Estimating the potential output of the New Zealand economy

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Potential output plays a central role in the formulation of monetary policy focused on maintaining low and stable inflation. In this article, the technique that the Reserve Bank currently uses to estimate potential output is outlined. A model that explains how the productivity component of potential output changes through time, and the implications that this has for future potential output growth, is also presented.

1 Introduction

An economy's level of potential output is determined by the quantity and quality of its productive factors and the prevailing level of technology. If, for example, firms acquire more machinery or introduce improved methods of production, then the potential output of the economy will increase. In this sense, potential output relates to the capacity of the economy to **supply** goods and services. Accordingly, the growth rate of potential output is the rate of growth that an economy can sustain for long periods of time.

If the economy grows at a different rate from that of potential output, then inflation will tend to adjust in response to **demand** pressures in key markets. In modern macroeconomic theory, the difference between aggregate demand and potential output is one of the key sources of change in inflation pressure. This difference is quantified using a measure of the 'output gap', which is simply the percentage difference between actual output and potential output. If the output gap is positive, aggregate demand exceeds potential output, and inflation tends to rise. Conversely, a negative output gap implies spare productive capacity in the economy, which tends to reduce inflationary pressure. Because of this relationship, the Reserve Bank requires a reasonable estimate of potential output and the associated output gap to use as an important input into the monetary policy-making process.

Unfortunately, potential output cannot be directly observed. Instead, economists have developed techniques that infer the level of potential output from information contained in observable macroeconomic data. This article outlines the techniques that the Reserve Bank currently uses to estimate the potential output of the New Zealand economy. First, we describe some of the early methods used by economists to measure potential output and discuss their weaknesses. Next,

we outline techniques that have been designed to overcome those weaknesses and describe the method that is currently used at the Reserve Bank to estimate the recent path of New Zealand's potential output. Finally, we discuss some research that underpins the Reserve Bank's estimate of how quickly the potential output of the New Zealand economy will grow in the future.

2 Estimating recent potential output

2.1 How do economists measure potential output?

One of the most sophisticated approaches to measuring potential output is to capture salient aspects of the economy's production process using an economic model. In essence, this technique attempts to relate the evolution of potential output to trends in the economy's factors of production, such as machinery and workers. Unfortunately, this approach is often impractical because of large uncertainties about the precise nature of the production processes involved. Trying to model accurately the level of technology in the economy is particularly ambitious.

The problems associated with using these types of techniques to measure potential output are particularly acute in the case of the New Zealand economy. Using an economic model to disentangle the fundamental aspects of the production process in New Zealand is an extremely difficult task because of the high degree of structural change that has occurred over the last decade or more. Further, the large uncertainties associated with measures of New Zealand's capital stock also imply that a purely structural approach to estimating potential output is not a feasible option.

Figure 1
Potential output, linear time trend
(1991/92 dollars)
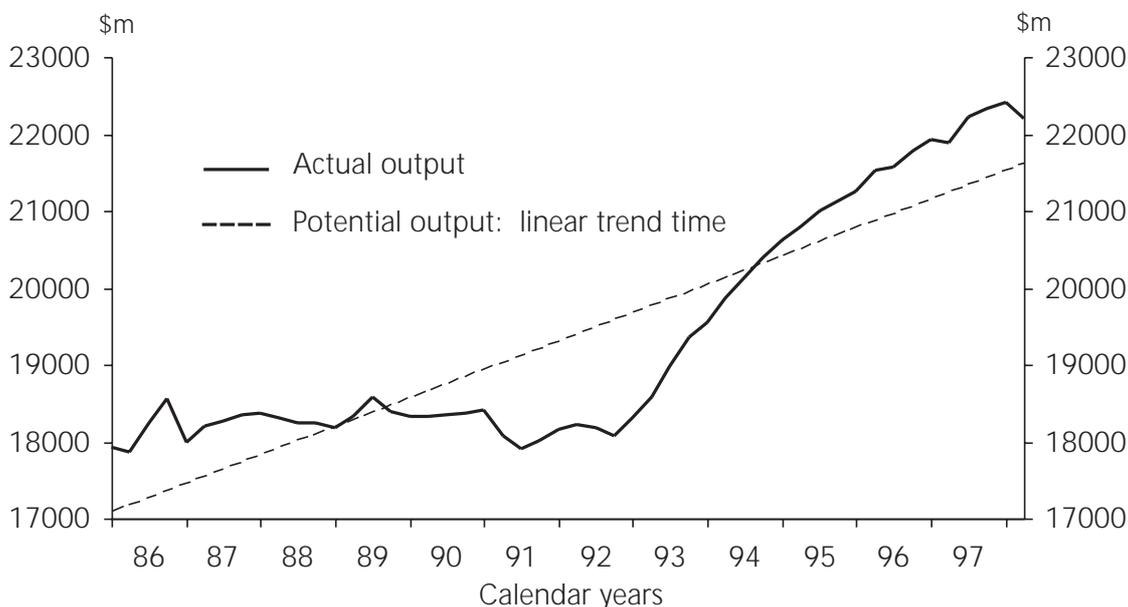
An alternative to structural techniques is to use simple time series techniques that estimate potential output solely from information contained in the actual output series. One such technique is simply to calculate a linear (straight line) time trend from the actual output series. Trend output is then taken as a measure of the economy's potential output. The results of this technique, applied to New Zealand real output, are shown in figure 1. As is apparent from the figure, this technique assumes that the economy's potential output evolves at a constant rate. The corollary to this assumption is that all of the movements in real output about the smooth time trend are interpreted as the result of changes, or shocks, to aggregate demand.

