Suite as! Augmenting the Reserve Bank’s output gap indicator suite

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NON-TECHNICAL SUMMARY

The Reserve Bank uses an output gap indicator suite (OGIS) to help estimate the current degree of capacity pressure in the economy. When the output gap is positive, capacity pressures are high and the labour market is likely to be tight. As a consequence, inflation is likely to increase through the Phillips curve relationship. The output gap is hence very important for monetary policy.

Unlike GDP, we cannot directly measure the output gap and the estimates of the output gap obtained from statistical models tend to get revised as new datapoints are added. This is particularly true for estimates of the output gap at the endpoint of history. Using a wider range of indicators to assess capacity pressures reduces the degree to which the output gap needs to be revised.

This paper augments the existing suite with new indicators. It also evaluates how well each indicator explains inflation in a Phillips curve model, and how well it forecasts inflation and GDP. Overall, we find that the indicators perform well in these evaluations, which confirms that they are useful variables to look at when assessing capacity pressures in New Zealand.

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1. Introduction

A careful assessment of the output gap is crucial for the Reserve Bank's monetary policy framework. When the output gap is positive, or equivalently, the economy is operating above potential, inflation will rise (Gerlach and Smets, 1999; Billi, 2011; Lienert and Gillmore, 2015). The output gap is also important for the Reserve Bank's new objective of supporting maximum sustainable employment. For instance, a negative output gap may imply that the use of resources, including labour, is below its maximum sustainable level (Armenter, 2011).

The output gap, defined as the difference between the level of the economy's gross domestic product (GDP) and its underlying productive capacity (potential GDP), is a summary measure of capacity pressure in the economy (figure 1). Potential GDP is not directly observable. Estimates of potential GDP, and hence the output gap, are sensitive to both the data sample and the methodology used. This is particularly the case for real-time estimates of potential GDP; as new data points are added to the sample, the estimate of potential GDP at the end of history may change considerably. As seen in figure 2, updating the information set over time has had a significant impact on the Bank's assessment of the output gap. For example, prior to the global financial crisis, the economy was thought to be operating at full capacity. However, as more data became available, the output gap was revised up substantially.

Estimates of the output gap are prone to large revisions in real time. As such, the Bank uses a suite of indicators to inform its estimate of the output gap, rather than relying on single model. The output gap indicator suite (OGIS), consisting of 8 indicators, was originally introduced in Armstrong (2015) and it has since been used to adjust our estimate of potential GDP up until the most recently available GDP data. This Note introduces 7 additional indicators into the suite.

Since economic theory suggests that a good indicator of economic slack should explain inflation and economic growth well, we also evaluate the performance of the indicator suite in explaining non-tradables inflation and GDP growth. The results for the inflation forecasting exercises suggest that the Reserve Bank's output gap
compares favourably to most of the indicators. We also find that most of the indicators are at least as good as the output gap at forecasting near-term GDP growth.

Figure 1: The output gap in New Zealand

![Graph showing the output gap in New Zealand with shaded recessions based on Hall and McDermott (2016). The blue line represents the output gap estimate from the February 2019 Monetary Policy Statement.]

Source: RBNZ estimates.
Note: Formally, the output gap $Y_{gap_t} = 100(Y_t - Y_t^P)/Y_t^P$ where $Y_t$ is the actual level of GDP in the economy, and $Y_t^P$ is the potential level of GDP. The grey shading indicates the recessions in New Zealand, based on Hall and McDermott (2016). The blue line shows the output gap estimate from the February 2019 Monetary Policy Statement.

Figure 2: The Reserve Bank's output gap estimates in real time

![Graph showing the Reserve Bank's output gap estimates in real time with blue line representing the February 2019 Monetary Policy Statement.]

Source: RBNZ estimates.
Note: The blue line shows the output gap estimate from the February 2019 Monetary Policy Statement.
2. Potential output and the OGIS indicators: Methodology

In this section, we describe how the Reserve Bank estimates potential output and briefly examine how the individual components of the OGIS are constructed.

2.1. How the Reserve Bank estimates potential output

The Reserve Bank uses a production function approach to estimate potential GDP over history (Lienert and Gillmore, 2015). The statistical filter that the Bank’s production function approach relies on is ‘two-sided’; in order to compute potential GDP at any point in time, the filter relies on current data, lagged data as well as the data from subsequent time periods. The dependence of the filter on data from the ‘future’ leads to what is often called the end-point problem. At the end of the sample, there are no future data available to assist with estimating the current level of potential GDP (Graff, 2004). Therefore, the recent history of estimated potential GDP can be revised substantially once future data become available.

