



# Reserve Bank of New Zealand Analytical Notes

The Reserve Bank's method  
of estimating "potential output"  
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## NON-TECHNICAL SUMMARY<sup>1</sup>

Inflation is often thought of as being influenced by two main factors: the expectations of firms and households about future inflation, and fluctuations in economic activity around its sustainable or “potential” level. When economic activity is running ahead of this level, a positive “output gap” is said to exist: available resources are under pressure and inflation tends to pick up. For a central bank focused on targeting medium-term inflation, understanding the extent of these pressures is important. The first step in that process is estimating the “potential” level of output – past, present, and future. How the Reserve Bank does that is the focus of this paper.

Neither potential output nor the output gap can be directly observed. And many of the data used to produce estimates are released with a lag, and are subject to revision, often for several years after the first data release. For example, at any point we have Statistics New Zealand’s latest provisional GDP estimates, but they are published almost six months after the end of the quarter to which they relate and are refined and revised over several years.

The Reserve Bank’s current baseline method of estimating potential output relies on estimating trends in historical data on labour supply, capital inputs, and a (residual) measure of total factor productivity (TFP). These trends are then combined, to produce an aggregate figure for potential output. The “production function” used to do the combining is itself a stylised representation, and reliant on other data (the shares of income going to labour and capital) that are only available with a considerable lag. And the trends tend to be quite sensitive to new data, or to data revisions.

“Potential output” is a powerful conceptual tool, prompting analysts and policymakers to think hard about how much of any observed economic activity is sustainable (in line with the economy’s capacity) and how much is above or below that level, which will tend to affect inflation. But experience suggests that any estimates for recent periods are best thought of as midpoints of a range: one might think of a “true” output gap as probably being within +/- one percentage point of that midpoint estimate.

Estimates of potential output using the statistical techniques outlined here are one element in the Reserve Bank’s forecasting and policy processes. Judgement and insights from other analytical tools are frequently used as complements in reaching the published views on the current state of resources pressures. As the data become more certain, the statistical techniques play a greater role in identifying developments in potential output in historical periods. The historical output gap estimates shapes our understanding of how inflation has typically behaved in New Zealand.

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<sup>1</sup> The authors are grateful for helpful comments and critique from Michael Reddell, Yuong Ha and Reuben Jacob.



## 1. INTRODUCTION

The output gap (the percentage difference between actual and potential output) is a key concept in the way most central banks now think about inflation. In concept, it is a summary measure of the state of the business cycle and of pressure on resources, and thus of one key influence on inflation. Inflation is thought of as being primarily explained by expectations of future inflation and the output gap – and thus both for explaining past inflation and for reaching a view of likely future inflation, decomposition of output into “potential output” and the “output gap” plays a key role. Because of the long lags between policy actions and inflation outcomes, output gap estimates are an important input for a forward-looking inflation-targeting central bank.

Potential output can be thought of as the level of activity that the economy can sustain without causing inflation to rise or fall, all else equal (for example, assuming no shock, such as big changes in oil prices). By implication, the difference between actual and potential output (the output gap) indicates the extent of excess demand, and therefore the direction and magnitude of this source of inflation pressure.<sup>2</sup> The focus of this note is on how the Reserve Bank estimates the output gap, and some of the challenges involved in producing such estimates.

## 2. METHODOLOGIES

There are a number of methods for estimating potential output and the output gap. Here we briefly outline three different approaches (the production function approach, time-series techniques and fully-estimated structural models of the economy) and refer the reader to more detailed descriptions in the literature.

The production function approach combines factor inputs such as capital and labour in a production function to determine the level of potential output. The major challenges of this method are how to aggregate different types of labour, machinery, natural resources and intermediate inputs across diverse sectors of the economy, as well as deciding on an appropriate functional form and how to model technological progress explicitly. This approach becomes increasingly complex the more disaggregated the estimation is.

