

Has the Rate of Economic Growth Changed?

Evidence and Lessons for Public Policy

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Has the Rate of Economic Growth Changed? Evidence and Lessons for Public Policy

New Zealand's recent rate of economic growth has remained strong despite a worldwide recession. Policymakers, the press, and the public have nonetheless been concerned that New Zealand's economic performance has lagged along some important dimensions. This lecture presents some new estimates of the rate of technological change in New Zealand and compares them to similar measures for the United States and elsewhere. New Zealand has not participated in the increased pace of technological progress seen elsewhere since the mid-1990s. Technological change creates sustainable increases in income and wages. Hence, it should be an important focus of policy discussions surrounding economic growth. The lecture also addresses how public policy should take into account technological change, especially given uncertainty about future prospects for its growth and the difficulties of public policy in changing its growth.

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The second half of the 1990s witnessed a pronounced increase in the rate of technological change in the United States and worldwide. The shallow recession of 2001/2002, the very pronounced declines in stock market values across the world, the evils of international terrorism, and the threat and now outbreak of war have produced considerable gloom and uncertainty for the world economic outlook.

Notwithstanding these negative factors weighing on the economy and perceptions about the prospects for economic growth, the level of current economic performance is outstanding along several dimensions.

- Though there is uncertainty as to whether recession has ended in the United States, output and disposable personal income are at record highs. That is, they have surpassed their levels at the business cycle peak in 2001.¹ There is uncertainty, however, about whether the recession has ended. This uncertainty arises because income and employment are telling very different stories about recovery. Income has clearly recovered, while employment lingers near its trough level.² This increase in income with flat employment is arithmetically equivalent to the increase in productivity that has occurred during this recession.

¹ In 2002:4, real GDP in the United States was 3.6 percent above its cyclical trough in 2001.

² See Hall, et al. (2003) for a discussion of this dilemma for the NBER business cycle dating committee.

- Inflation remains very much under control. During the late 1990s, when the U.S. economy was running at high rates of growth and low rates of unemployment, inflation continued its nearly steady decline of the past two decades. Unlike many previous business cycles, the downturn in 2001 does not have an anti-inflationary tightening of interest rates by the Fed as its impetus.

This is not to say that the U.S. economic outlook is benign. It faces low personal and government saving, a depreciating currency, a record current account deficit, deflated asset prices, shaky consumer confidence, and geopolitical uncertainty. These factors may point to rocky economic performance in the short or even medium term.

Nonetheless, the performance of the headline indicators of income, productivity, and inflation over recent years has been excellent despite a mild recession.

How has New Zealand's performance compared with the U.S. and other industrialized countries? New Zealand had had very good inflation experience over the past decade. Indeed, New Zealand has led the world in showing how to contain inflation through a transparent target for low and stable inflation. The record for economic growth is more mixed. Recent economic performance has been quite strong.

- Unemployment is at its lowest level since the start of the economic reforms.
- New Zealand's recent and current rate of GDP growth has run ahead of the world average.
- New Zealand has not suffered from the worldwide downturn that started in early 2001 and that has been compounded by the uncertainty arising from international terrorism and war. Indeed, the worldwide concerns about

security and war are likely contributing to the relatively strong performance of New Zealand's economy.

Notwithstanding this better-than-average performance of the New Zealand economy quite recently, there is broad sentiment that the economy is underperforming. Growth *per se* does not lead to an increase in prosperity. For example, an element in the relatively rapid growth rate in New Zealand currently is the high level of net migration. This net migration adds to aggregate productive capacity and signals the migrants' confidence in the economic prospects for New Zealand.

But to support sustainable increases in standards of living, productivity must increase. Increases in productivity derive mainly from accumulation of capital and from adoption of improvements in technology. Hence, policymakers in New Zealand are correct to highlight the importance of productivity growth for improvements in economic welfare.

This paper addresses several issues concerning productivity and the response of policy to it.

First, it presents a framework for measuring technological change using observed data. The aim of this framework is to go from observed data on output and inputs to a measure of the rate of technological change. Special attention is given to abstracting from cyclical factors that affect current measurements, but do not have permanent effects on technology and therefore the sustainable level of production and wages.

Second, I apply this framework to data for the United States. This analysis gives a picture of how the productivity frontier is evolving. Then, to the extent that the required source data are available, I then present results for New Zealand.

Third, notwithstanding economists' best efforts at measurement, assessing the current rate of technological change involves some uncertainties. Moreover, even with fairly accurate measures of historical and current rates of technological change, they give only a very limited indication of the prospects for growth going forward. Policymakers must bear the burden of making decisions based on a forecast of the rate of technological change and what it implies for the sustainable growth rate of the economy. This paper considers how monetary policy might take into account this uncertainty about the future course of the real economy. The paper also has some further discussion of what public policy can and cannot do about productivity growth.