The Bank’s estimation of potential GDP, already constrained by the lack of data for the current quarter, is further complicated by the end-point problem associated with two-sided statistical filtering. The OGIS enriches the information set available to the Bank. By examining what the suite implies for capacity pressure, we can suitably adjust our output gap estimate and reduce the risk of substantial revisions in the future.

2.2. A description of the output gap indicators

The original OGIS introduced in Armstrong (2015) consisted of 8 indicators. This Analytical Note augments the suite with 7 more indicators. The 15 indicators that are evaluated here can be roughly divided into two categories.

The first set of indicators is related to the labour market. Labour is a key input into the production process, and hence, when the economy is running above potential we would therefore expect the labour market to be tight, that is, employment (unemployment) to be above (below) trend. The labour market indicators are computed using a variety of methodologies, such as Hodrick-Prescott filtering and Kalman filtering. Data reduction techniques, such as principal component modelling, are also considered.
Table 1 summarises the labour market indicators and briefly describes how they are constructed. Additionally, it indicates whether the indicator was part of the original OGIS presented in Armstrong (2015).

Table 1: Labour market indicators

<table>
<thead>
<tr>
<th>Indicator type</th>
<th>Description</th>
<th>Armstrong (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLFS employment rate gap</td>
<td>Total employment as a share of working-age population. Calculated using an HP filter with $\lambda = 40,000$.</td>
<td>Yes</td>
</tr>
<tr>
<td>QES employment rate gap</td>
<td>Filled jobs as a share of working-age population. Calculated using an HP filter with $\lambda = 40,000$.</td>
<td>Yes</td>
</tr>
<tr>
<td>Phillips curve unemployment rate gap</td>
<td>Using the Kalman filter on a reduced-form Phillips curve model to estimate the NAIRU.(^2)</td>
<td>-</td>
</tr>
<tr>
<td>New Keynesian model unemployment rate gap</td>
<td>Using the Kalman filter on a New Keynesian structural model to estimate the NAIRU.</td>
<td>-</td>
</tr>
<tr>
<td>RBNZ forecast system unemployment rate gap</td>
<td>Using the estimate of the trend unemployment rate from the RBNZ's forecasting model. Calibrated at the end of history using the above unemployment rate gaps.</td>
<td>Yes</td>
</tr>
<tr>
<td>HP-1600 unemployment rate gap</td>
<td>Using an HP filter with $\lambda = 1,600$.</td>
<td>Yes</td>
</tr>
<tr>
<td>HP-100000 unemployment rate gap</td>
<td>Using an HP filter with $\lambda = 100,000$.</td>
<td>-</td>
</tr>
<tr>
<td>Hours worked gap</td>
<td>The gap between average hours worked per-person, and an estimate of the trend level of average hours worked per-person from the RBNZ forecasting model (with adjustment to exclude changes in labour force).</td>
<td>-</td>
</tr>
<tr>
<td>Hours worked gap (MA)</td>
<td>A four-quarter moving average of the hours worked gap, which is quite volatile from quarter to quarter.</td>
<td>-</td>
</tr>
<tr>
<td>Labour utilisation composite index in levels (LUCILE)(^3)</td>
<td>A principal component of a range of labour market variables.</td>
<td>-</td>
</tr>
</tbody>
</table>

Many of the indicators in table 1 are also included in our suite of labour market indicators that we use to assess capacity pressures in the labour market (see Robinson, Culling, and Price, 2019). The labour market suite is intended to provide a holistic overview of the labour market, in order to assist the Monetary Policy Committee in assessing maximum sustainable employment. Many of these variables

\(^2\) The NAIRU is an acronym for the non-accelerating inflation rate of unemployment. These models are documented in Jacob and Wong (2018).

\(^3\) This is a modified version of the labour utilisation composite index developed in Armstrong, Kamber, and Karagedikli (2015). See Appendix A.1 for details.
do not attempt to distinguish between the trend and cycle of different variables, and as such are less useful for estimating the output gap. Only labour market indicators that estimate a trend and cycle component of each variable are included in the OGIS.

Labour market indicators only provide partial information about capacity pressure in the wider economy. The second set of indicators captures capacity pressures in other spheres of economic activity. For example, the Quarterly Survey of Business Opinion (QSBO) indicators are much broader, looking at demand, capital, and finance as factors limiting the expansion of firms from a range of industries.