The most commonly used approaches to estimating potential output involve time-series techniques and structural models of the economy. These decompose output into trend and cycle, which are assumed to represent the supply and demand factors of the economy respectively. Time-series techniques include the univariate Hodrick-Prescott (HP) and Band Pass (BP) filters, which extract trend output from GDP data

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<sup>2</sup> For a detailed discussion of potential output and the output gap, see Claus et al. (2000).



alone, and multivariate (MV) filters which use a wider range of data than GDP alone. Structural vector autoregressive (SVAR) models combine multivariate time-series techniques with some structural assumptions about the nature of economic relationships. Unobserved components models also use multivariate time-series filtering techniques, while specifying tighter restrictions on economic relationships, which may be important to the user. Finally, fully-estimated structural models of the economy are used to estimate potential output and the output gap that are consistent with all other variables in the model. Within this class, potential output from DSGE models represents the level of output the economy would attain if the nominal price and wage rigidities in the models were removed.<sup>3</sup>

What methods have been used by the Reserve Bank? From 1997 to 2009, the Bank used a multivariate (MV) filter in its estimation of potential output, in which HP-filtered GDP was augmented with other macroeconomic data, such as inflation, inflation expectations, the unemployment rate and capacity utilisation.<sup>4</sup> This approach sought to use a range of sources to provide conditioning information beyond what could be drawn from the trend in GDP itself.

In 2009 the Reserve Bank moved away from this MV method to a more structural approach centred on a standard production function, and which uses highly aggregated filtered data. In this method, the estimation of potential output does not use inflation data at all – so that the resulting output gap can be used *independently* to highlight the direction of possible future inflationary pressures.

### 3. THE RESERVE BANK'S CURRENT METHODOLOGY

#### 3.1. MODELLING FRAMEWORK

The Reserve Bank uses a production function approach to estimate potential output. In this view, output is determined by capital inputs (capital stock and capacity utilisation), labour inputs (hours worked per person and the labour force) and total factor productivity (TFP) as a residual. Trends are extracted from the input series to remove the cyclical and higher frequency components, and those trends are then combined in the production function as potential output.

This approach focuses on a range of factors that can be thought of as explaining potential output, thus using more data than would a filter on a single variable (e.g. real GDP itself). As stated above, inflation data are not used explicitly in the estimation of potential output.

The production function is:

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<sup>3</sup> Overviews of various methods for estimating potential output and the output gap are included in St Amant & van Norden (1998), Döpke & Chagny (2001) and Mishkin (2007).

<sup>4</sup> Conway and Hunt (1997) and Graff (2004) describe the Bank's MV filter methodology.



$$Y_t = A_t(C_t K_t)^{(1-\alpha)}(H_t L_t)^\alpha \quad (1)$$

where  $Y_t$  is output,  $A_t$  is TFP,  $C_t$  is capacity utilisation,  $K_t$  is capital stock,  $H_t$  is hours worked per person, and  $L_t$  is number of persons employed. The parameter  $\alpha$  is labour's share in output ( $0 < \alpha < 1$ ), assumed to be  $2/3$ .<sup>5</sup>

The number of persons employed,  $L_t$ , is:

$$L_t = E_t P_t N_t \quad (2)$$

where  $E_t$  is the employment rate (calculated as 1 minus the unemployment rate),  $P_t$  the participation rate, and  $N_t$  the working age population.

The logarithmic production function is (lower case denotes logs):

$$y_t = a_t + (1 - \alpha)(c_t + k_t) + \alpha(h_t + l_t) \quad (3)$$

where

$$l_t = e_t + p_t + n_t \quad (4)$$

Data are available for most variables, and then the production function itself is used to back out (log) TFP ( $a_t$ ) as a residual:<sup>6</sup>

$$a_t = y_t - (1 - \alpha)(c_t + k_t) - \alpha(h_t + l_t) \quad (5)$$

Trends are estimated for inputs of the production function (equations 3 and 4) using an unobserved components model. This extracts trends by filtering each component, anchored by a long-run trend assumption.<sup>7</sup> All trends are time-varying. GDP, capital stock, working age population and TFP trends converge to constant growth rates, while capacity utilisation, hours worked per person, the employment rate and the participation rate trends converge to constant levels. Individual components and their estimated trends are illustrated in Appendix 1.

<sup>5</sup> This assumption is supported by the latest data, which averages 0.668 for the five years to 2013, calculated from annual data for compensation of employees, indirect taxes, operating surpluses and nominal GDP.