I. Measuring Technological Change³

A. Abstracting from cyclical factors

Measured productivity growth increased dramatically during the second half of the 1990s in the United States. Despite the recession, the rate of productivity growth has continued to be high through 2002. Does this increase in productivity growth herald a new industrial revolution based on computers and information technology? Is this increase just a bit of temporary good luck? Or is it merely mismeasurement arising from the increase in effort, factor utilization, or factor accumulation that accompanies a booming economy?

The answers to these questions cannot be definitive until more time passes.⁴

In particular, it is very hard to address the question of whether the current good

³ The theoretical framework in this section and the results for the United States presented in this section are drawn from Basu, Fernald, and Shapiro (2001) and updates to the calculations presented in that paper.

performance of productivity is temporary. The boom in the stock market provides some ancillary evidence that might bear on this question, yet it is subject to differing interpretations.⁵ Moreover, the improvements in productivity have proven to be much more sustained than stock market prices. This paper's approach, however, is to limit our attention to the internal evidence on output and inputs and their cyclical relationship. These relationships will allow us to extract an estimate of technology from productivity and therefore shed light on what has happened in the recent past, but these estimates will to an extent leave open the question of the future of growth in technology.

A major contribution of this paper is to analyze two potentially offsetting cyclical factors in measured productivity: factor utilization and adjustment costs. Attention to factor utilization has a long history in productivity measurement. The basic idea is that unaccounted-for changes in utilization and effort will raise measured productivity without having any effect on true technology. Solow (1957) made a correction for utilization of capital in his seminal paper. In the productivity literature that followed, such adjustments were routine (either explicitly or by averaging over the business cycle). Though early real business cycle literature missed the point about cyclical productivity, there has been a resurgence of attention to this issue.⁶

⁴ Recent papers examining these issues include Baily and Lawrence (2001), Gordon (2000), Jorgenson and Stiroh (2000), Nordhaus (2000), Oliner and Sichel (2000), Stiroh (2001), and Whelan (2000).

⁵ For example, both Robert Hall (2001a) and Robert Shiller (2000) attribute the boom to information technology, but Hall presumes that the stock market is reacting to underlying fundamentals relating to information technology while Shiller believes that popular perceptions about information technology have given impetus to a speculative bubble.

⁶ Greenwood, Hercowitz, and Huffman (1988) is an early real business cycle model that does incorporate variable utilization. See Shapiro (1986b, 1993, 1996), Basu

Adjustment costs similarly require that measured productivity be adjusted to yield an estimate of technology. Broadly speaking, adjustment costs reduce output to the extent that productive resources are diverted from production to adjustment when firms undertake capital accumulation or hiring. Hence, when adjustment is increasing, output growth will be temporarily damped, yielding an underestimate of technological change.

Adjustment costs have received less attention than utilization, at least in the recent literature in macroeconomics. Yet, they have a role in productivity measurement that is closely linked to that of utilization. First, if increases in factor utilization and increases in factor adjustment are positively correlated, then the utilization and adjustment have opposite effects on measured productivity. Second, costs of adjustment presumably drive cyclical variation in utilization. If quasi-fixed factors were costless to adjust (i.e., not really quasi-fixed), then there would be no need to pay for costly variation in their utilization.⁷ Hence, the recent literature that emphasizes variable utilization implicitly or explicitly assumes some quasi-fixity or fixed cost. We show how measurement of technology is affected by this inherent interaction when the quasi-fixity is motivated by adjustment costs.

Factor utilization and adjustment play a potentially important role in understanding the acceleration in productivity in the 1990s. The 1990s began with a

(1996), Basu and Kimball (1997), and Burnside, Eichenbaum, and Rebelo (1995) for the importance of variable utilization in cyclical productivity.

⁷ Adjustment and utilization need not move together. First, the timing may be different, as we find during the 1990s. That is, since utilization is confined to a bounded range, it may return to its long-run level at some point during an expansion, whereas factor accumulation continues; see Sims (1974). Second, adjustment and utilization could even move in opposite directions. For example, if

shallow recession. Though the time between the peak in second quarter of 1990 and the trough in first quarter of 1991 was not particularly long, the speed of the recovery was unusually slow. Once growth accelerated, there was a substantial cyclical contribution of utilization to measured productivity. This cyclical bounce in measured productivity, of course, simply offset the cyclical decline experienced going into the recession. This cyclical effect is quite standard, though it is important to keep track of it in assessing the performance of the 1990s. We find that utilization contributed about 1/2 percentage point per year to growth in the measured Solow residual in the 1992-1994 period as the economy recovered from recession. Since then, utilization has bounced around from year to year, but on balance, has contributed *negatively* to growth in the Solow residual, and thus does not explain the increase in growth in the second half of the 1990s.

