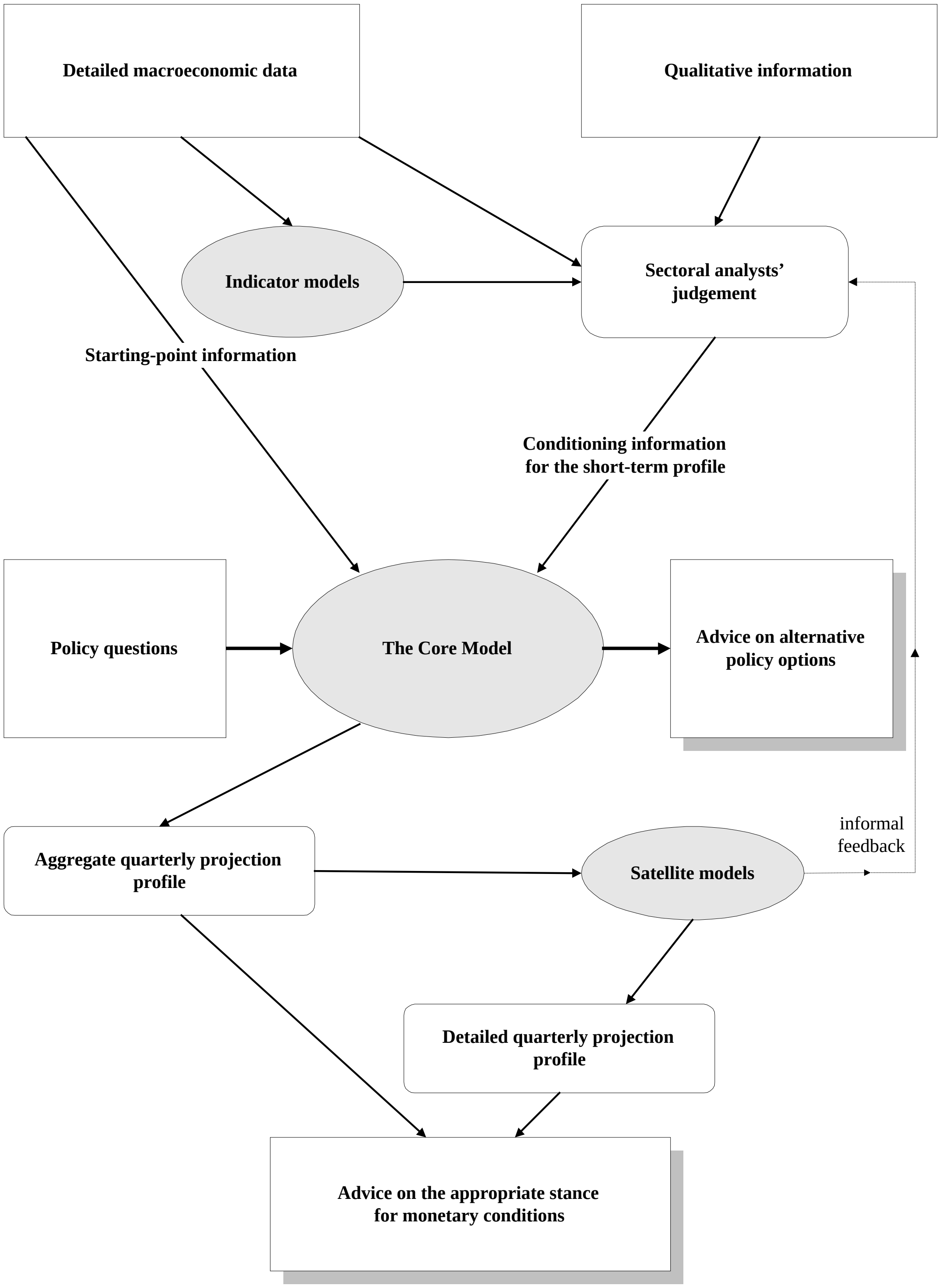
The Forecasting and Policy System is a new framework developed at the Reserve Bank to assist in formulating economic projections and policy analysis. Figure 1 is a schematic of the FPS. A formal macroeconomic model sits at the core of FPS.[1] This model can be used in isolation to analyse a wide variety of policy issues. However, when the system is used to carry out economic projections the core model is augmented by two additional types of models – indicator models and satellite models. The indicator models are reduced-form models designed to provide short-term forecasts by capturing the basic time-series properties of the data. The satellite models are used to disaggregate the profile produced by the core model.

The satellite models have a number of roles. Firstly, they help the Bank's forecasters to analyse developments in their specific sectors. In FPS, forecasters can incorporate information that the system does not capture by judgementally adjusting the projections generated by the core model. The satellite models demonstrate the effects of this judgement at a more disaggregated level. If the disaggregated results prove unsatisfactory, forecasters can modify their aggregate judgements accordingly.

Secondly, the satellite models provide the detailed breakdown of the projections required for public release. In many instances the definitions of variables used in the core model are more aggregated than officially-published data. For example, private investment in dwellings is treated as part of model consumption rather than part of investment.

[1] Details of the core model are presented in Black et al. (1997).

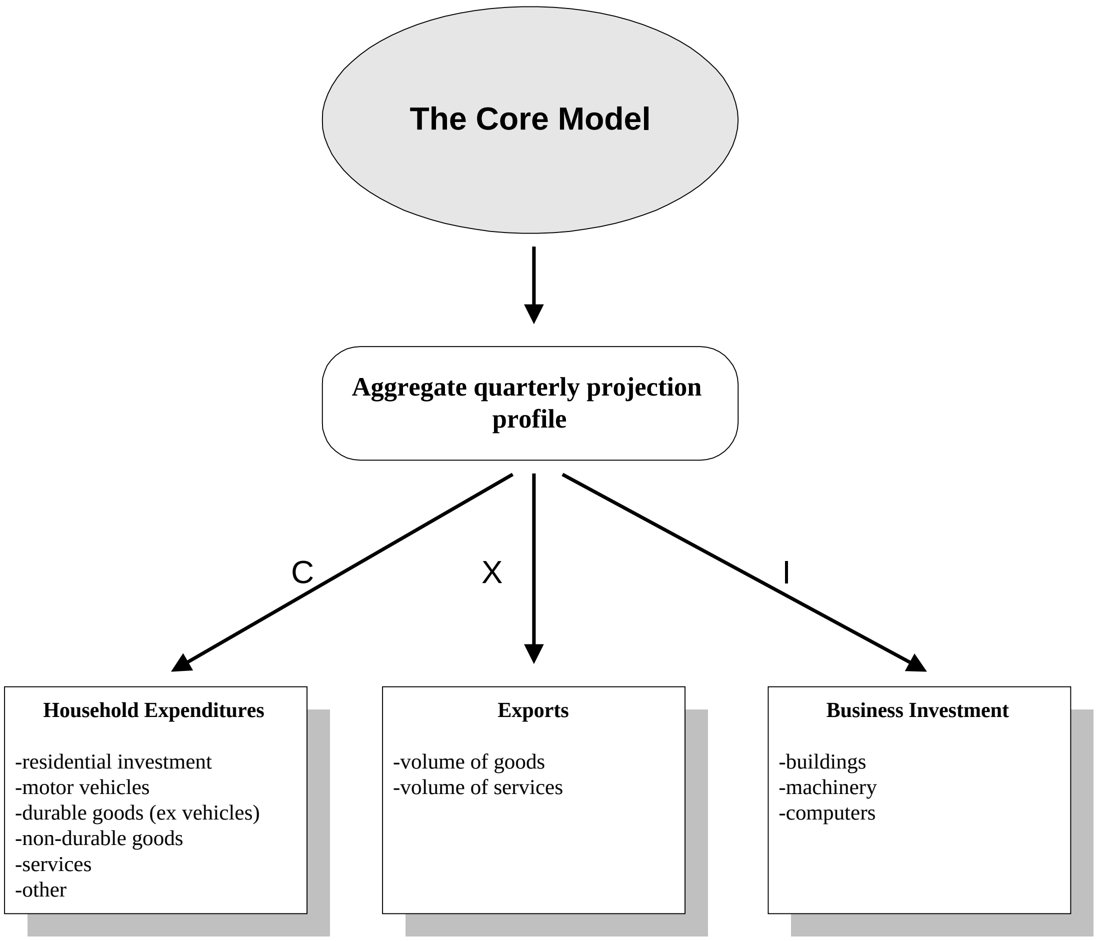
Figure 1: The Forecasting and Policy System



Finally, using satellite models to decompose the aggregate profiles from the core model ensures that the core model's general equilibrium structure can be kept relatively simple and theoretically consistent. As in the core model, the structure of the satellite models is based on dynamic adjustment around explicit equilibrium paths. In addition, attention is focused on ensuring that the models are theoretically consistent, have sensible dynamic properties and reflect the time-series properties of the data. The explanatory variables in the satellite models come primarily from the core model, but other external sources have also been used where appropriate.