In the 1970s, economists began to question the assumption that an economy's capacity to produce goods and services grows at a constant rate through time. The historical experiences of many economies suggested that changes in potential output do not follow a straight line trend. The oil shocks of the 1970s, for example, had a dramatic (negative) impact on the productive capacity of many economies, as some existing production technologies ceased to be viable. These types of experiences suggested that there is no reason to assume that an economy's level of potential output evolves smoothly through time.

This new view of the world implies that movement in real output can occur as a result of shocks to aggregate demand *and* shocks to potential output. From this perspective, techniques for estimating potential output must determine the components of changes in actual output that are attributable to changes in aggregate demand and those that are attributable to changes in potential output. One technique that has been widely used to effect this decomposition is called the Hodrick and Prescott[1] (HP) filter. Unlike the constant time trend discussed above, the HP filter was designed to reproduce a trend line that "students of business cycles and growth would draw through a time plot"[2] of the real output series. Since the late 1980s, a number of central bank economists have been using the trend line calculated by the HP filter as an estimate of the economy's potential output. The HP trend of New Zealand real output is shown in figure 2, overleaf.

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[1] This filter is discussed in Hodrick and Prescott (1997). A brief discussion on the mathematics of the HP filter is given in box 1.

[2] Kydland and Prescott (1990), page 8.

Figure 2
Potential output, HP filter
(1991/92 dollars)
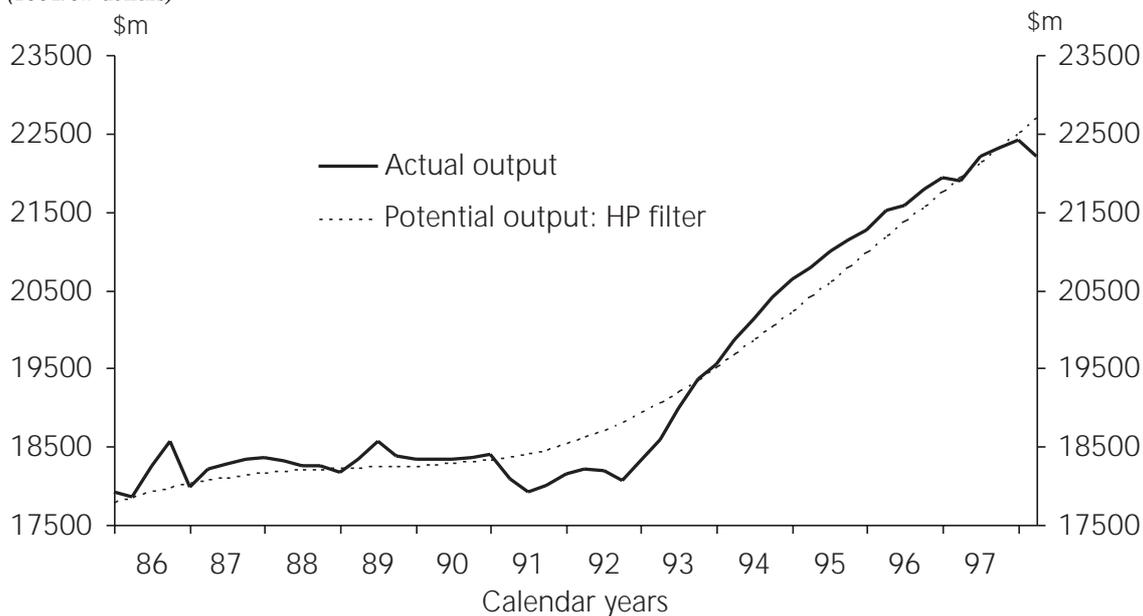
Effectively, the HP filter estimates potential output by separating the permanent changes in actual output from the temporary changes. If actual output increases permanently, then trend output, as measured by the HP filter, will also increase. However, if an increase in actual output is only temporary, and is subsequently reversed, then the HP trend of output will not be greatly affected by the changes in actual output. For example, as can be seen in figure 2, real output in New Zealand experienced a blip upwards at the start of 1986. This occurred because consumers increased their spending in anticipation of the goods and services tax (GST). The increase in output was, to a large extent, reversed at the end of 1986 after the GST had been introduced. This pattern of change to real output does not cause a substantial increase in the HP trend because the HP filter identifies the initial increase in output as temporary. In contrast, the HP filter interprets much of the increase in actual output that occurred from 1993 onwards as permanent.