The 1990s are distinct, however, in the changes in factor accumulation, particularly that of capital. The 1990s experienced a boom in business investment in the United States of unprecedented size and duration. Information technology equipment – computers plus telecommunications equipment – has been a major part of the story. Its share in total business fixed equipment investment increased dramatically in the 1990s. The share of information technology investment in GDP rose from 3 percent to almost 6 percent. Much of this information processing equipment has been purchased by the non-manufacturing sector.

capital depreciates in use, a high shadow cost of current capital relative to future capital can decrease utilization and increase adjustment.

B. Measurement Framework

This section outlines the mechanics of correcting measured total factor productivity (the Solow residual) for cyclical factors. Taking into account these corrections yields an estimate of the rate of technological change.

Solow residual, dp , is defined as the growth in output minus a share-weighted change in the value of inputs. For the U.S. data, the data are based on Jorgenson's multifactor database, which adjusts capital and labor for changes in quality. For the New Zealand data, the data are from the Treasury's compilation of industry value added, capital, and hours data. The New Zealand data have no adjustment for the quality of factors. The shares used to weight inputs are evaluated at sample means, i.e., give a first-order approximation to an arbitrary production function. An alternative would be to use time-varying shares, e.g., using a moving average of current and lagged shares, as in a Törnqvist index. This procedure gives a second-order approximation (Diewert, 1976).

Growth in *technology*, dz^V , is constructed by subtracting various corrections from the Solow residual. Specifically,

$$dz^V = dp - R - du - da$$

where the corrections are defined as follows:

Reallocation, R : This term adjusts for changes in the composition of output across industries. It adjusts for changes in observed productivity arising from changes in industrial composition. These can arise for differences in the *level* of productivity across industries and differences in returns to scale across industries. See Basu, Fernald, and Shapiro (2001, p. 134) for the detailed formulas. The reallocation term plays little role in the U.S. data for this period. As of yet, there is no attempt to

calculate it for New Zealand. Doing so requires industry-by-industry estimates of returns to scale. It also depends on having estimates of the share of materials in gross output, which is not available in the present data set. Future work should attempt to construct estimates of reallocation for New Zealand, though getting precise estimates will be difficult owing to the short sample of data in the post-reform period. Moreover, there are no estimates of reallocation in the updated estimates for the United States presented in this paper because the necessary sectoral data are incomplete as of now.

Adjustment costs, da : The calibration of adjustment costs on the growth in real fixed private nonresidential investment for the aggregate economy. Based on estimates by Shapiro (1986a), we assume the (negative of the) elasticity of output with respect to investment is -0.035 , so that the effect of adjustment on measured output and productivity is $da = -0.035di$, where di is the growth rate of investment.

How is this formula derived? We assume that adjustment costs enter the production function as follows:

$$Y = F(\cdot)(1 - \Phi(I/K))$$

where Y is gross output, $F(\cdot)$ is the usual production function in the level of inputs, I is gross investment, K is the capital stock, and Φ is a zero-degree homogenous function in the investment rate. Basu, Fernald, and Shapiro show that $da = -\phi di$ where

$$\phi = \left(\frac{\Phi'}{1 - \Phi} \frac{I}{K} \right)$$

is the elasticity of the adjustment cost with respect to the investment rate. Marginal adjustment cost, the partial derivative of output with respect to investment, is related to ϕ as

$$\frac{\partial Y}{\partial I} = -\frac{\Phi'}{1-\Phi} \frac{Y}{K} = -\phi \frac{Y}{I}.$$

Shapiro (1986a) estimates marginal adjustment cost from the Euler equation for capital accumulation. His parameterization of marginal adjustment cost is as follows

$$\frac{\partial Y}{\partial I} = -g_{kk} I \cdot Y.$$

Combining these equations yields a parametric version of the elasticity of the adjustment cost with respect to the investment rate,

$$\phi = g_{kk} I^2.$$

Shapiro's estimate of the adjustment-cost parameter g_{kk} is 0.0015 and I averages 4.83 in his data. Hence, the calibration of ϕ is therefore equal to 0.035. Though this estimate implies relatively rapid adjustment to steady state, adjustment costs are not trivial. They account for 0.7 percent of output or about 9 percent of the cost of investment.