Figure 2 illustrates the demand-side satellite models presented in this paper. The demand side of the FPS core model is comprised of domestic expenditure (C,I,G) and net exports (X-M). Of these, government expenditure (G) is treated as exogenous over the projection period. Imports (M) are endogenous, but are projected by the core model at a sufficiently disaggregated level. Consequently, satellite models are required to disaggregate the profiles for real household expenditure (C), the volume of exports (X) and real business investment (I).

Figure 2: FPS Demand-side Satellite Models



The rest of this paper is arranged as follows. The theoretical framework of the demand-side satellite models is described in section 2. This framework is then used to develop the household expenditure satellite model presented in section 3. This is followed by the exports satellite model in section 4 and the business investment satellite model in section 5. A summary and conclusions are presented in section 6.

2. Theoretical framework

The relationship between the FPS core model and the demand-side satellite models is similar to the connection between the Bank of Canada's QPM core model and its associated satellite models as described in Poloz, Rose, and Tetlow (1994). The satellite models embody the same design philosophy as the core model, that is, they are based on dynamic adjustment towards a theoretically-consistent steady state and attention is focused on the models' properties in artificial and historical simulations. Furthermore, information is transmitted directly from the core model to the satellites.

In general, a demand-side satellite model takes an aggregate variable generated by the core model and disaggregates it into components by expressing the components as shares of the aggregate variable.

To illustrate the general method, consider the decomposition of household expenditure (consumption). Given the overall level of consumption C, the consumption of item i, C_i, is expressed as a share s_i of total consumption expenditure,

$$s_i = \frac{C_i}{C}.$$

The expenditure shares are determined by an equilibrium component and a disequilibrium component. The short-run equilibrium path s_i_eq, that converges to a steady-state value, is driven by variables such as tastes and preferences, production technology and relative prices. For simplicity, however, this path is proxied using a Hodrick-Prescott filter that converges to a fixed steady-state share.[2] The steady-state shares are set exogenously, based on current and expected trends in the data. Through time, the actual share of expenditure on i, s_i, can diverge from its equilibrium share, but a number of error correction mechanisms ensure that the share converges back to its equilibrium path.

Stock adjustment plays a vital role in the modelling process for durable items. Given an exogenous depreciation rate d_i, maintaining a desired stock K_i_eq requires a period-by-period expenditure equal to C_i_eq. This relationship is given by the cumulation identity

$$K_i\_eq_t = (1 - d_i) K_i\_eq_{t-1} + C_i\_eq_t .$$

Divergences between the actual stock and the desired stock feed back into the expenditure share.

Each satellite model explicitly models all except one of the components of an aggregate variable. The last component is determined residually to ensure that the satellite components sum to the aggregate variable. Taking the above assumptions together, the equation for each explicitly modelled expenditure share can be expressed in the general form

[2] In most instances these filters were calculated with λ set at 1600. Other settings were tried, but did not have a significant impact on the results.

$$\log(s_i / s_i\_eq)_t = \alpha_j \sum_{j=1}^{n} \log(s_i / s_i\_eq)_{t-j} + \beta_j \sum_{j=1}^{m} \log(K_i / K_i\_eq)_{t-j}$$
$$+ \delta_j \sum_{j=0}^{p} \log(C / C\_eq)_{t-j} + other + s_i\_shk_t.$$

Specifically, the gap between the expenditure share and its equilibrium path is determined by additional 'gap' terms. The most important gap terms are the error correction terms between the actual share and the equilibrium share, the gap between the stock for item *i* and the equilibrium stock, and the gap between total actual expenditure and equilibrium expenditure. Other gap variables can also be added to model the expenditure shares for particular items. For example, the share of household expenditure allocated to residential investment could be influenced by disequilibrium in house prices. Similarly, the composition of exports can be influenced by disequilibrium in the real exchange rate. The shock variable at the end of the equation represents the error term.

Below are the details of the demand-side satellite models. For each satellite model, we present the numerical assumptions of the steady-state, the estimated coefficients and the model's dynamic properties. Dynamic properties are assessed by a number of artificial and historical simulations.

3. Household expenditure satellite model

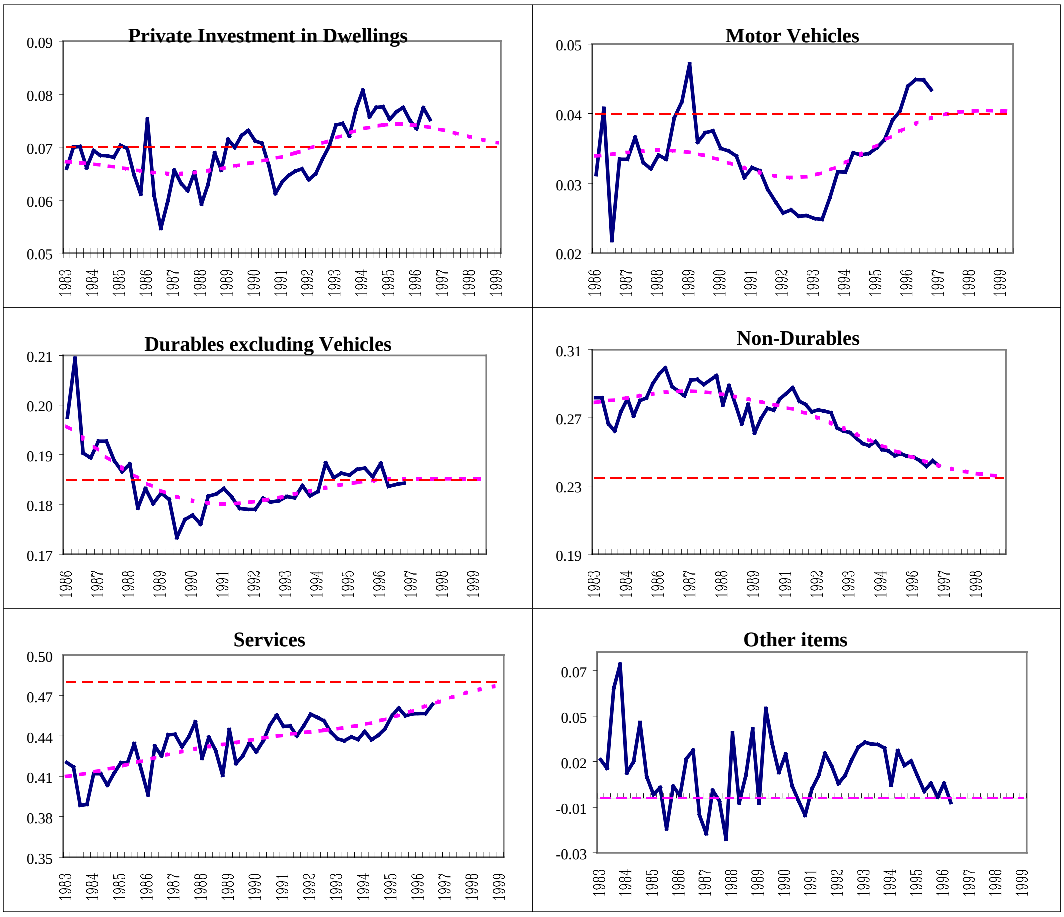
The household expenditure satellite model disaggregates total household expenditure into the following components: residential investment, vehicles, durable goods excluding vehicles, non-durable goods, services, and other goods. The expenditure on other goods, which includes the change in inventories, net tourist expenditure and private non-profit expenditure is determined residually in the model.

For each item, a steady-state share is chosen. In addition, for each durable item a starting value and a depreciation rate are required to construct the actual and desired stocks. The following subsection describes the decisions made in more detail.

3.1 Steady-state share and stocks

The steady-state expenditure shares were set exogenously. These shares were chosen based on trends in the actual shares and expected significant shifts in relative prices. Figure 3 shows the expenditure shares and the equilibrium paths that converge onto the steady state.