<sup>6</sup> Appendix 2 illustrates how this residual estimate correlates well with officially published annual data.

<sup>7</sup> We assume the trend of capital to be identical to the capital series over history, without filtering. The quarterly capital data is already a relatively smooth series. Filtering would make it more difficult to capture the discrete fall in the level of capital at 2011Q1 associated with the Christchurch earthquakes.



The trends are combined according to the production function to obtain the estimate of (log) potential output ( $\bar{y}_t$ ).

$$\bar{y}_t = \bar{a}_t + (1 - \alpha)(\bar{c}_t + \bar{k}_t) + \alpha(\bar{h}_t + \bar{l}_t) \quad (8)$$

where

$$\bar{l}_t = \bar{e}_t + \bar{p}_t + \bar{n}_t \quad (9)$$

The data used, and the sources of those data, are summarised in Table 1. All data are quarterly and seasonally adjusted, except capital which is annual data transformed to quarterly. These techniques work well for historical periods (for example, estimates of potential output and the output gap in the years prior to the 2008/09 recession). However, data issues come to the fore the more recent the period one is estimating.

**Table 1: Variables, data sources, and data availability**

Variable	Description	Data source	Data available in mid-November 2014
$Y_t$	Output: real production GDP	Statistics NZ, National Accounts	2014Q2 (release date: 18Sep2014)
$C_t$	Capacity utilisation (economy-wide)	NZIER, QSBO	2014Q3 (release date: 07Oct2014)
$K_t$	Capital: productive capital stock	Statistics NZ, National Accounts, & RBNZ calculation	Year ended March 2013 (release date: 28Nov2013)
$H_t$	Hours worked per person <ul style="list-style-type: none"> <li>• Total weekly hours</li> <li>• Total official employed</li> </ul>	Statistics NZ, HLFS	2014Q3 (release date: 05Nov2014)
$N_t$	Working age population	Statistics NZ, HLFS & RBNZ calculation <sup>8</sup>	2014Q3 (release date: 05Nov2014)
$P_t$	Participation rate	Statistics NZ, HLFS	2014Q3 (release date: 05Nov2014)
$E_t$	Employment rate = 1 – unemployment rate	Statistics NZ, HLFS	2014Q3 (release date: 05Nov2014)

The data used in the model are all published with a lag (in some cases a considerable lag). To illustrate this, Table 1 shows the latest data that were available in mid-November 2014 and used for the calculation of the potential output estimate that appeared in the December 2014 *Monetary Policy Statement (MPS)*. Only for periods up to March 2013 did we have published data for all series. Many of these data (notably GDP, capital stock, and population) are subject to revisions for several years after they are first published.

<sup>8</sup> The Statistics NZ Working Age Population (WAP) data include estimates between each population census; so recent years' data may be revised in the following census. Before filtering the data, we add a long-term forecast of population to the Statistics NZ WAP series in order to capture the expected boost to potential output from strong migration flows.



Discussion of the output gap often focuses on the estimate for the quarter in which an *MPS* is being published. Those estimates draw on the production function model, but (because much of the data for the current quarter are not yet available), we have to extend each series with a forecast to the current quarter, using indicator models, information from business information visits, and analysts' judgement.<sup>9</sup>

### 3.2 HISTORY AND FORECAST

The Reserve Bank's estimation of potential output (and of the output gap) is undertaken in two distinct stages: (i) estimation of potential output over history based on past data, and (ii) separate forecasts of the future paths of the output gap and potential output.

The model outlined in the previous section is used to estimate potential output *over history* to the current quarter. Because the data for the model components are published with a lag, we forecast each series to the current period before putting them into the model to produce the estimate of potential output over history. The output gap ( $x_t$ ) over history to the current quarter is then calculated as the difference between the log of actual output and potential output:

$$x_t = y_t - \bar{y}_t \quad (10)$$

Initial forecasts of the *forward path* of the output gap are made using the Bank's forecasting model, NZSIM, so that it is consistent with the forecasts of all other variables in the model.<sup>10</sup> The forecast output gap may be judgementally adjusted (based on data that are not in the model).