But how can we be sure that the HP filter accurately decomposes actual output into its potential output (permanent) and demand (temporary) components? Because of the extensive use of the HP filter, a lot of research has been directed at answering this question.[3] This work indicates that the HP filter will only provide a robust estimate of potential output if the actual real output series satisfies a number of quite stringent criteria. Further, the real output series for most countries often do not satisfy the necessary requirements.[4] As a consequence, there is no guarantee that the HP filter will provide an accurate measure of potential output.

Another problem associated with using the HP filter to measure an economy's level of potential output is that estimates near the end of the sample period are unstable and are likely to be revised significantly when new observations of the actual output series become available. This occurs because it is unclear whether recent changes in output will be permanent or temporary. As a result, the HP filter is even less likely to provide an accurate measure of potential output at the end of the sample period. Yet, it is the most recent estimates of potential output that are the most important in providing a platform for forecasting near-term inflation.

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[3]   Some recent examples of this research include Harvey and Jaeger (1993), Cogely and Nason (1995) and Guay and St-Amant (1996).

[4]   For the HP filter to give an accurate measure of an economy's potential output, the real output series must satisfy the following conditions. Firstly, changes to the supply component cannot have a larger influence on the evolution of real output than changes to the demand component. Secondly, the cycles in real output that arise solely from the changes in demand cannot last for more than roughly eight years. However, real output series typically have *either* a supply component that is important relative to the demand component (violating the first condition) *or* a demand component whose variability is largely a function of long-lived cycles (violating the second condition).

Accordingly, it is estimates of potential output near the end of the sample period that policy makers need to be the most certain about.

2.2 How can the weaknesses of the HP filter be overcome?

There are three general ways in which researchers have tried to improve the accuracy with which the HP filter measures an economy's level of potential output:

1   A number of authors use other observable economic data that may contain information about the extent to which demand in the economy differs from potential output.[5]

2   The 'smoothness constraint', which determines how closely the HP trend follows the actual output series, can be adjusted to reflect more correctly the relative importance of changes in the supply and demand components of real output.[6]

3   Estimates of potential output near the end of the sample period can be constrained so that they are less likely to be revised as more data on real output becomes available through time.[7]

Research at the Reserve Bank has examined all of these strategies. The technique that has been developed as a result of this research builds on the HP filter and is called the multivariate (MV) filter.

Consistent with point 1 above, the MV filter uses a range of macroeconomic information to identify more accurately the supply and demand components of real output. Recent inflation in the economy is one source of information that is used by the MV filter to improve the estimate of potential output. This is because inflation responds very differently to changes in potential output and changes in aggregate demand. For example, if output increases because of an increase in aggregate demand, then inflation will tend to rise. However, if the increase in output is the result of an increase in potential output, then inflation will tend to fall. Accordingly, the MV filter uses the information contained in the inflation series to help identify the components of output growth attributable to changes in demand and changes in potential output. The MV filter also uses information from the labour market to help estimate potential output. This is because conditions in the labour market can provide a useful indication of conditions in the goods market. For example, a sustainable decline in the rate of unemployment may be indicative of an increase in the economy's potential output. Finally, a survey measure of the economy's capacity utilisation rate is also incorporated into the MV filter because this is the only observable information that is conceptually close to the notion of potential output.

All of this macroeconomic information is incorporated into the estimation technique in a fairly general way. We do not impose rigid structural assumptions because of the significant uncertainty that exists about the explicit nature of the macroeconomic relationships involved.

We have also examined the implications of altering the value of the 'smoothness constraint' of the HP filter to reflect a higher incidence of aggregate supply shocks in the New Zealand economy over certain periods, as discussed in point 2 above. We have found that making this alteration does not have a significant effect on the estimate of potential output. Finally, in keeping with point 3 above, the estimate of potential output is constrained by a long-run growth assumption at the end of the sample period. This improves the stability of the estimate as more data becomes available.[8]

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[5]   In Laxton and Tetlow (1992), HP filter estimates of potential output are conditioned using the additional information suggested by the economic framework within which the estimate of potential is used. Laxton and Tetlow find that conditioning information from the inflation process and the labour market improves the accuracy of the HP filter estimate of potential output.

[6]   Razzak and Dennis (1995) lower the smoothness constraint (λ) in the HP filter so that the HP trend follows the actual output series more closely. In this way the adjusted HP filter attributes more of the variability in actual output to innovations in the HP measure of potential output. See Box 1 for some details on the role of λ in the HP filter.