Figure 3: Household expenditure satellite model
Expenditure shares and their steady-state values
(Solid line is actual share, dotted line is short-run equilibrium share, dashed line is steady state)



The expenditure on private investment in dwellings has been more or less stationary over the last decade, with a clear cyclical pattern. As a result, the steady-state share is set close to the share's historical mean at 6.5 percent. The expenditure share allocated to motor vehicles, on the other hand, experienced an upward trend from 1993 onwards, which is presumably due to the fall in the relative price of motor vehicles following the large inflow of used cars from Japan over this period. Consequently, the steady-state share has been set at 4 percent.

The pattern for expenditure on durable goods excluding vehicles has been relatively stable over history. This pattern is rather surprising since the relative price of imported durables such as electronic goods and clothing should have fallen significantly since the removal of tariffs and import restrictions in the late 1980s. These results suggest that vehicles have a much higher price elasticity than other durable goods. The steady-state share is therefore set close to its recent average at 18 percent. The graph for non-durable items shows a clear downward trend, which is probably due to substitution between non-durables and services.[3] It is assumed that the trend will continue for the next few years, but will eventually converge to a steady-state share of 23.5 percent.

3 Non-durable consumption consists largely of food and alcohol not consumed in restaurants and hotels, which are instead treated as consumption of services. Therefore, the downward trend is probably caused by the increasing ability to dine out given the recent deregulation in this sector.

The expenditure share for services mirrors the change in non-durable consumption with a steady upward trend. It is assumed that the move towards a more service-based economy will continue over the projection horizon and will eventually level off at about 48 percent. Finally, the residual expenditure item consists of changes in inventories, net tourist expenditure, and expenditure by private non-profit organisations. The steady-state share for the residual item is restricted to equal one minus the shares of the other items. Currently, this share equals zero.

Finally, it is necessary to calculate the actual and desired stocks for the three durable items in the model – residential housing, vehicles and durables excluding vehicles. As explained in Section 2, stock-flow accounting plays an important role in determining the expenditure of durable items. Full details of the derivation of the stocks in this model are provided in Appendix A.

3.2 Estimation

The results of the model estimation are presented in this section. The equations were estimated in partial-log form because this was found to enhance their simulation properties. The share and gap variables in the models are stationary by construction, so the problems associated with non-stationary variables are avoided. As explained in Section 1, attention is focused primarily on ensuring that the models have sensible dynamic properties and reflect the time-series properties of the data. Therefore, in some cases insignificant coefficients are left in and other coefficients are imposed to improve the model's simulation results and ensure convergence to a stable steady state.[4] Each equation was estimated using quarterly data over the period March 1989-March 1997. The estimation results are shown below in Table 1.

[4] In any case, the equations do not contain constants, therefore, the sum of their residuals does not necessarily equal zero and most standard diagnostic tests are invalid.

Table 1: Household expenditure satellite model
Estimation results
Dependent variable for each item: $(s_i - s_{i}\_eq)_t$

Variables \ Expenditure	Residential Investment	Motor Vehicles	Durables ex Vehicles	Non-Durables	Services
$(s_i - s_{i}\_eq)_{(t-1)}$	0.186494 (1.40)	0.214343 (1.26)	0.499492 (3.27)	0.49175 (2.93)	0.13245 (0.56)
$(s_i - s_{i}\_eq)_{(t-2)}$		0.306376 (2.31)		0.258777 (1.56)	
$\log(K_i/K_{i}\_eq)_{(t-1)}$		-0.01☞			
$\log(K_i/K_{i}\_eq)_{(t-2)}$	-0.668358 (-2.60)		-0.01☞		
$\log(C/C\_eq)_{(t-1)}$	0.046772 (3.39)	0.026191 (2.11)	-0.00967 (-1.04)		-0.08385 (-1.65)
$(q-q\_eq)_{(t-3)}$	0.016859 (1.56)				
$((r-r\_eq)/100)_{(t-2)}$	-0.02☞	-0.01☞			
output gap$_{(t-1)}$				0.04☞	0.04☞
Dummy variable (=1 for 1989:1-89:2, 0 elsewhere)		0.007356 (4.82)			
Dummy variable (=1 for 1995:4-96:4, 0 elsewhere)		0.002022 (2.15)			
R-squared	0.763	0.841	0.273	0.417	0.232
Adjusted R-squared	0.738	0.818	0.249	0.398	0.207
Durbin-Watson	1.740	1.423	2.047	1.839	2.026

☞ *calibrated parameters* *t-statistics in parentheses*

The dynamics in the equation for residential investment arise from gaps in the lagged expenditure share, aggregate consumption and the housing stock. In addition, expenditure on new dwellings is influenced by Tobin's *q* for houses less than 3 years old and short-term real interest rates.[5] The coefficient on the interest rate gap is calibrated to ensure that it has a negative sign.

The equation for expenditure on motor vehicles has the standard gap variables noted above, a real interest rate gap, and two dummy variables that capture the impact of deregulation. The coefficients on the stock gap and the interest rate gap have been calibrated because the estimated coefficients had theoretically inconsistent signs. These restrictions do not have a great effect on the magnitude of the other coefficients.

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[5] The equilibrium path for Tobin's *q* is estimated by a Hodrick-Prescott filter. The interest rate gap is from the core model.

Dynamics around the equilibrium path for durable goods excluding vehicles are driven by the expenditure-share gap, the stock gap and the aggregate-consumption gap. As in the equation for vehicles, the coefficient on the stock gap has been calibrated to ensure that the model converges to its steady state.

As seen in Figure 3, the path for non-durables is determined almost exclusively by the equilibrium path. The coefficient on the output gap has been calibrated to generate a more cyclical dynamic path. Finally, as with non-durables, expenditure on services is determined primarily by the equilibrium path, with few dynamic terms. Although some dynamic terms have been included to improve the model's simulation properties, they are statistically insignificant.

3.3 Simulation properties

3.3 (a) Artificial simulation properties

The model's dynamic properties are tested using a simulation experiment, in which the satellite is used to disaggregate the response of the core model to a one percent increase in the central bank's inflation target.[6] In the core model, the monetary authority reduces interest rates below control, which boosts household consumption, opens a positive output gap and raises inflation towards the new target. Initially, however, inflation overshoots the target, leading to a tightening in policy that forces consumption to cycle below its original level.

The effect of this shock on the components of household expenditure is shown below in Figure 4. The largest impact is on residential investment and consumption of motor vehicles. The strong impact on these items is due to the direct interest rate channel. Non-durables consumption is also affected slightly more than total consumption.

On the other hand, the consumption of services and durable goods excluding vehicles tends to react rather less than aggregate consumption. This reflects the significant trends in their expenditure shares and their limited cyclical behaviour. The relatively large shares allocated to durable goods excluding vehicles and services mean that these items only need to be marginally less cyclical than the aggregate in order to offset the movements in residential investment and motor vehicles.