The future path of potential output is forecast (independently of NZSIM), using assumptions about each component of potential output and our forecasts for particular variables. The forecasts of the output gap and potential output are combined to produce the forecast of GDP:

$$y_t = \bar{y}_t + x_t \quad (11)$$

While it is possible to model both trend (potential output) and cycle (the output gap) within one framework, we choose to model these separately. Why? The key focus for monetary policy is the business cycle, with the aim of stabilising inflation. Therefore, constructing separate models for potential output and the output gap allows us to concentrate our forecasting effort on the cyclical component. Separately estimating

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<sup>9</sup> By "current quarter", we mean the same quarter as the date of the *MPS*. For example, in preparing the December 2014 *MPS*, we extend the component data series with forecasts to 2014Q4.

<sup>10</sup> NZSIM is a DSGE "gaps model", that is all variables/data in the model are in the form of deviations from trend, thus reflecting the economic cycle. See forthcoming Reserve Bank of New Zealand Discussion Paper on NZSIM.



the output gap, our view of the cycle remains independent of any major revision in the level of GDP or other factors that may change our view of the level of potential output.

It is important to note that our estimated path of potential output includes fluctuations with the business cycle. This can be seen in figure 1, with the slowing of the growth of potential output (flattening of the red line) associated with the downturn in real GDP during the 2008/09 recession. Given this, the output gap (figure 2) represents unsustainable fluctuations in output.

Figure 1: Real GDP and potential output

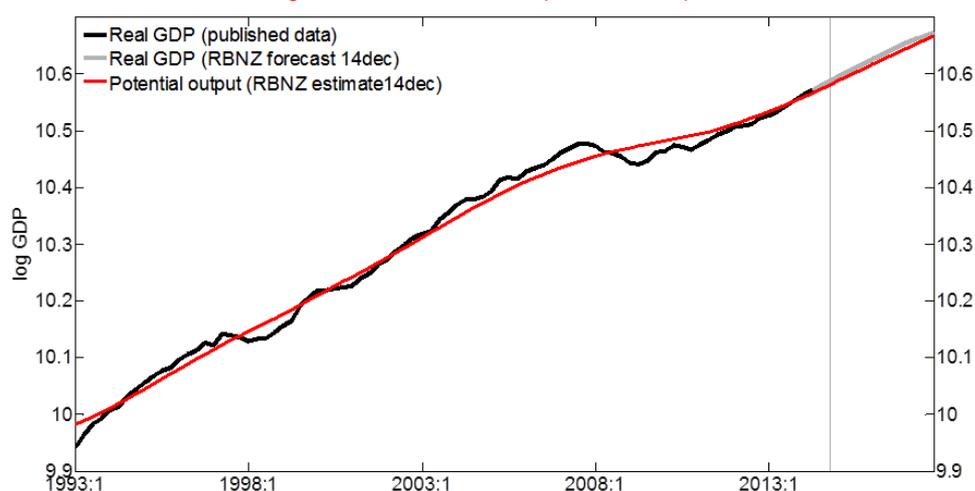
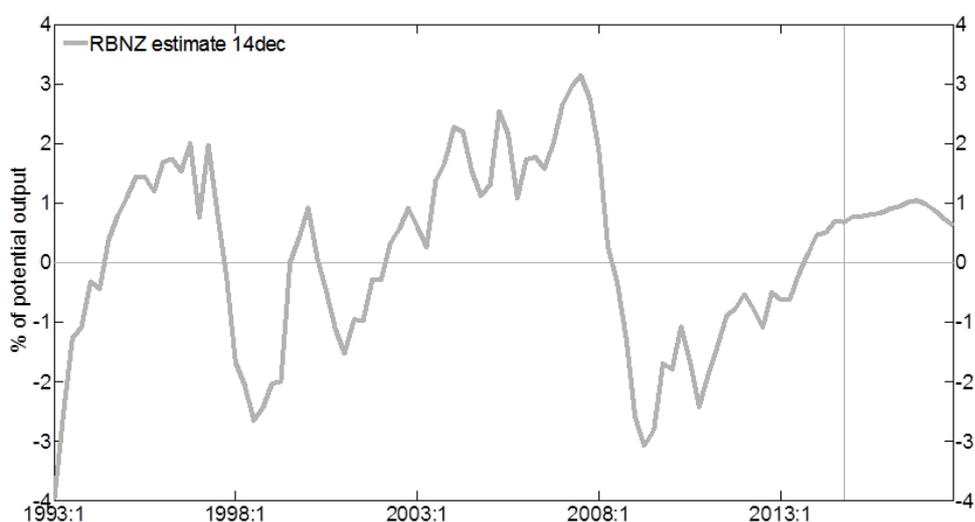