Table 2 summarises the non-labour market indicators. As with the labour market indicators, we rely on a wide range of approaches, ranging from simple statistical filters to a structural vector autoregression (VAR). Appendix 1 explains how each indicator is constructed in more detail.

Table 2: Non-labour market indicators

<table>
<thead>
<tr>
<th>Indicator type</th>
<th>Description</th>
<th>Armstrong (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSBO principal component</td>
<td>A principal component of 50 QSBO measures related to capacity pressure.</td>
<td>Yes</td>
</tr>
<tr>
<td>QSBO composite</td>
<td>Combines measures of capacity utilisation and ease of finding labour.</td>
<td>Yes</td>
</tr>
<tr>
<td>Core business investment</td>
<td>A measure of core business investment, as a share of potential GDP.</td>
<td>Yes</td>
</tr>
<tr>
<td>Structural VAR</td>
<td>A structural vector-autoregression of GDP and non-tradables inflation, identified using long-run restrictions</td>
<td>Yes</td>
</tr>
<tr>
<td>Hamilton filter</td>
<td>GDP filtered using the linear projection method in Hamilton (2017).</td>
<td>-</td>
</tr>
<tr>
<td>Mean of indicator suite</td>
<td>This is the mean of the output gap indicator suite (in real time).</td>
<td>-</td>
</tr>
</tbody>
</table>

3. Data

We evaluate real-time estimates of the indicators between 2001Q2 and 2018Q3, which gives us 71 real-time vintages. The first vintage runs from 1996Q2 to 2001Q2. The real-time evaluations are carried out recursively, so for each vintage, the next
quarter of data is added, and the evaluation is carried out over the new extended sample. This continues until the 71st vintage, running from 1996Q2 to 2018Q3, the final data point for GDP at the time of the analysis. All variables used to construct the indicators are seasonally adjusted. Where possible, the seasonal adjustment is carried out in real time, as the seasonal pattern can change over time.

3.1. Examining the real-time vintages of the indicators

The level of economic slack suggested by the indicators is subject to substantial revision (figures 3 and 4). This can come from revisions to the data, in particular the national accounts, or changes to model estimates as new data are incorporated. Filtered and seasonally adjusted data will also change as new observations become available.

The large differences between the real-time and ex-post vintages of the indicators stress the importance of carrying out the evaluation exercises in real time. We implement the statistical evaluations in the next section.
Figure 3: Real-time labour market indicators

Note: All indicators are scaled to the mean and variance of the output gap in real time. Each indicator is measured in percentage point deviations from zero.
Figure 4: Non-labour market indicators and indicator mean

Note: All indicators are scaled to the mean and variance of the output gap in real time. Each indicator is measured in percentage point deviations from zero. The indicator mean is the real-time mean of the output gap indicator suite.
4. Evaluation of the indicators

We can test whether the indicators in the suite are good measures of capacity pressure using several approaches. One approach is to consider the real-time estimates of the mean of the OGIS against the current and real-time Reserve Bank estimates of the output gap. This shows that the real-time mean of the OGIS did a better job of detecting the period of increased capacity pressure prior to the 2008 recession in New Zealand (Figure 5).

Figure 5: Real-time output gap indicator suite mean

Another approach, following Armstrong (2015), is evaluating how well each indicator can forecast inflation and GDP. The logic underpinning these evaluation metrics is simple:

- A positive output gap means that resources are being intensely utilised, which should result in inflationary pressure both now and over the future. This relationship is embodied by the Phillips curve.

- A positive output gap signals weaker growth in the future as GDP returns to its potential level (Marcellino and Musso, 2010).
Since the Phillips curve provides a link between capacity pressure and inflation, we first evaluate how well each indicator explains inflation in a Phillips curve. In the second exercise, we examine how each indicator forecasts GDP and inflation out-of-sample. We use the performance of the Reserve Bank’s real-time output gap as the benchmark in each evaluation exercise.

4.1. In-sample Phillips curve evaluation

For the Phillips curve exercise, we create a real-time estimate for each of the indicators. This is done by taking the final datapoint for each vintage of the indicator, and combining them into one time series. We can then assess how well these real-time time-series fit in a Phillips curve relationship. We estimate the following equation:

$$
\pi_t = \beta_0 + \beta_1 \pi^e_{t-4} + \beta_2 \text{Indicator}_{t-4} + \epsilon_t, \quad (1)
$$

where $\pi_t$ is one year-ahead annual non-tradables inflation from the Consumers Price Index. Non-tradables inflation is a key component in the Bank’s inflation forecasts— it tends to be the most persistent part of the CPI and correlates best with the New Zealand business cycle (McDonald 2017). The second regressor, apart from the output gap indicator, is inflation expectations denoted by $\pi^e_{t-4}$. $\epsilon_t$ is the residual that follows a Normal distribution.