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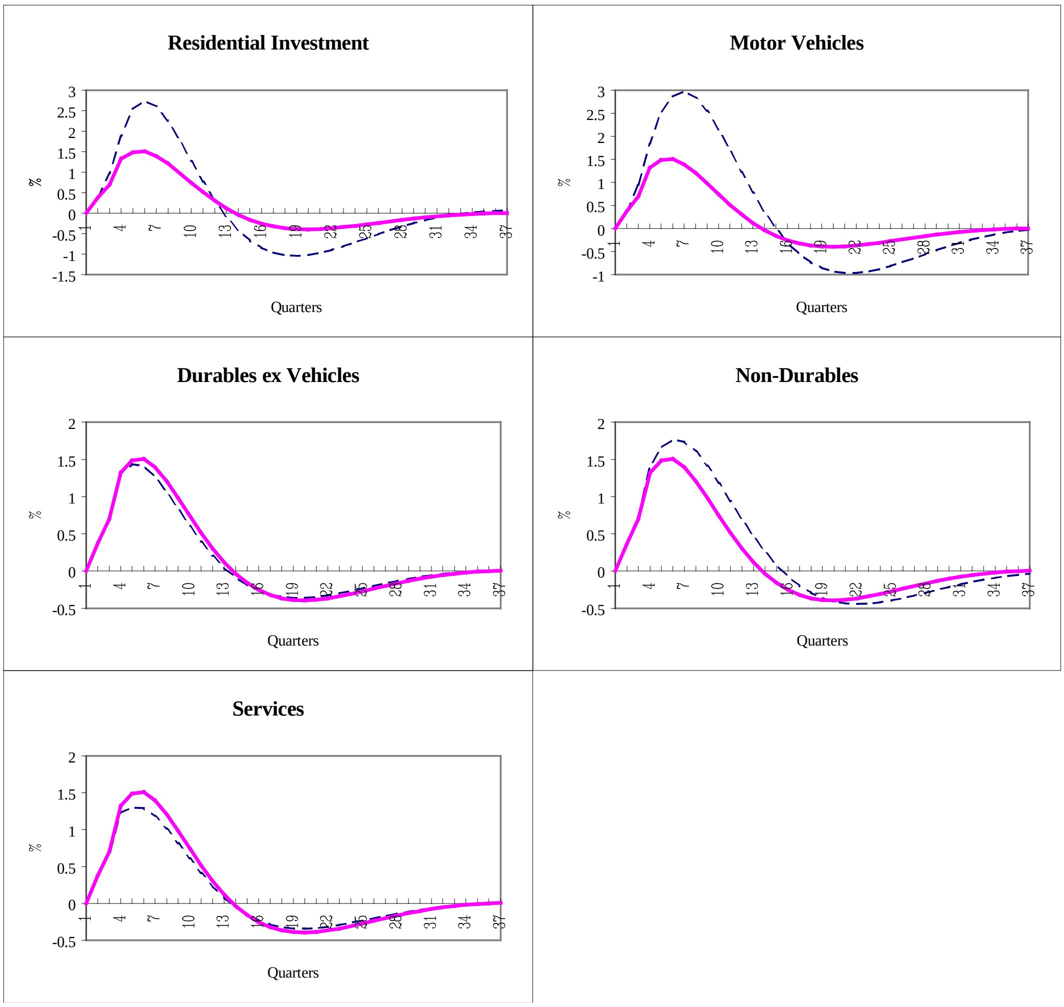
[6] Details of dynamic simulations with the FPS core model are described in Black *et al*. (1997) section 5.2 (pp. 63-79).

Figure 4: Household expenditure satellite model
Artificial simulation results
(Shock minus Control)
(Solid line is total household expenditure, dashed line is component)



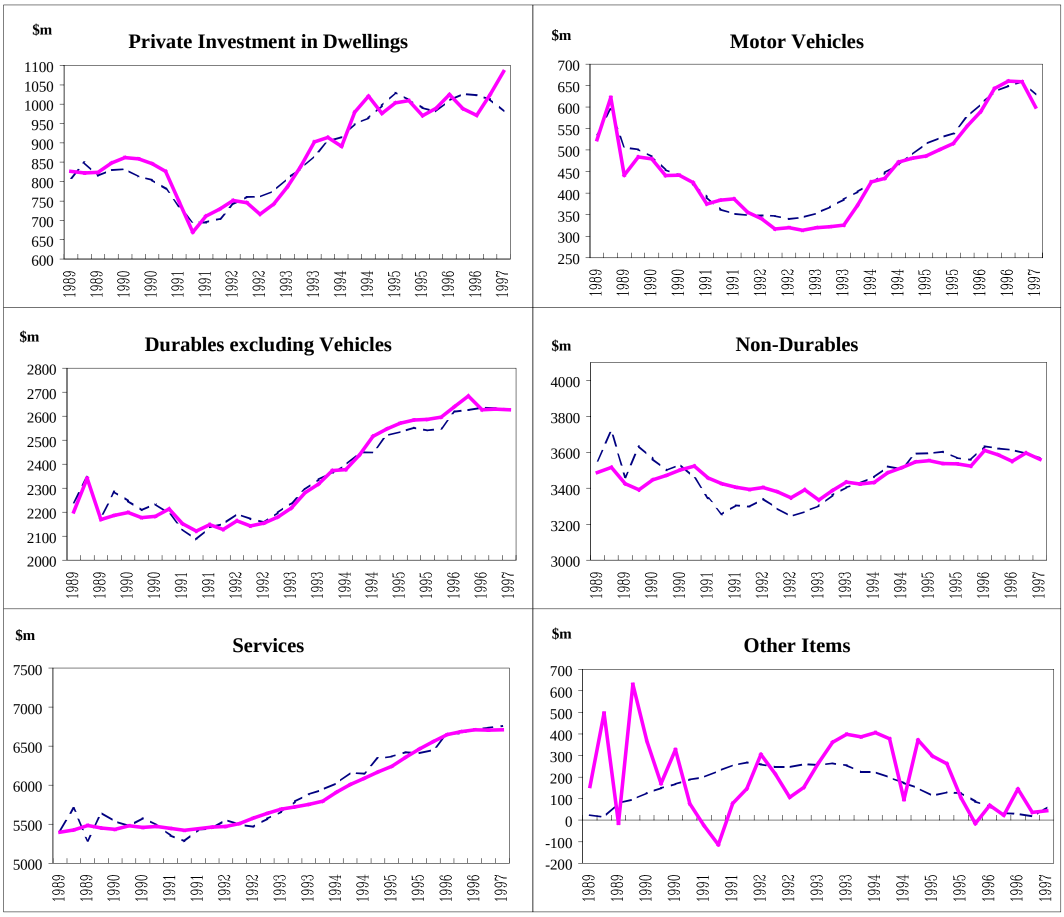
The relative magnitudes of the shock responses for each component seem plausible. For example, the consumption of large expenditure items such as housing and motor vehicles should react more to policy tightenings than the consumption of items such as food and clothing. In addition, the results confirm that the satellite model converges to its steady state within a reasonable period of time.

3.3(b) Historical simulation properties

To examine the household expenditure satellite model's ability to track the historical data, the model is simulated dynamically to compare predictions with historical values.

Figure 5 indicates that the model tracks residential investment quite closely over history and seems to pick the major turning points accurately. The forecasts for motor vehicle consumption also appear to be quite good.

Figure 5: Household expenditure satellite model
Historical simulations
(Solid line is actual, dashed line is simulated)



The path for durable goods excluding vehicles is extremely smooth over history and the model tracks the actual series quite closely. Similarly, non-durables consumption is fairly smooth and the model's predictions track the actual series quite closely, apart from a few spikes at the start of the period. Consumption of services is the smoothest of all the components and as seen in the previous sections, there is little dynamic variation around the equilibrium trend path. Once again, the model prediction is driven largely by the choice of the steady-state share.

The residual item in the satellite model (changes in inventories, net tourist expenditure, and consumption by private non-profit organisations) has been very volatile over history, as the figure above shows, making it extremely difficult to model accurately. However, from 1993 onwards, the model does capture the downward trend in this item.

4. Exports satellite model

This section describes the exports satellite model in FPS. The satellite model is designed to split the volume of aggregate exports into two components: goods and services. The exports of goods are modelled explicitly and service exports are determined residually to ensure that the components are consistent with the aggregate.

4.1 Modelling approach

The exports satellite model uses the methodology described earlier in Section 2. However, because exports consist largely of services and non-durable goods, no stock-flow adjustment process is involved. The structure of the estimated equation is

$$\log\left(s_i / s_i\_eq\right)_t = \alpha j \sum_{j=0}^{n} \log\left(X / X\_eq\right)_{t-j} + \beta j \sum_{j=1}^{m} \log\left(s_i / s_i\_eq\right)_{t-j} + other + s_i\_shk_t$$

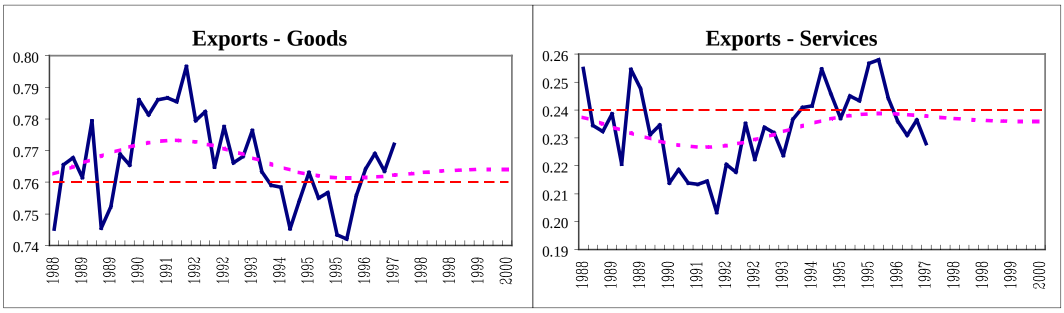
The gap between actual and desired export shares of item i, s_i/s_i_eq, is explained by its own gap lagged, the aggregate export gap X / X_eq, and 'other' gap variables such as the real exchange rate or world demand.