Figure 2: The output gap



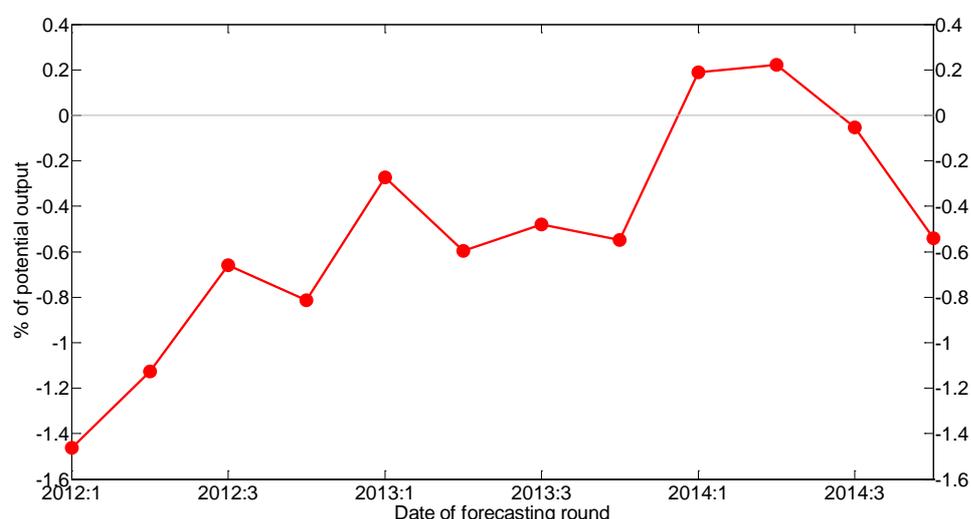
The future is, of course, unknown and can only be estimated with considerable margin of error – shocks happen and behaviours change. There is a significant amount of uncertainty surrounding the estimates of potential output and the output gap, even for the historical period. Some of this is inevitable because it is an unobservable variable – outside a model there is no “true” output gap we can benchmark estimates against. In addition, because the model relies on the filtering of



component series, many of which are themselves subject to revisions, the technique is sensitive to the end-point problem. That is, as more data become available, the estimate of potential output (and of the output gap) for a particular quarter changes. That makes sense: any judgement about the extent of excess demand will inevitably be conditioned to some extent by new information about what happened subsequently.

Figure 3 helps illustrate the scale of the issue, by reference to our published estimates of the output gap for the March quarter of 2012, approximately three years ago. The estimate made in 2012Q1 was based on GDP data to 2011Q3 and forecasts to 2012Q1. Figure 3 shows that the 2012Q1 output gap as calculated in 2012Q1 was -1.46. Since then, estimates have changed considerably as data for subsequent quarters have become available and as the GDP data have been revised.

Figure 3: Changing estimates of the 2012Q1 output gap



#### 4. CONCLUSION

The estimation of potential output and the output gap are important to an inflation-targeting central bank, such as the Reserve Bank of New Zealand, because they provide an estimate of the degree of pressure on resources – and therefore a way of understanding inflation – past, present and future.

The statistical method that the Reserve Bank uses to generate estimates of potential output has changed over the years. The current method, used since 2009, combines a production function approach with time-series filtering of data. However, this method is used only as a tool to help the Monetary Policy Committee formulate its view of the current state of the business cycle. Published estimates represent a considered view, informed by the statistical model and specific judgements. Estimates for current and recent quarters in particular are inevitably subject to a material margin of uncertainty.