[7]   To this end, Butler (1996) conditions filter estimates of potential output at the end of the sample period using a long-run growth restriction on potential output.

[8]   For a comprehensive description of the MV filter and its properties see Conway and Hunt (1997), "Estimating potential output: a semi-structural approach," RBNZ discussion paper G97/9.

2.3 The resulting estimate of potential output

The estimate of the output gap[9] obtained using the multivariate (MV) filter is presented in figure 3. The figure also shows an estimate of the output gap obtained using the pure HP filter. The bar graph in figure 3 is the change in annual inflation. During some periods, the two estimates of the output gap are quite similar. There are, however, some important differences. First, the MV filter suggests that there was considerably more excess supply in the economy during the period of declining inflation in the late 1980s than does the HP filter. More generally, there is a stronger and more stable relationship between inflation and the MV estimate of the output gap.[10]

As well as providing a more accurate measure of inflationary pressures in the economy, the MV filter estimate of potential output is more stable than the HP filter estimate at the end of the sample period. As discussed above, estimates of potential output near the end of the sample period tend to be revised significantly as new data becomes available. The relative stability of estimates of potential output obtained using both techniques can be assessed by considering figures 4 and 5. In each figure, the dashed line at each date represents the estimate of potential output that the respective technique would generate if the available data ended at that date. The solid line is the estimate of potential output that each technique generates when all of the data is used. The closer are the dashed and the solid lines, the smaller are the revisions to the estimate of potential output and the output gap that occur as new data become available. Figure 4 shows results for the MV filter, and figure 5 those for the HP filter. A comparison of the two figures illustrates that the magnitudes of the revisions using the MV filter technique are roughly half the size of the revisions that occur under the HP filter technique.

In summary, by using additional information from observable macroeconomic data, the MV filter has improved our estimate of potential output over the historical period. Further, the additional information and the long-run growth restrictions imposed at the end of the sample period reduces the extent of revisions to the estimate of potential output as new data becomes available.
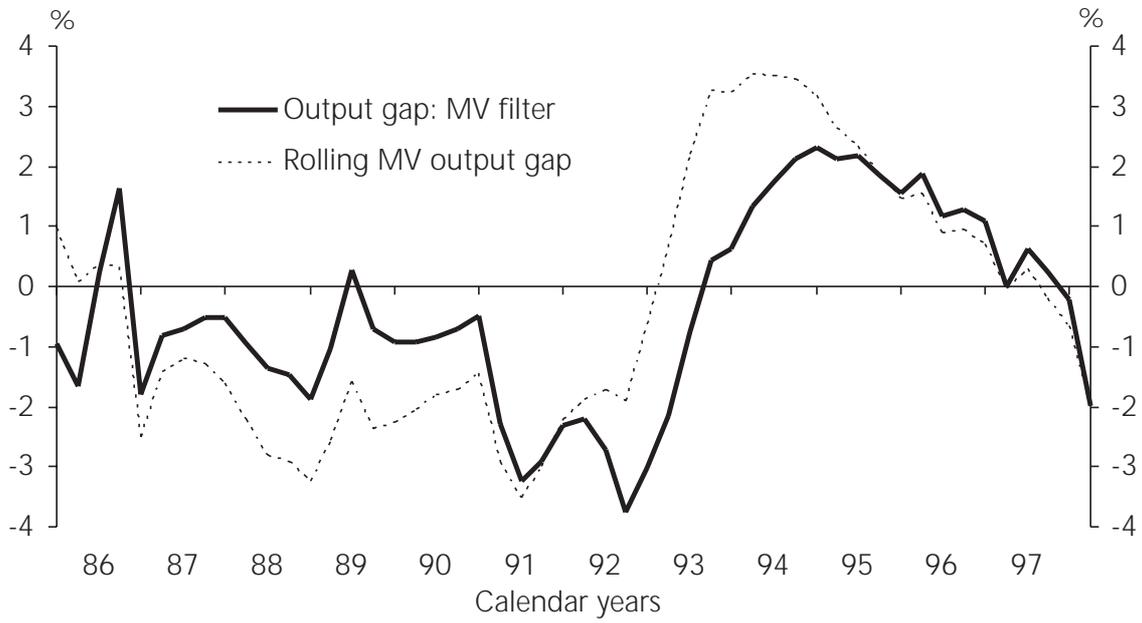
## Figure 3
The output gap, multivariate filter