4.2 Steady-state shares

As discussed above in Section 2, the actual export shares adjust around their short-run equilibrium paths, which converge towards the chosen steady-state values. The short-run equilibrium shares are computed by running a Hodrick-Prescott filter conditioned on the steady-state shares through the actual shares.

Figure 6 below displays exported goods and services as shares of aggregate exports. The horizontal lines represent the steady-state shares, which are assumed to be 0.76 for goods and 0.24 for services. The dotted lines represent the short-run equilibrium paths that eventually converge to the steady state shares. Despite the increasing diversification of exports, the overall split between exports of goods and services has not changed greatly on average. It also appears that the share of exported goods has increased during the last 2-3 years, despite the strong exchange rate appreciation over this period.

Figure 6: Exports satellite model
Export shares and their steady-state values
(Solid line is actual share, dotted line is short-run equilibrium share, dashed line is steady state)



4.3 Estimation

The equation for exported goods was estimated over the period March 1989 to March 1997 using Ordinary Least Squares. The final specification chosen was again based on statistical robustness, artificial simulation properties and the characteristics of historical simulations.

Table 2: Exports Satellite Model
Estimation Results
Dependent Variable: $log(s_i/s_{i}\_eq)_t$

Variables \ Expenditure	Exported Goods
$\log(X/X\_eq)_t$	0.334521 (5.44)
$\log(X/X\_eq)_{(t-1)}$	-0.293972 (-4.62)
$\log(s_i/s_{i}\_eq)_{(t-1)}$	0.593697 (4.77)
R-squared	0.627
Durbin-Watson	1.607
Adjusted R-squared	0.600
t-statistics in parentheses	

The estimated equation for exported goods contains the aggregate export gap, lagged aggregate export gap and a lagged export share gap. All the estimated coefficients have the expected signs – a net positive coefficient for the aggregate export gap and a positive coefficient for lagged own export gap.

The real exchange rate gap and the output gap for the rest of the world were also tested as explanatory variables. In most cases, however, these variables were statistically insignificant, indicating that they do not have any additional transmission channels other than that which is captured in aggregate exports. Furthermore, in many cases adding these variables caused undesirable dynamic simulation properties (discussed in the next sub-section). For these reasons, both the real exchange rate gap and the world output gap were omitted from the final equation.

5. Simulation properties

5.4(a) Artificial simulation properties

A number of simulation experiments were conducted to test the dynamic behaviour and long-run properties of the satellite model. As noted previously, these experiments disaggregate the impact of shocks carried out in the FPS core model.[7] It is assumed that the economy is initially at steady state. Each of the experiments are discussed below.

An increase in the inflation target

The FPS core model was used to simulate a one percentage point increase in the central bank's inflation target. Figure 7A shows the response in aggregate exports (solid line) and its two components. The volume of exported goods (dashed line) expands immediately and to a slightly larger degree than aggregate exports. Exported goods reach a peak approximately nine quarters after the shock, which is similar to aggregate exports. The exports of services (dotted line) appear to have a smaller and slower response than total exports. The finding that exported services react to a lesser degree than total exports is plausible, because it is likely that exported services are relatively less sensitive to exchange rate movements. Further out, aggregate exports and its components settle back to their steady-state values. This occurs because in the core model nominal shocks have a neutral impact on real variables in the long run.

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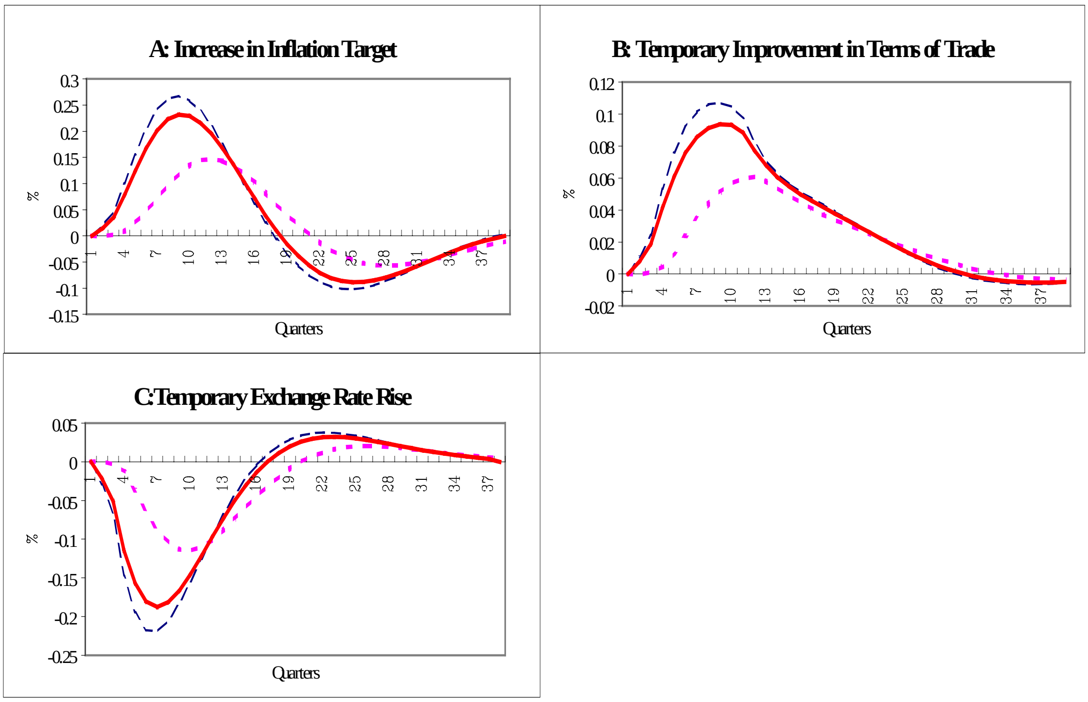
[7] For further details of these shocks in the core model, see Black *et al*. (1997).

Figure 7: Exports satellite model
Artificial simulation results
(Shock minus Control)
(Solid line is aggregate exports, dashed line is goods exports, dotted line is services exports)



Temporary improvement in the terms of trade

A temporary terms of trade shock was simulated in the core model. In the core model, aggregate exports rise as the higher price of exports increases firms' incentive to export. In the satellite model, as Figure 7B indicates, exported goods immediately respond, followed by exported services. Because this is only a temporary change in the terms of trade, aggregate exports and its components all return to their steady-state values after about seven years.

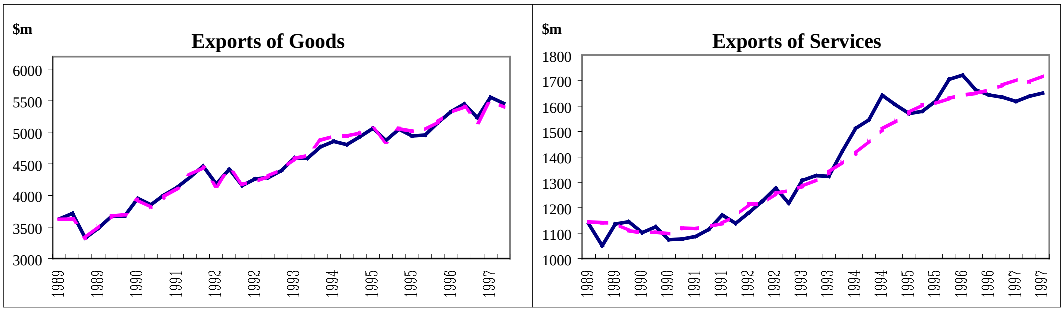
Temporary appreciation in the real exchange rate

The FPS core model was also used to simulate a temporary appreciation in the real exchange rate by one percent. The currency appreciation causes a temporary reduction in exports as the price of exports in domestic currency terms falls. The impact of the shock in the satellite model is illustrated in Figure 7C. As in the terms of trade shock, exported goods respond immediately, and by a greater degree than total exports. Exported services lag in their response. After about nine years, aggregate exports and its components have returned to their steady-state values.

5.4(b) Historical simulation properties

The satellite model's ability to track the historical data is assessed by simulating the model dynamically over history. As shown in Figure 8, the model's predictions for exported goods track the historical data quite closely and appear to pick both the trend and the turning points.