We use two different measures of inflation expectations in the Phillips curve exercise. The first expectations measure is the one-year-ahead expectations of annual CPI inflation, from the RBNZ Survey of Expectations. The second expectations measure is a three-year moving average of past inflation. This is a backwards-looking measure of inflation expectations, as opposed to the RBNZ Survey of Expectations measures, which are forward-looking. As discussed in McDonald (2017), this adaptive expectations measure was introduced to the Reserve Bank’s inflation forecasting.

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4 For each indicator, the 71 vintages of data are compiled in a triangular matrix, with 71 columns. Each column to the right has one more datapoint than the previous column. So by collating the final datapoint of each column, we obtain the real-time estimate of each output gap indicator at each point in history.

framework after models using forward-looking measures were consistently surprised to the downside by persistently low inflation outturns. McDonald (2017) finds that Phillips curve models using the three-year average of past annual inflation produces more accurate forecasts of inflation than models using forward-looking expectations.\(^6\)

For each indicator, and the output gap, we estimate each specification of Equation 1. Each estimation uses different datasets, which complicates formal testing of the differences in performance. However, assessing the overall fit of the different regressions, as summarised by the R-squared statistics, is instructive: these statistics tell us how much of the variation in non-tradables inflation is explained by each indicator, for a given measure of inflation expectations.

In Figures 6 and 7, we compare the R-squared statistics for each indicator and each specification. The unemployment gap estimate from the New Keynesian model, the unemployment gap from the HP filter with the smoothing parameter \(\lambda\) set to 100,000, and the SVAR perform well over both specifications. The output gap estimated from the Hamilton filter fits the worst in both cases. The Reserve Bank’s output gap (shaded in red), which does well in both regressions, delivers an R-squared of around 60% or higher, which is slightly better than the mean of the indicator suite (shaded in green). The latter finding is reassuring because the indicator suite has only been in use at the Bank since 2015.

\(^6\) This result is also in line with Karagedikli and McDermott (2016) who find that, over recent years, inflation expectations in New Zealand have become more backward-looking.
Figure 6: Goodness-of-fit for the Phillips curve model with non-tradables inflation and the RBNZ 1-year ahead inflation expectations

Figure 7: Goodness-of-fit for the Phillips curve model with non-tradables inflation and 3-year moving average inflation expectations
4.2. Out-of-sample inflation forecast performance

Since a good indicator of capacity pressure in the economy should have some information about future inflation, we use the same Phillips curve model as in the previous section. However, the key difference here is that we focus on the ability of the indicator to predict inflation in an out-of-sample context. We recast the Phillips curve as

\[ \pi_{t+4} = \beta_0 + \beta_1 \pi_t + \beta_2 \text{Indicator}_t + \epsilon_t, \]

where \( \pi_{t+4} \) = annual non-tradables inflation 4 quarters ahead and \( \pi_t \) is either the RBNZ 1-year head inflation expectations or the 3 quarter moving average of CPI inflation. \( \epsilon_t \) is an independently and identically distributed error term that is drawn from a Normal distribution.

Unlike for the in-sample Phillips curve fitting exercise, where we used only the endpoints of the real-time vintages for each indicator to explain inflation, we use every datapoint in each real-time vintage of the indicators for our out-of-sample forecasting exercises.

As with the in-sample exercise, we benchmark the forecast performance of each indicator in the suite against the Reserve Bank’s official measure of the output gap. We compute the root mean squared forecasting errors (RMSFEs) across real-time vintages for each forecasting model and compare them with the RMSFE of the Reserve Bank’s real-time output gap estimate. We then use the forecast comparison test formulated by Diebold and Mariano (1995) and West (1996) to assess whether these models have significantly different forecasting ability compared to the Reserve Bank’s output gap estimate.