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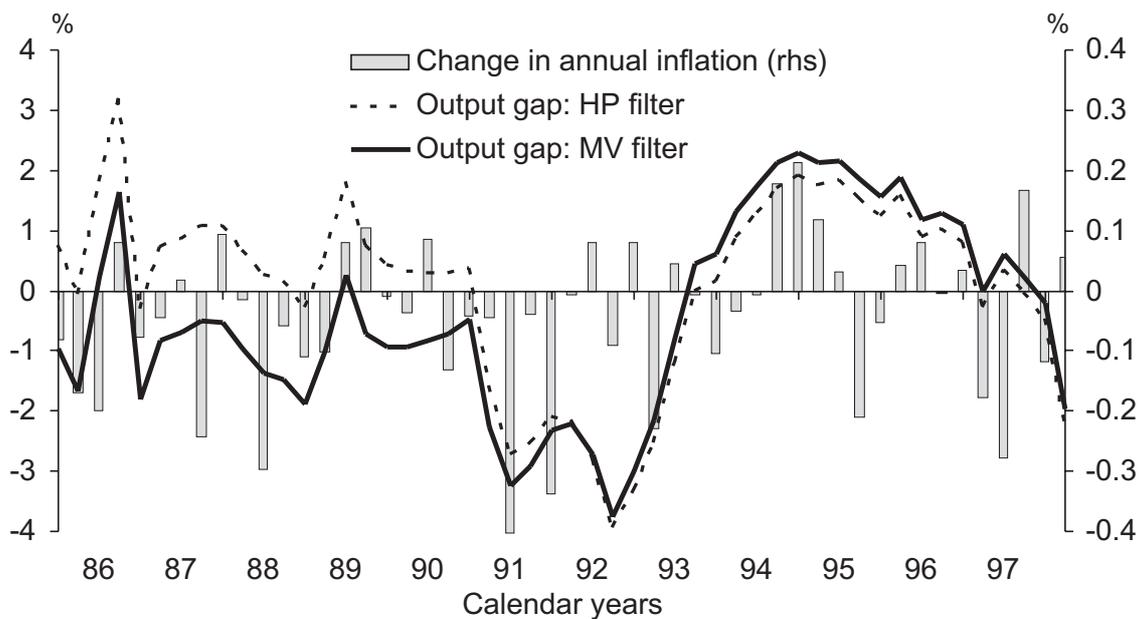
[9]   Recall from the introduction that the output gap is the difference between the demand for goods and services and potential output (expressed as a percentage).

[10]   For example, over a one year window, the correlation between the change in annual inflation and the MV filter output gap is, on average, 40 percent better than that obtained using the HP filter output gap.

Figure 4
MV rolling and actual estimates of output gap

Figure 5
HP rolling and actual estimate of output gap
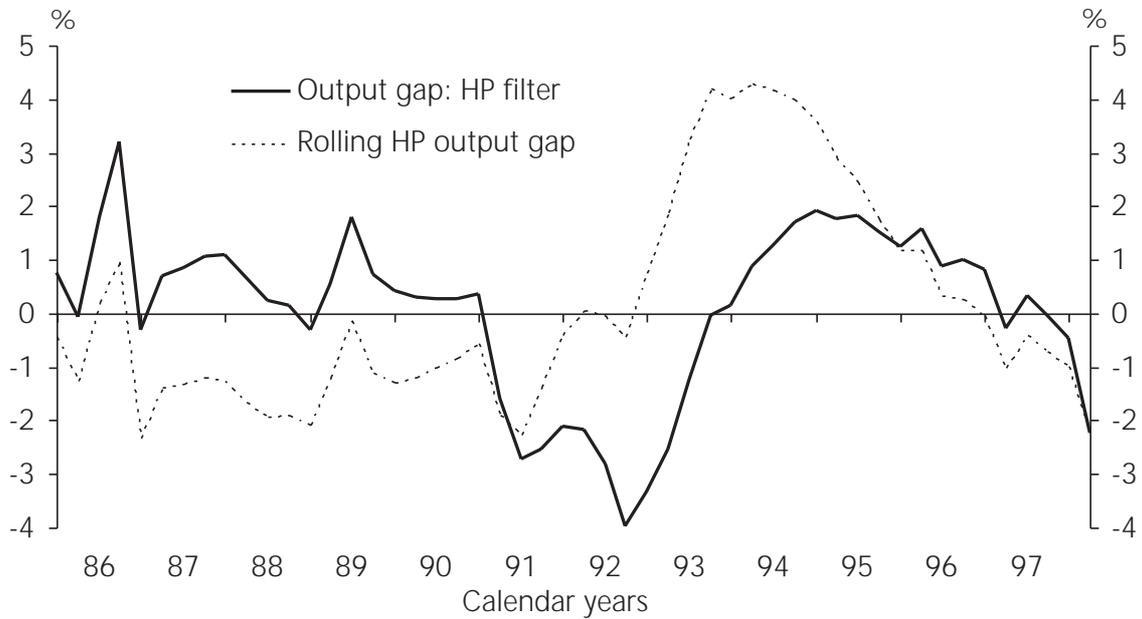
3 Potential output going forward