Figure 8: Exports satellite model
Historical simulations
(Solid line is actual, dashed line is simulated)



The forecasts for services are determined residually. The forecast consistently tracks the historical data quite closely during the early years when the variance in the data is small. During the latter years the forecast seems to have missed some of the fluctuations in the data. However, given the magnitude of exported services in relation to total exports, the relative size of the error is very small.

Based on these results, it appears that the satellite model is a useful forecasting tool. The model's dynamic properties in response to artificial shocks seem to be reasonable. In addition, the predicted values generated by the dynamic simulations tend to track the historical data reasonably well.

6. Business investment satellite model

This section describes the business investment satellite model in FPS. The satellite model is designed to split aggregate investment from the core model into three components: buildings,[8] plant and machinery (referred to as 'machinery'), and computers. The satellite model explicitly models investment spending on buildings and machinery, with spending on computers determined residually to ensure that the satellite components aggregate to total investment.

6.1 Modelling approach

In the FPS core model, investment adjusts to achieve and maintain the long-run desired capital/output ratio. Consequently, the satellite model emphasises the capital stock adjustment process in explaining investment expenditure. The three components (K_i) of the

8 'Buildings' consists of investment in non-residential construction, other construction, land improvement, and public investment in dwellings.

aggregate capital stock (K), buildings, machinery and computers, are expressed as shares (k_i) of the aggregate.[9]

In practice, the actual composition of the capital stock may differ from firms' desired or optimal composition. The desired share of capital allocated to each item (k_i_eq) is determined by factors such as relative prices, user costs and production technology. However, these values are again proxied using a Hodrick-Prescott filter that converges to a steady-state value. The desired levels of each component of the capital stock is simply the desired share multiplied by the desired aggregate capital stock,

$$K_i\_eq = k_i\_eq{*}K\_eq.$$

Inverting the perpetual inventory equation yields desired investment levels for each item,

$$I_i\_eq_t = K_i\_e_t - (1-d_i)K_i\_eq_{t-1}.$$

Finally, the general functional form for the investment equations used is

$$\log\left(Ii/Ii\_eq\right)t = \alpha j \sum_{j=0}^{m} \log\left(I/I\_eq\right)t - j + \beta j \sum_{j=1}^{n} \log\left(Ii/Ii\_eq\right)t - j + \delta j \sum_{j=1}^{p} \log\left(ki/ki\_eq\right)t - j$$
$$+ other + Ii\_shk_t$$

In the equation above, the gap between actual and desired investment on item i (Ii/Ii_eq) is related to its own lag, the aggregate investment gap (I/I_eq), its own capital share gap (k_i/k_i_eq) and other gap variables (such as monetary policy variables).

6.2 Desired stocks and flows

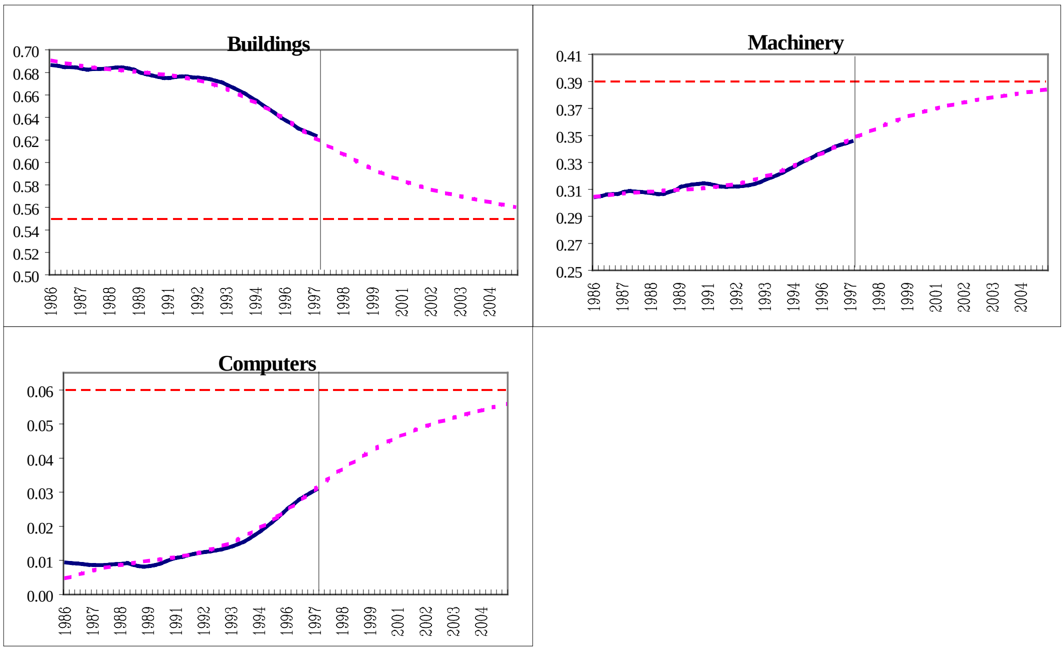
As discussed above, the first step in determining values for desired investment flows is to calculate desired values of the capital stocks. Below are the underlying assumptions for these computations.

Capital stock shares

The actual and desired capital stock shares for machinery, buildings, and computers are displayed below in Figure 9. The steady-state values for machinery, buildings, and computers (determined residually) are 39 percent, 55 percent, and 6 percent respectively. The graphs clearly demonstrate the changes in the composition of the capital stock in New Zealand. There is clearly an increasing degree of mechanisation and computerisation, which reflects changes in production technology and the falling relative prices for these items. These trends are offset by the declining share of buildings.

9 Full details of the derivation of the capital stocks are provided in Appendix B.

Figure 9: Business investment satellite model
Actual and desired capital stock shares
(Solid line is actual share, dotted line is desired share, dashed line is steady state)

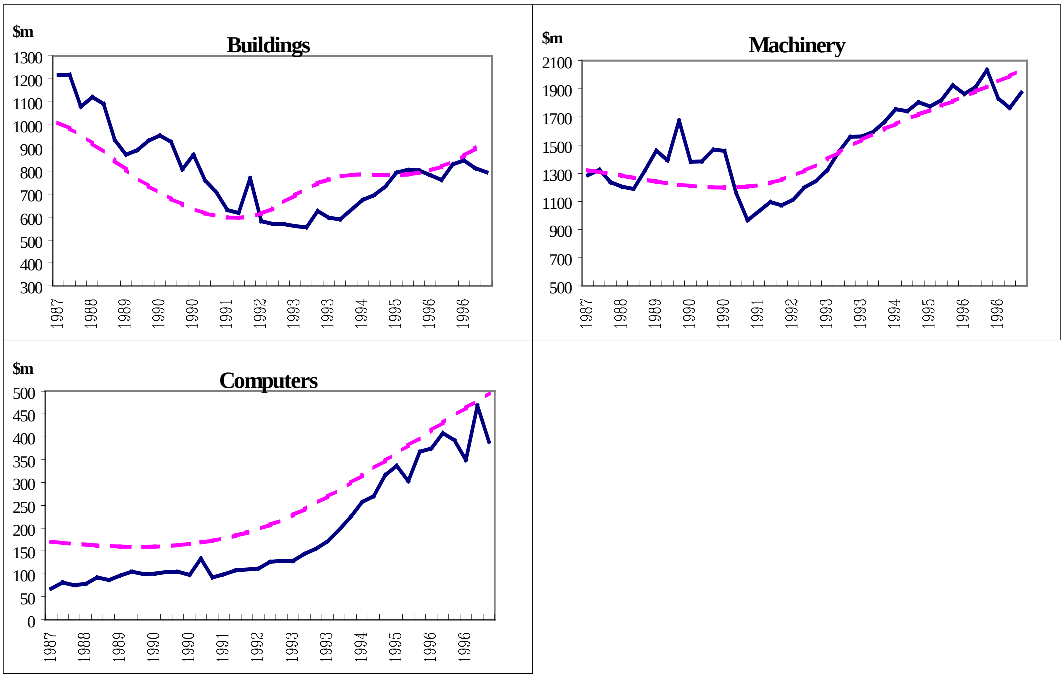


Desired investment spending

As noted above, desired investment for each item is derived by inverting the perpetual inventory formula. As a consequence, the desired series may not cut through the actual investment series as smoothly as a filtered series would do. Figure 10 displays the desired values against the actual historical values.