Figures 8 and 9 present the results from the two specifications of the Phillips curve. In each figure, the y-axes present the absolute RMSFEs for each indicator presented on the x-axes. The statistics for the RBNZ output gap are represented by red bars, the means of the indicator suite are indicated in green while the rest are marked in blue. If an indicator’s RMSFE is higher (lower) than the horizontal dashed line, it implies that...
its inflation forecast accuracy is worse (better) than the RBNZ output gap. If the forecasts are significantly different from that of the RBNZ output gap, red stars indicate the degree of significance.

The results in figure 8 (using the survey measure of inflation expectations) show the SVAR gap is the only indicator that does better at forecasting inflation than the RBNZ output gap, but the Diebold-Mariano-West test statistic is not statistically significant. On the other hand, 6 indicators and the mean of the indicators do significantly worse, at least at a 10% level of significance. The rest of the indicators deliver forecasts that are not significantly different from that of the RBNZ output gap.

Figure 8: 1-year ahead non-tradables inflation forecasting performance using RBNZ 1-year ahead inflation expectations as expectations measure

The results in figure 9 (using the adaptive measure of expectations) show that 11 indicators, including the mean of the indicator suite, perform significantly worse than the RBNZ output gap at the 10% level of statistical significance. The inflation forecasts...
from the rest of the indicators are not statistically different from that of the RBNZ output gap.

**Figure 9**: 1-year ahead non-tradables inflation forecasting performance using 3-year moving average inflation expectations as expectations measure

![Graph showing inflation forecasting performance](image)

**Measure of expectations**: RBNZ 1y↑ 3Y MA of CPI APC

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**4.3. Out-of-sample forecast performance for GDP growth**

We now assess the ability of each indicator to predict future GDP growth. If capacity pressure is high, and the economy is operating ‘above potential’, it could signal that GDP growth will decline in the future as the economy returns to potential. The real-time vintages of each output gap indicator forecast the final vintage of quarterly GDP growth in the following regression model:

\[ Y_{t+h} = \beta_0 + \beta_1 \text{Indicator}_t + \epsilon_t \] (3)
where $Y_{t+h}$ is quarterly GDP growth from 1 to $h$ quarters ahead and $\varepsilon_t$ is an independently and identically distributed error term drawn from a Normal distribution.\footnote{We select the final vintage of GDP growth because it has been through Stats NZ's annual benchmarking process, and is therefore likely to be better measured than real-time GDP estimates.}

We set the maximum forecast horizon $h$ to 10 quarters ahead and collect the forecast errors of each indicator at each horizon. To evaluate the indicators, we use the Reserve Bank's output gap estimate as the baseline, and compare the RMSFE of each indicator with the RMSFE of the output gap, at each horizon. Finally, as in the inflation forecasting exercise, we use the Diebold-Mariano-West test to evaluate whether each indicator forecasts GDP growth significantly differently to the RBNZ's output gap at each horizon.

Figure 10 shows the RMSFE of each labour market indicator, relative to the RMSFE of the Reserve Bank's output gap estimate and Figure 11 presents the analogous results for the non-labour market indicators. The RMSFE of the Reserve Bank's output gap estimate is normalised to one, so that a relative RMSFE greater (smaller) than 1 means that the indicator is worse (better) at forecasting GDP. The x-axis shows the forecast horizon, and the y-axis shows the relative RMSFE of each indicator. We present results for Diebold-Mariano-West tests of statistical significance for each forecast horizon in Tables A.2.1 and A.2.2 in Appendix A.2.

In Figures 10 and 11, it is clear that every indicator forecasts quarterly GDP growth better than the Reserve Bank's output gap for at least one forecast horizon. Most of the indicators are statistically significantly better at forecasting GDP in the near term, which we define here as one to five quarters ahead. The forecasting performance of the mean of the indicator suite is significantly better than the output gap in the first quarter ahead. For later forecast horizons up to 2 years ahead, the GDP growth forecast from the mean of the suite, is statistically indistinguishable from that of the output gap. The superior performance of most of the indicators, including the mean, over the first year or so suggests there is value in indicators of capacity pressure in addition to the RBNZ output gap.
Figure 10: RMSFEs of the labour market indicators (relative to output gap) for forecasting GDP growth

Figure 11: RMSFEs of the non-labour market indicators (relative to output gap) for forecasting GDP growth
5. Conclusion

This paper updated the Reserve Bank’s output gap indicator suite with new measures. We compared how well the indicators and the Bank’s output gap explain inflation in a Phillips curve framework, in real time. The paper also evaluated the ability of the indicators, relative to the Bank’s output gap measure, to forecast GDP growth and non-tradables price inflation.