3.1 Forecasting potential output

For a monetary authority that targets inflation, potential output research does not end with a reliable historical estimate. Current monetary conditions influence the demand for goods and services in the future. Accordingly, policy makers also require an accurate estimate of the economy's future potential output to be confident that future aggregate demand can be satisfied without generating inflationary pressure. Obviously, the MV filter, which relies on actual data, cannot provide an estimate of potential output in the future. In this section, we discuss some recent research that underpins the Reserve Bank's estimate of how quickly the potential output of the New Zealand economy will grow in the future.[11]

As discussed in the introduction, an economy's level of potential output is determined by the quantity of its productive factors, such as workers and machinery, and the prevailing level of technology. Our estimate of New Zealand's potential output in the future is based simply on forecasts of these individual components. More specifically, we combine estimates of the trend labour supply (workers) and the capital stock (machines) with a forecast of the level of 'technology' to estimate the future potential output of the New Zealand economy. These individual components are combined using a Cobb-Douglas production function, the mathematical details of which are discussed in box 1.

Forecasts of the trend labour supply and capital stock are taken from the projection database of the Reserve Bank's *Forecasting and Policy System* (FPS).[12] Forecasting the level of technology that will prevail in the future is a more complicated task. In the current context, the level of technology determines the way in which the economy's productive factors are combined so as to produce output. In this sense, 'technology' determines how much output can be produced from a given quantity of these inputs. If, for example, firms introduce a more efficient production technique, then the quantity of output that can be produced from a given quantity of inputs will increase. Therefore, 'technology' can also be thought of as measuring the **productivity** of the economy's factors of production. A useful starting point in trying to forecast future productivity in the economy is to understand the factors that have driven productivity growth in the past.

3.2 Productivity growth in the New Zealand economy

Until the 1990s, New Zealand's rate of economic growth has been markedly worse than that of other Western industrialised countries over the post-war period.[13] Previous research done at the Reserve Bank attributes this poor growth performance to relatively weak growth in New Zealand's level of productivity.[14] That is, for a given increase in the factors of production, the New Zealand economy has tended to produce significantly less output than other industrialised countries.

One branch of economic growth theory posits that the economic performance of less productive economies should converge towards that of the world's most technologically advanced economies. This occurs because international competitive pressures provide incentives for firms to seek out and employ the most efficient methods of production. Research examining the historical experience of many countries has found that this theory does tend to hold if the countries considered have similar preferences for goods and services, have well-developed legal institutions and systems of governance, and allow competitive market forces to operate to a large degree.

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[11] This research is discussed in detail in Conway and Hunt (1998).

[12] This is the system of macroeconomic models that the Reserve Bank uses to generate the forecasts contained in the *Monetary Policy Statements*. For a comprehensive discussion on the core model of the FPS, see Black, Cassino, Drew, Hansen, Hunt, Rose and Scott (1997).

[13] Evans, Grimes, Wilkinson and Teece (1996) find that GNP per capita in New Zealand has fallen from 92 percent of US per capita income in 1938 to around 50 percent at the end of the 1980s. Smith and Grimes (1990) report that per capita income in New Zealand has fallen from around 125 percent of the OECD average in 1950 to only 75 percent in 1985. Other studies confirm New Zealand's recent poor growth performance. For example, Dowrick and Nguyen (1989) find that over the period 1973 to 1985 the growth rate in New Zealand per capita GDP was less than half the OECD average. Hall (1996) comments that "New Zealand's average growth performance has been the worst of any OECD country … for the overall post-war period" (page 31).

[14] See Smith and Grimes (1990). Hall (1996) reaches a similar conclusion.

In the context of the New Zealand economy, it seems reasonable to assume that our preferences for goods and services are similar to those of other industrialised countries and that our institutional structures are sound. Until recently however, competitive market forces have been a less significant determinant of economic activity in comparison to other developed countries. Since the mid-1980s, New Zealand's economic reforms have opened the domestic economy to international competitive forces and have fostered a domestic economic environment operating on the basis of competitive market principles. In fact, enhancing the degree to which foreign and domestic market forces are able to operate in the New Zealand economy has been a principal aspect of the reform experience. Accordingly, the economic theory outlined above suggests that the productivity of the New Zealand economy should have begun to improve towards that of the world's leading economies as a result of economic reform.

To investigate this proposition, we calculate estimates of trend productivity for the New Zealand and United States economies. These estimates effectively measure the ratio of aggregate inputs to aggregate outputs in both of these economies. In other words, these measures provide an index of

the efficiency with which the inputs to the production process (capital and labour) are combined to produce final goods and services, consistent with the discussion in section 3 above.[16] By using potential output and trend labour input, these measures abstract from variation in productivity caused by the business cycle so that longer-term developments become apparent.