The trends in desired investment spending in machinery and computers largely reflect the changes in desired capital stocks for each item. Investment spending on machinery and computers has increased steadily since 1991 as the desired capital stocks have risen. On the other hand, investment in buildings has had two separate periods. Investment in buildings fell steadily during the late 1980s as the desired share of capital stock fell during the de-regulation and privatisation of government organisations. Recently, however, actual and desired building investment has increased, even though the desired share of building stock has continued to decline.

Figure 10: Business investment satellite model
Actual and desired investment expenditure
(Solid line is actual investment, dashed line is desired investment)



6.3 Estimation

The investment equations are estimated using OLS over the sample period March 1989 to March 1997. While several other configurations and variables were tested, only the final results are presented below. The final specifications were chosen based on statistical robustness, and artificial and historical simulation properties. A number of variables, such as the yield gap and the real exchange rate were tested in the estimated equations. However, the estimated coefficients for these variables indicated that there is no additional policy effect over and above the impact on aggregate investment.

Table 3: Business investment satellite model
Estimation results
Dependent variable: $log(I_i/I_i\_eq)_t$

Variables \ Expenditure	Machinery ex-computers	Buildings
$log(I/I\_eq)_t$	1.132195 (10.22)	0.792652 (3.90)
$log(I/I\_eq)_{(t-1)}$	-0.670854 (-4.13)	-0.36326 (-1.32)
$log(I_i/I_i\_eq)_{(t-1)}$	0.0575894 (5.85)	0.666861 (6.92)
$log(k_i/k_i\_eq)_{(t-1)}$	-3.84947 (-3.15)	-6.583555 (-1.73)
R-squared	0.918	0.880
Durbin-Watson	2.146	2.299
Adjusted R-squared	0.909	0.867
t-statistics in parentheses		

Each estimated investment equation contains the lagged investment gap for the item, the aggregate investment gap and the capital share gap for each item. The estimated coefficients in both equations have the expected signs. Specifically, a net positive coefficient for the aggregate investment gap, a positive coefficient for item *i*'s investment gap, and a negative coefficient for the capital share gap.

It is interesting to note that the contemporaneous coefficient on the aggregate investment gap in the equation for machinery is greater than one. This implies that, holding other factors constant, there is a greater than proportional passthrough of shocks from aggregate investment to investment in machinery. On the other hand, the coefficient in the building equation suggests a less than proportional passthrough from aggregate investment.

6.4 Simulation properties

6.4(a) Artificial simulation properties

Two artificial simulation experiments were conducted to test the dynamic behaviour and long-run properties of the satellite model: a change to the inflation target and a temporary demand shock.[10]

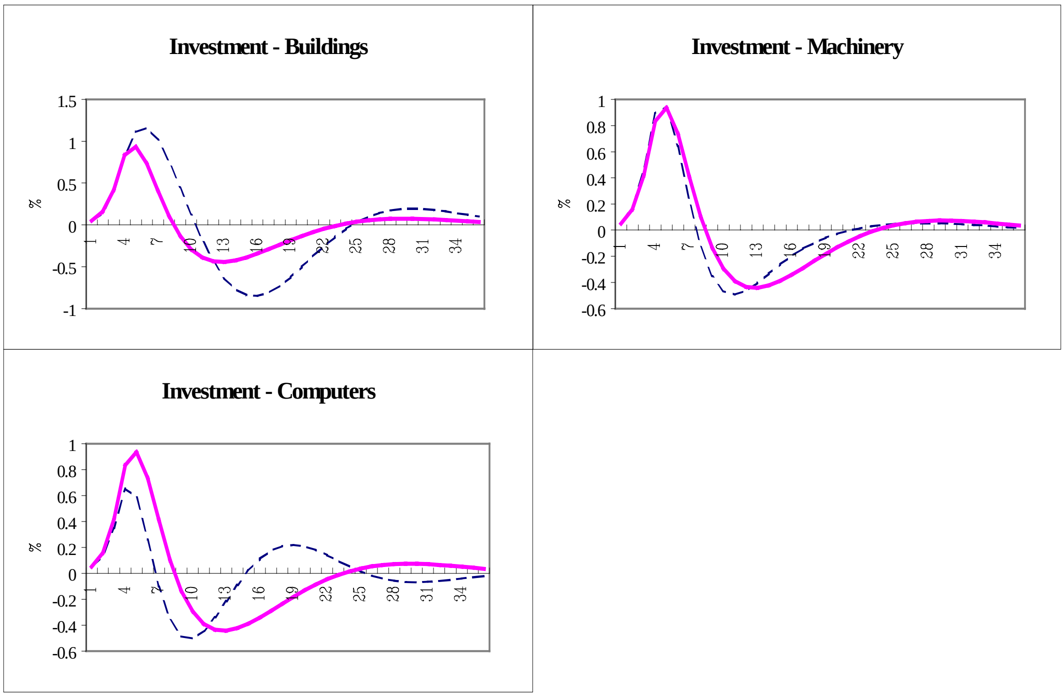
Changes to the inflation target

The FPS core model is used to simulate a one percentage point increase in the central bank's inflation target. Figure 11 shows the response of aggregate investment and its components to this experiment. Investment in machinery expands immediately and to the same degree as

10 For further details of these shocks in the core model, see Black *et al*. (1997).

aggregate investment. Machinery investment peaks approximately five quarters after the shock, which is similar to the aggregate investment response.

Figure 11: Business investment satellite model
Artificial simulation results
(shock minus control)
(Solid line is Aggregate Investment, dashed line is component)



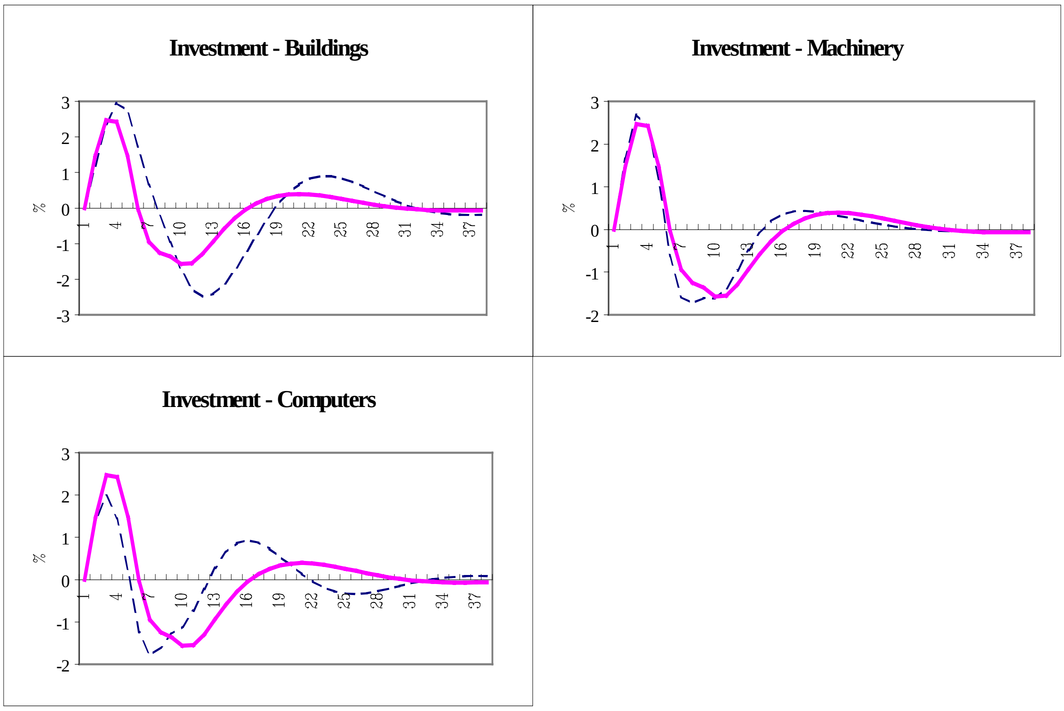
The adjustment for buildings takes slightly longer to complete than aggregate investment. Investment in buildings peaks about seven quarters after the shock. In addition, the magnitude of the change for building investment is higher than the aggregate. Since 'buildings' includes items such as land improvement and other construction, it is unclear, *a priori*, whether the response should be higher or lower than the aggregate.

The results for investment spending in computers are generally reasonable, especially considering that investment spending in computers is determined residually. The small magnitude of the change for computers is caused by the relatively large change in building investment. It is possible that the investment in computers is somewhat independent of movements in aggregate investment due to a long-term trend of substitution towards computers and away from other types of capital goods.