The results suggest that the Reserve Bank’s output gap does not do badly, relative to all the other indicators. However, several indicators perform as well as or slightly better than the output gap in explaining and forecasting inflation and GDP growth. This lends credence to the use of a suite of indicators rather than any single measure, to inform the Bank’s assessment of capacity pressures. We will continue to assess the statistical properties of the indicators, and the output gap indicator suite will evolve further as data sources develop and methodologies improve.
REFERENCES


APPENDIX

A.1. How each indicator is calculated

This section outlines how each indicator in the output gap indicator suite is calculated.

Employment rate gap (HLFS) – used in Armstrong (2015)
This gap is calculated using the employment rate minus an estimate of its trend. The employment rate is total employment divided by the working-age population. Total employment and working-age population estimates are from the *Household Labour Force Survey (HLFS)*, published by Stats NZ. We filter the employment rate using the HP filter in order to obtain an estimate of its trend. A stiff filter is used, with the smoothing parameter set to 40,000.

Employment rate gap (QES) – used in Armstrong (2015)
This gap is calculated using the employment rate minus an estimate of its trend. The employment rate is total filled jobs divided by the working-age population. Total filled jobs comes from the *Quarterly Economic Survey (QES)*, published by Stats NZ. An HP filter is used to estimate the trend in this employment rate, with the smoothing parameter set to 40,000.

Unemployment rate gap (RBNZ internal measure) – used in Armstrong (2015)
This gap is calculated using the unemployment rate minus an estimate of its trend. The trend is an estimate of the trend unemployment rate, calculated by the Reserve Bank’s forecasting model, NZSIM (documented in Kamber, et. al., 2015). Recently, the NAIRU estimates from the models in Jacob and Wong (2018) have been used to calibrate the endpoint of NZSIM’s in-sample unemployment rate trend estimate.

Unemployment rate gap (Phillips curve model)
This gap is calculated using the unemployment rate minus an estimate of its trend. The trend is an estimate of the non-accelerating inflation rate of unemployment (NAIRU). The NAIRU is calculated using the reduced-form Phillips curve model documented in Jacob and Wong (2018). The unemployment rate estimate is from the HLFS.

Unemployment rate gap (New Keynesian model)
This gap is calculated using the unemployment rate and an estimate of the NAIRU. The NAIRU is estimated using a New Keynesian dynamic stochastic general equilibrium model, also documented in Jacob and Wong (2018).

Unemployment rate gap (HP filter, \( \lambda = 1600 \)) – used in Armstrong (2015)
For this unemployment rate gap, the estimate of the trend unemployment rate is calculated using the HP filter, with the smoothing parameter set to the standard 1600 for quarterly data.
Unemployment rate gap (HP filter, $\lambda = 100,000$)
For this unemployment rate gap, the estimate of the trend unemployment rate is calculated using the HP filter, with the smoothing parameter set to a more-stiff 100,000.

Hours worked gap
This measure looks at the deviation of average hours worked per person from its trend, with an additional adjustment that aims to exclude the impact of changes in the labour force. The formula for the indicator is:

$$\text{Hours gap}_t = \log \left( \frac{1 - u_t}{1 - u^*} \right) + \log \left( \frac{hpp_t}{hpp^*} \right)$$

where $u_t =$ the unemployment rate, $u^* =$ RBNZ internal measure of trend unemployment, $hpp_t =$ hours worked per person, and $hpp^* =$ RBNZ internal measure of trend hours worked per person. The hours worked per person measure is constructed from the total hours worked divided by the working-age population, both from the HLFS.

Hours worked gap (Moving average)
The hours worked measure outlined above is quite volatile from quarter to quarter. We therefore consider a smoothed version of the hours worked gap, which is a four quarter moving average of the indicator.

Labour utilisation composite index in levels (LUCILE)
This indicator is modified version of the labour utilisation composite index developed in Armstrong, Kamber, and Karagedikli (2016). The LUCILE indicator is a principal component of a range of different labour market data series, listed below in Table A.1.1.
Table A.1.1: Data series used to compute the LUCILE indicator