Figure 6 shows the level of trend productivity in the New Zealand and United States economies. The sample period is from 1985Q4 to 1997Q2. Consistent with prior expectations, the **level** of trend productivity in the United States is substantially higher than in New Zealand. Figure 7 displays the **growth rates** of trend productivity in New Zealand and the United States. One of the most notable features of the graph is the increase in the growth rate of trend productivity in the New Zealand economy at the beginning of the 1990s. From the end of 1985 until 1991, trend productivity growth in New Zealand averages just above zero percent per annum, substantially less than trend productivity growth in the United States. From 1991 until 1997, the average annual growth rate in New Zealand's trend productivity increases to around 1 percent. The analogous figure in the US over this period is 0.6 percent.

Figure 6
Levels of NZ and US trend productivity

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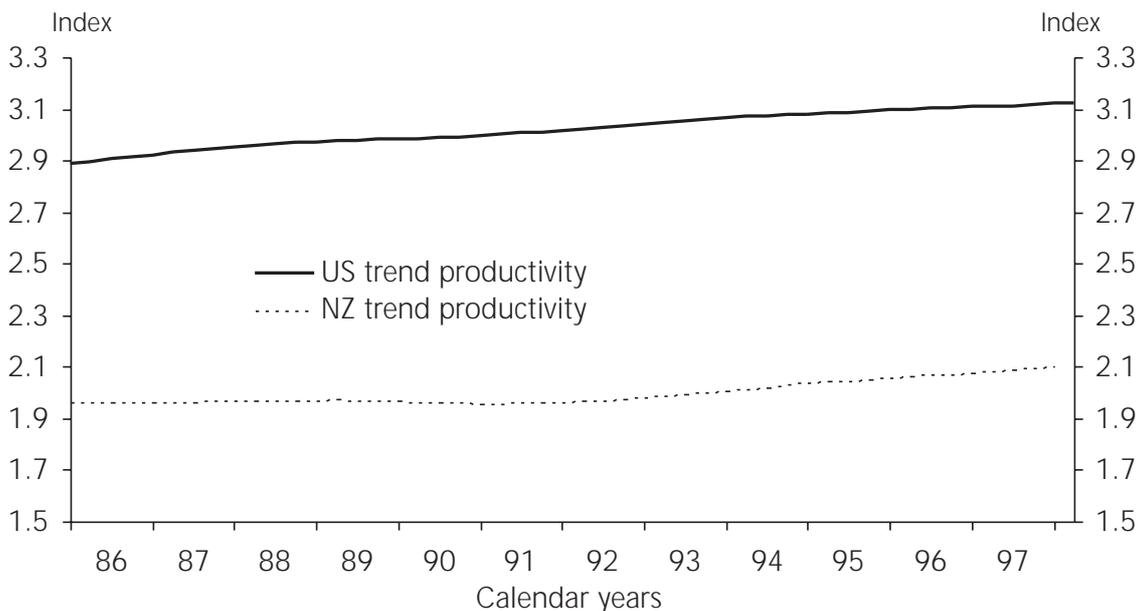
[15] Brief details of how we calculate these measures of productivity are given in box 1.

Figure 7
Annual growth rates of US and NZ productivity
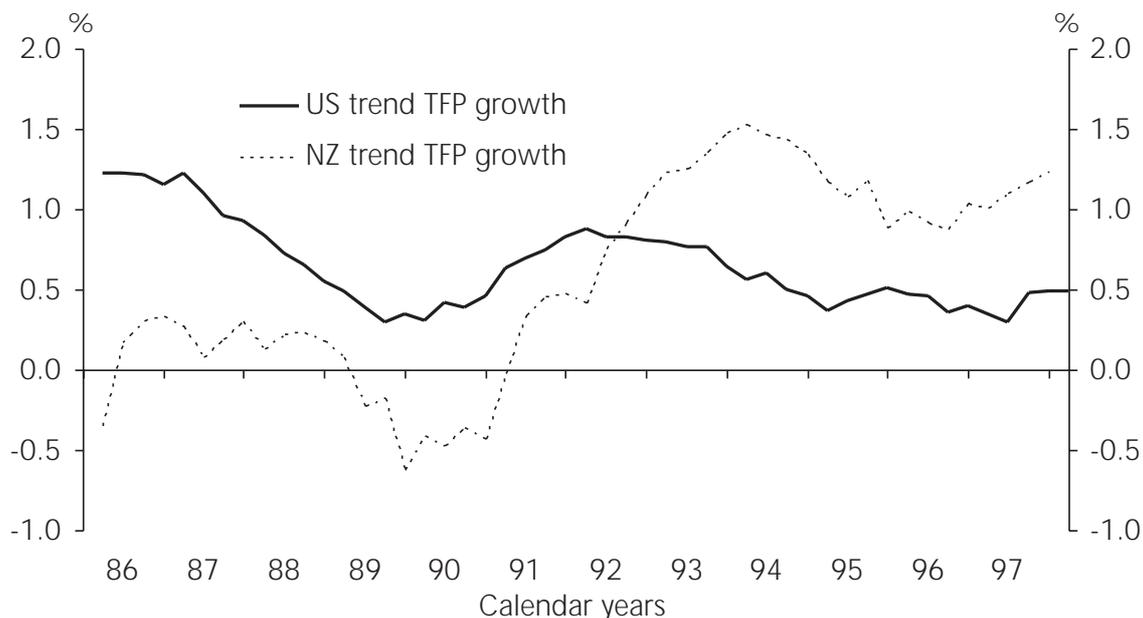
On the face of it, the data appear to be consistent with the predictions of the theory. It is also possible to test the theory in a slightly more rigorous fashion. If we write down a formal model that relates productivity growth in New Zealand to productivity growth in the United States, we can use traditional econometric techniques to estimate the model and apply formal statistical tests to the predictions of the theory. More details about the model we use are given in box 1.