Temporary demand shock

In this shock, the FPS core model is used to simulate a temporary increase in consumption and investment expenditure, which lasts for four quarters. The results for this experiment are similar to the results produced in the first simulation. Figure 12 shows that investment in machinery expands at the same time and to the same degree as aggregate investment. Similarly, investment in buildings tends to lag behind aggregate investment and react by a greater magnitude. All the components of investment eventually return to their steady-state values.

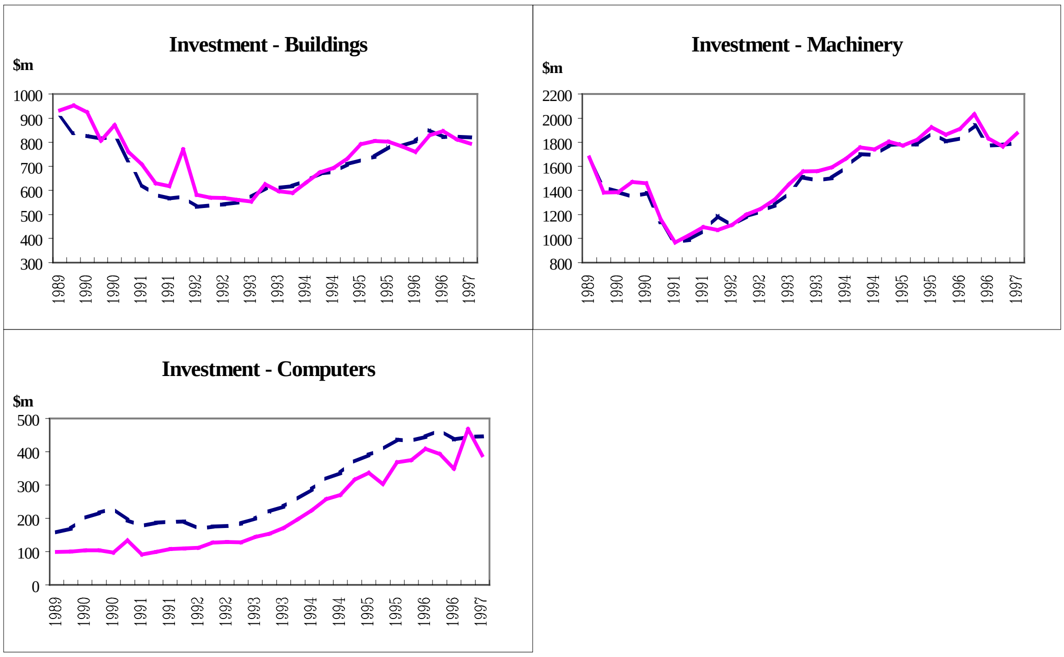
Figure 12: Business investment satellite model
Artificial simulation results
(shock minus control)
(Solid line is Aggregate Investment, dashed line is component)



6.4(b) Historical simulation properties

The model's ability to track the historical data is assessed by carrying out a dynamic simulation and examining its predictions for the components of investment. As Figure 13 indicates, the forecasts for machinery investment track the historical data quite closely and pick both the trend and the turning points. The model's forecasts for building investment also track the historical data quite well, although not as closely as for machinery. The model misses the short-lived jump in building investment which occurred in 1992. The forecast for computers, which is determined residually, is consistently over-estimated because the model tends to under-estimate machinery investment. This could be remedied by recalibrating the machinery equation to increase the degree of persistence. However, given the magnitude of computer investment relative to total investment, the relative size of the error is small.

Figure 13: Business investment satellite model
Historical simulations
(Solid line is actual, dashed line is simulated)



In summary, based on this simulation analysis, the model appears to be a useful tool for decomposing the artificial shock experiments and aggregate forecasts produced by the core model. The analysis conducted here suggests that the satellite model has reasonable dynamic properties.

7. Summary and conclusions

This paper has described the FPS demand-side satellite models. The household expenditure, exports, and business investment satellite models are designed to disaggregate the relevant macroeconomic variables generated by the FPS core model. They allow forecasters to analyse developments in each sector at a more disaggregated level and provide the detailed breakdown of the data required for public release.

The demand-side satellite models decompose the aggregates by modelling the shares allocated to each disaggregated item. The dynamic paths of these shares are explained by an equilibrium component and dis-equilibrium component.

As in the core model, attention is focused on ensuring that the models are theoretically consistent, have sensible dynamic properties and reflect the time-series properties of the data. Therefore the models were assessed by examining their dynamic response to artificial shocks and their ability to track the historical data. The satellite models presented here appear to have sensible simulation properties and generally track the data extremely well.

There are, however, a number of areas for further work. It may be useful to augment the household expenditure model with an income satellite model, which dissaggregates the aggregate household income flows into components such as compensation of employees and operating surplus. Combining the household expenditure model with an income model would provide a complete represention of the Household Income and Outlay Account.

In addition, further work could be carried out to incorporate monetary policy variables into the exports model and the business investment model. Although policy does affect aggregate exports and investment in the core model, there is no provision in the satellite models for additional policy channels into specific components. Finally, all of the models' behaviour in artificial shock experiments may be revisited if additional information on the relative effect of shocks on the demand components becomes available.

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Appendix A

Determining stocks of durable items for the household expenditure satellite model

Housing

The starting point for the housing stock in 1986 was derived by multiplying the number of houses by the average real house price. The 1986 *Census of Population and Dwellings* reports that there were 1,095,747 dwellings in New Zealand. Data from Valuation New Zealand indicate that the average house price in mid-1986 was around $84,745 in nominal terms, or $128,971 in real (1991/1992) terms.[11] This produces a starting point of approximately $129,000 million.

Depreciation rates on houses vary across studies from 1.5 percent (Diewert and Lawrence, 1994) to 4 percent (Featherstone,1995). Given this range, the rate was set at 2.5 percent per annum.

Motor vehicles

The only previous study of the stock of motor vehicles in New Zealand is the work by Diewert and Lawrence (1994). The starting point for the vehicle stock in this study was set at the same level as Diewert and Lawrence's series in 1986 and converted into real terms ($12,035 million).[12] The starting point for the equilibrium stock was set slightly higher ($12,208 million) to reflect the deregulation process occuring in the motor vehicle industry at that time.

The rate in the satellite model was set at 15 percent per annum.

Durables excluding vehicles

There was little information available about the stock of durables excluding vehicles. To derive the starting point it was assumed, for simplicity, that the stock was not changing in the first period, ie $\Delta K^{durxv} = 0$. Substituting this assumption into the perpetual inventory equation gives

$$0 = -d^{durxv} K_{t-1}^{durxv} + C_t^{durxv}$$

or

$$K^{durxv} = C^{durxv} / d^{durxv}.$$

The depreciation rate was set at 24 percent per annum.

The capital stock estimates are available on request.

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11 Nominal house price data were obtained from Valuation New Zealand (1988) *The Urban Real Estate Market in New Zealand* Research Paper 89/1. Real prices were estimated by deflating the nominal figures by the deflator for private investment in dwellings.

12 Diewert and Lawrence's nominal stock for 1986 was $11,830 million. The nominal price was deflated by the price change in new cars from the CPI regimen.

Appendix B
Determining the business capital stock in the FPS core model and the business investment satellite model

The business capital stock for the FPS core model is estimated using a standard perpetual inventory methodology. The capital stock has three components – non-residential buildings, plant and machinery (excluding computers) and computers. The individual stocks are also used in the business investment satellite model to decompose the aggregate investment profile generated by the core model.

Unpublished work conducted at the NZ Treasury in 1996 estimated the capital stock in New Zealand from 1949 to 1995. Their capital stock estimates were split into buildings and machinery (including transport equipment). The Treasury capital stock estimates for 1982 were taken as the starting point for the FPS series. These figures were adjusted to ensure consistency with the 1991/92 re-basing of the national accounts. The starting-point stocks were also adjusted down by around 10 percent to remove non-market capital items. The machinery stock was then split into computer and non-computer items. To estimate the stock of computers, it was assumed that computers accounted for 3 percent of the total stock of machinery in 1986. After this starting point, flows of investment in imported data processing equipment were cumulated.

The depreciation rates on buildings, machinery excluding computers and computers were 3.8 percent, 12.3 percent and 33 percent respectively. These figures were based on the results found in various studies carried out on overseas data.

The capital stock estimates are available on request.