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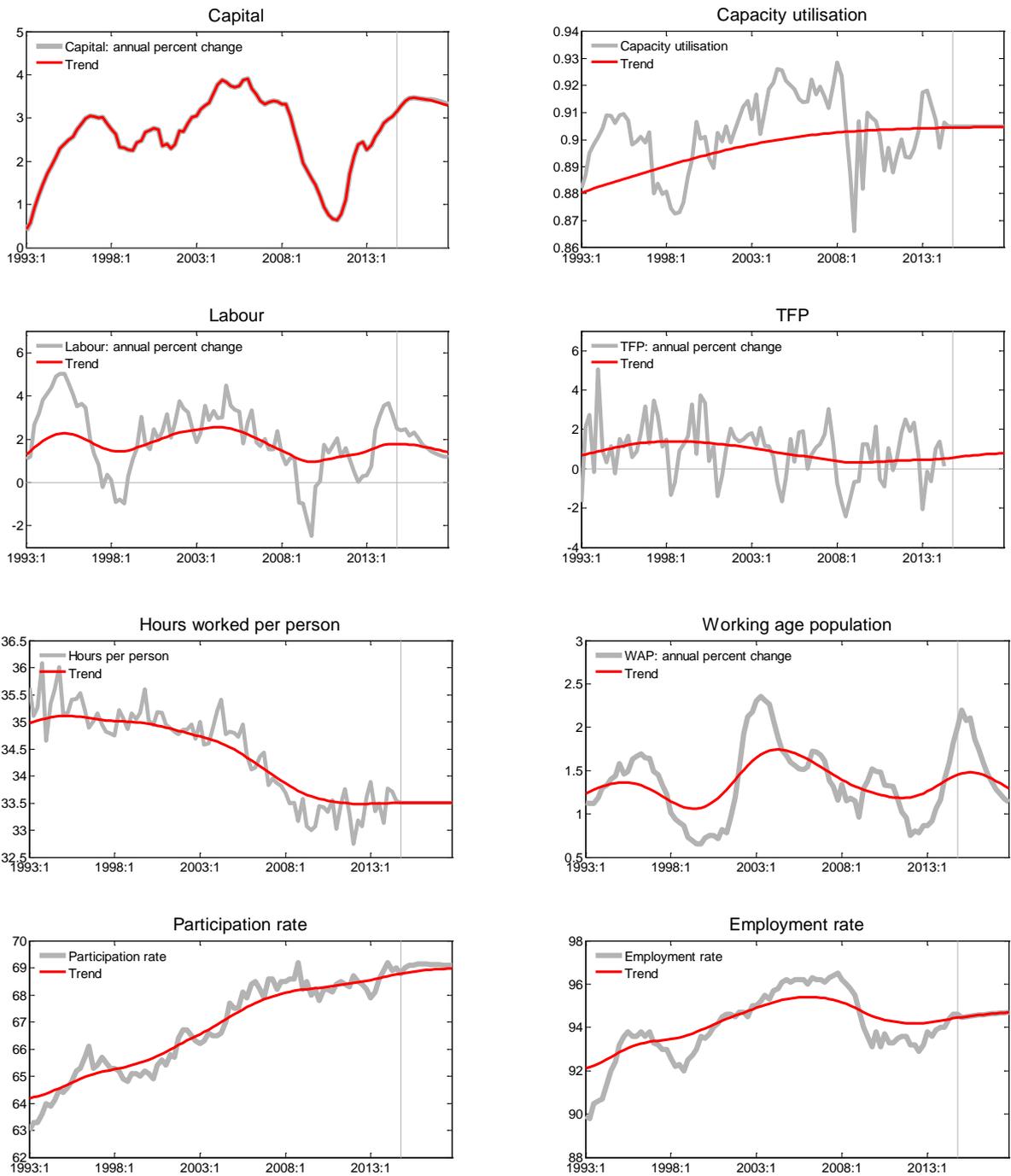
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APPENDIX 1: MODEL COMPONENTS AND THEIR TRENDS

Figure 4: Components and trends



## APPENDIX 2: HOW ACCURATE ARE OUR TOTAL FACTOR PRODUCTIVITY ESTIMATES?

In the model, TFP is estimated as a residual. How well does the resulting quarterly series correlate with the official annual TFP series, published by Statistics New Zealand? In figure 5 we can see that the model-generated quarterly data (scaled, red line) fits fairly closely with the officially published annual series (blue line). An annual series created from the quarterly model-generated data (grey line) is also fairly highly correlated with the official TFP measure.