<table>
<thead>
<tr>
<th>Variables</th>
<th>Transformation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment rate</td>
<td>% of labour force</td>
<td>HLFS</td>
</tr>
<tr>
<td>Underemployment rate</td>
<td>% of labour force</td>
<td>HLFS</td>
</tr>
<tr>
<td>Unemployment (under 27 weeks)</td>
<td>% of labour force</td>
<td>HLFS</td>
</tr>
<tr>
<td>Unemployment (over 53 weeks)</td>
<td>% of labour force</td>
<td>HLFS</td>
</tr>
<tr>
<td>Transitions from unemployed to employed</td>
<td>% of unemployed</td>
<td>HLFS</td>
</tr>
<tr>
<td>Transitions from not-in-the-labour force to employed</td>
<td>% of not in the labour force</td>
<td>HLFS</td>
</tr>
<tr>
<td>Transitions from employed to unemployed</td>
<td>% of employed</td>
<td>HLFS</td>
</tr>
<tr>
<td>Employment rate</td>
<td>% of working-age population</td>
<td>HLFS</td>
</tr>
<tr>
<td>Equivalent full-time unemployment rate</td>
<td>% of labour force</td>
<td>HLFS</td>
</tr>
</tbody>
</table>

QSBO principal component – used in Armstrong (2015)
This variable is a principal component of 50 variables from the Quarterly Survey of Business Opinion (QSBO), which is published by the New Zealand Institute of Economic Research (NZIER).

QSBO composite – used in Armstrong (2015)
As documented in Armstrong (2015), this indicator ‘combines observed capacity variables (surveyed measures of capacity utilisation and labour tightness) using unobserved factor shares’ (p. 6). The formula for this indicator is

\[ Y = \alpha \times \text{Difficulty finding labour} + (1 - \alpha) \times \text{Capacity utilisation}, \]

where difficulty finding labour is a measure that equally weights the difficulty finding skilled and unskilled labour measures from the QSBO, capacity utilisation is a variable in the QSBO, and \( \alpha \) = the labour share of income (set to two thirds – in line with the calibration of the Reserve Bank’s main forecasting model, NZSIM).

Core business investment – used in Armstrong (2015)
This is a gap calculated with the following formula:

\[ \text{Core investment gap} = \frac{\text{Core business investment}}{\text{Potential output}} \]

where potential output is the Reserve Bank estimate of potential output documented in Lienert and Gillmore (2015), and core business investment is a measure of investment designed to isolate the more cyclical component of investment in New Zealand. As noted in Armstrong (2015), core business investment is total business
investment minus investment in intangible assets, data processing equipment, and the chain-linked residual.

**Structural vector autoregression (SVAR) – used in Armstrong (2015)**
The SVAR uses inflation and output in the model, and is identified with long-run restrictions as in Blanchard and Quah (1989).

**Hamilton filter**
This indicator uses the linear projection filtering method developed in Hamilton (2017) to decompose movements in output into a trend and cyclical component. The cyclical component is an estimate of the output gap. We use 4 lags of output in the regression used for forecasting GDP growth, and forecast 8 quarters ahead, as per the suggestions of Hamilton (2017).

**Mean of the indicators**
This measure is often used to summarise the information provided by the output gap indicator suite. As a result, it is important to know how well this indicator performs in real time. The measure is constructed from all the output gap indicators, in real time, and after they have been standardised and scaled to the output gap.
A.2. Output gap forecasting exercise results

Table A.2.1: GDP growth forecasting results for labour market indicators— root mean square forecast errors relative to the RBNZ output gap