Estimating such a model suggests that the economic reforms have reduced the impediments to the transfer of technology into the New Zealand economy. It appears that as economic activity in New Zealand has become more exposed to competitive forces, firms have had to seek out and employ more efficient methods of production to remain competitive. This process helps to explain why New Zealand's productivity growth has exceeded that in the United States since the early 1990s. Further, the estimation results suggest that productivity growth in New Zealand should continue to exceed that in the United States for a considerable period into the future. This reflects the fact that the current difference between the levels of productivity in the two countries is considerably larger than the model suggests it will be in the long run. Consequently, there is scope for New Zealand productivity to 'catch up' to that in the United States. This is expected to be achieved through a prolonged period of relatively more rapid productivity growth in New Zealand.

Using this estimated model of future productivity in the New Zealand economy, and the projected paths for the capital stock and trend labour supply contained in the FPS projection database, a forecast of New Zealand's potential output can be generated. According to this forecast, potential output in the New Zealand economy will grow at an annual rate of around three percent over the next five years.

4 Future Research

Future research work will continue to focus on other techniques for estimating potential output and methods for evaluating alternative estimates.[16] Focus will also be given to developing a better understanding of the processes that drive the components of the economy's supply capacity, so that we can formulate more accurate forecasts of the future path of potential output. Because it is unobservable and central to the conduct of monetary policy, potential output will continue to be focus of extensive research and vigorous debate.

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[16] Research currently underway uses multi-variate time series models (SVARs) and more sophisticated unobserved components models to estimate alternative measures of potential output. We are also developing more techniques for evaluating alternative estimates. Work currently underway is using spectral analysis to compare the implied business cycle properties of alternative estimates of the output gap.

Box 1

1 The Hodrick-Prescott filter:

The HP filter calculates a trend output series that minimises the expression:

$$\sum_{t=1}^{T}(y_t - \tau_{y,t})^2 + \lambda\sum_{t=2}^{T-1}[(\tau_{y,t+1} - \tau_{y,t}) - (\tau_{y,t} - \tau_{y,t-1})]^2$$

where y_t is the log of actual output and $\tau_{y,t}$ is its trend. The first term is the sum of the squared deviations of trend output from actual output. The second term penalises variations in the growth rate of trend output. The parameter λ is a smoothness constraint that determines how closely trend output follows the actual output series. The value of λ reflects, at least implicitly, a view about the relative importance of supply and demand shocks in the output series.

2 The Cobb-Douglas production function:

The Cobb-Douglas production function, applied to potential output, is as follows:

$$y_p = A \times k^\alpha \times \tau_{emp}^{1-\alpha}$$

where y_p is potential output, A is a productivity measure, κ is the capital stock and τ_{emp} is trend employment. The variable a is the share of capital used in the production process and is set equal to 0.35. Productivity can be measured simply as follows:

$$A = \frac{y_p}{(k^\alpha \times \tau_{emp}^{1-\alpha})}$$

3 The empirical model of productivity convergence:

The following equation is estimated:

$$\Delta A_t^{NZ} = \Delta A_{t-4}^{US} + \beta[\log(A_{t-4}^{US}) - \log(A_t^{NZ})] + \psi_t + \varepsilon_t$$

where Δ is the first difference operator, A^{NZ} and A^{US} are measure of productivity for New Zealand and the US respectively. The variable ψ is a constant designed to capture the degree of impediments to the transfer of technology between New Zealand and the United States, and ε is residual error. A positive and significant value of β implies that growth in New Zealand productivity is positively influenced by the size of the levels gap in trend productivity between New Zealand and the United States, indicating technological catch-up.

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