<table>
<thead>
<tr>
<th>h</th>
<th>HLFS employ. gap</th>
<th>QES employ. gap</th>
<th>Hours worked gap</th>
<th>Hours worked gap (MA)</th>
<th>Unemp. gap (RBNZ FC system)</th>
<th>Unemp. gap (HP lambda = 100,000)</th>
<th>Unemp. gap (HP lambda = 1600)</th>
<th>Unemp. gap (NK NAIRU)</th>
<th>Unemp. gap (PC NAIRU)</th>
<th>LUCILE princ.comp.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.93*</td>
<td>0.95</td>
<td>0.93***</td>
<td>0.95***</td>
<td>0.96**</td>
<td>0.95</td>
<td>0.95</td>
<td>0.97***</td>
<td>0.95***</td>
<td>0.93***</td>
</tr>
<tr>
<td>2</td>
<td>0.93</td>
<td>0.91**</td>
<td>0.92**</td>
<td>0.95</td>
<td>0.96*</td>
<td>0.95</td>
<td>0.95</td>
<td>0.97</td>
<td>0.95</td>
<td>0.93</td>
</tr>
<tr>
<td>3</td>
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<td>0.88***</td>
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<td>0.95</td>
<td>0.97</td>
<td>0.96</td>
<td>0.96</td>
<td>0.93*</td>
<td>0.97</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>0.93*</td>
<td>0.92***</td>
<td>0.95</td>
<td>0.96</td>
<td>0.96</td>
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<td>0.95</td>
<td>0.95</td>
<td>0.98</td>
<td>0.93</td>
</tr>
<tr>
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<td>0.91***</td>
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<td>1.00</td>
<td>1.01</td>
<td>0.98</td>
<td>0.98</td>
<td>0.93</td>
<td>1.02</td>
<td>0.97</td>
</tr>
<tr>
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<td>0.95</td>
<td>1.00</td>
<td>1.00</td>
<td>1.01</td>
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<td>0.98</td>
<td>0.95</td>
<td>1.01</td>
<td>0.94</td>
</tr>
<tr>
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<td>0.92</td>
<td>0.96</td>
<td>1.02</td>
<td>1.00</td>
<td>1.01</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>1.00</td>
<td>0.92*</td>
</tr>
<tr>
<td>8</td>
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<td>0.95</td>
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<td>0.98</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>1.00</td>
<td>0.98</td>
<td>0.89**</td>
</tr>
<tr>
<td>9</td>
<td>0.92</td>
<td>0.93</td>
<td>0.95**</td>
<td>0.95**</td>
<td>0.96</td>
<td>0.97*</td>
<td>0.97*</td>
<td>0.98</td>
<td>0.95*</td>
<td>0.86**</td>
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<tr>
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<td>1.00</td>
<td>1.00</td>
<td>0.97</td>
<td>0.98</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Note: Table A.2.1 shows the RMSFE of each labour market indicator relative to the RBNZ output gap estimate, at each forecast horizon. We evaluate how well each indicator in the indicator suite forecasts quarterly GDP growth, from 1 to 10 quarters ahead. The Diebold-Mariano-West test is used to assess if an indicator’s forecast performance is significantly different from the Reserve Bank’s output gap. If the relative RMSFE is smaller than one, it implies that the indicator has a better forecast performance than the RBNZ output gap. The superscripting by the symbol * indicates that an indicator performs significantly differently than the output gap at the 10% significance level at a particular horizon. ** indicates significance at the 5% level, and *** at the 1% level. Relative RMSFEs are rounded to 2 decimal places.
Table A.2.2: GDP growth forecasting results for non-labour market indicators—root mean square forecast errors relative to the RBNZ output gap

<table>
<thead>
<tr>
<th>h</th>
<th>QSBO princ. comp.</th>
<th>QSBO composite</th>
<th>Core bus. invest.</th>
<th>SVAR (Blanchard-Quah) gap</th>
<th>Hamilton filter gap</th>
<th>Mean of all indicators</th>
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<td>0.90**</td>
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<td>0.96**</td>
<td>0.96</td>
<td>0.97***</td>
</tr>
<tr>
<td>2</td>
<td>0.92*</td>
<td>0.91*</td>
<td>0.99</td>
<td>0.96**</td>
<td>1.00</td>
<td>0.96</td>
</tr>
<tr>
<td>3</td>
<td>0.93</td>
<td>0.93*</td>
<td>0.94</td>
<td>0.96</td>
<td>0.94</td>
<td>0.96</td>
</tr>
<tr>
<td>4</td>
<td>0.96</td>
<td>0.98</td>
<td>0.97</td>
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<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
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<td>1.02</td>
<td>1.02</td>
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<td>0.96</td>
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<tr>
<td>6</td>
<td>1.03</td>
<td>1.02</td>
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<tr>
<td>9</td>
<td>0.95*</td>
<td>0.96*</td>
<td>0.94*</td>
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<tr>
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<td>0.99</td>
<td>0.94</td>
<td>1.01</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

**Note:** Table A.2.2 shows the RMSFE of each non-labour market indicator relative to the RBNZ output gap estimate, at each forecast horizon. We evaluate how well each indicator in the indicator suite forecasts quarterly GDP growth, from 1 to 10 quarters ahead. The Diebold-Mariano-West test is used to assess if an indicator’s forecast performance is significantly different from the Reserve Bank’s output gap. If the relative RMSFE is smaller than one, it implies that the indicator has a better forecast performance than the RBNZ output gap. The superscripting by the symbol * indicates that an indicator performs significantly differently than the output gap at the 10% significance level at a particular horizon. ** indicates significance at the 5% level, and *** at the 1% level. Relative RMSFEs are rounded to 2 decimal places.