Shapiro's estimates apply to value added, as do our aggregate estimates. For our industry-level gross output estimates, the value-added ϕ needs to be scaled by a multiplicative factor $(1-s_M)$ where s_M is the share of materials. When aggregated, these industry-level adjustment cost terms correspond to value-added calculation.

I am aware of no corresponding estimate of adjustment costs for New Zealand data. One could apply U.S. estimates, though future work should produce comparable estimates for New Zealand data.

Utilization: Basu, Fernald, and Shapiro use growth in hours per worker by industry (multiplied by an econometrically estimated coefficient) to proxy for unobserved variations in utilization. The notion is that if firms want extra labor input, but cannot immediately get more workers, they will work existing workers both longer (more hours per worker) and harder (more unobserved effort); also, if the cost of varying capital's workweek is a shift premium, then firms are likely to add additional shifts at the same time that they increase labor's workweek.

We used hours per worker by industry (from the BLS establishment survey). We then detrend to remove low-frequency variations in hours per worker (in order to make sure that our resulting utilization series does not have a trend). We then take the growth rate of that detrended hours-per-worker series, dh . Using annual data from Jorgenson and Stiroh, we estimate the coefficient on hours growth by industry from the following regression: $dp_i = c_i + \beta_i dh_i$, where dp_i is growth in the Solow residual (i.e., we impose constant returns and perfect competition), using as instruments the sum of the previous year's monetary shocks from an identified VAR; and current and lagged values of the Ramey-Shapiro military-buildup dummies and of the growth in the world price of oil.

For New Zealand, I use a similar procedure as an approximation. Instead of using data on the change in average weekly hours as the utilization proxy, this paper bases its estimates on the Reserve Bank of New Zealand's estimate of the GDP gap

(expressed as a percentage). The estimated relationship between the Solow residual for the aggregate market sector and the GDP gap, gap , is as follows:

$$dp = 0.97 + 0.56gap + dz, \quad \text{see} = 1.6. \\ (0.42) \quad (0.30)$$

There is the expected positive relationship between the gap and the growth of Solow residual. The coefficient of 0.56 is only marginally statistically significant. There are only 12 observations. Hence, the point estimate should be regarded as tentative and subject to substantial sampling error.⁸ A coefficient of 0.56 is economically significant. A 1 percentage point increase in the gap adds 0.56 percentage point to the growth in the Solow residual owing to cyclical factors.

C. Data sources

For the United States, the industry-level data are based on the dataset by Dale Jorgensen and associates and is available on Jorgenson's WWW page. These data are

⁸ There are a number of ways to explore improving the estimates. The estimation here is by ordinary least squares. The relationship should also be estimated by instrumental variables using instruments correlated with aggregate demand by uncorrelated with true technology dz . These might include international variables that affect demand for New Zealand's production. Moreover, this estimate is for the aggregate. The coefficients could be estimated at the industry level, though Basu, Fernald, and Shapiro chose to pool at the aggregate level. (A preliminary look at industry-level estimates found them to be highly variable and imprecisely estimated.) Finally, alternative utilization proxies should be studied. These could include the change in the gap, change in average weekly hours, the change in the number of shifts, change in overtime hours, etc.

I have explored a number of these possibilities and have not found a viable empirical specification for the New Zealand data other the one presented here. In particular, I have explored using the change in aggregate weekly hours as the utilization measure in parallel to Basu, Fernald, and Shapiro. The point estimate of its coefficient is negative, though with a very large standard error, whether the estimated via OLS or instrumental variables. (Instruments that I tried included the change in the world GDP gap, the change in world interest rates, and the change in the Australia-US

available only through 1999. The estimates for years since then are based on a variety of sources and involve some extrapolation, so they should be regarded as preliminary.⁹

The data for New Zealand are a new compilation of Stats NZ source data assembled by the Treasury.¹⁰ The dataset contains output, labor hours, capital, compensation, and profits for nine market sectors and the non-market sector. All the results presented here are based on aggregating the market sectors. In contrast with the U.S. data, the data on labor input are not adjusted for changes in quality. Hence, such quality changes will appear in the measure of technology for New Zealand, but not in the measure for the United States.¹¹

exchange rate. These variables should affect demand in New Zealand, but are exogenous with respect to New Zealand.)

⁹ For labor productivity, we use the BLS quarterly series for 2000 through 2002. For capital services, we interpolate from annual growth rates for capital services, taken from the BLS multifactor productivity dataset through 2000. For 2001, we assume that capital services grew at 4.3 percent, from Oliner and Sichel (2002). For 2002, we assume that capital services will grow at 3 percent. For labor quality, we use estimates provided by Dan Aaronson and Dan Sullivan of the Federal Reserve Bank of Chicago.

¹⁰ I am grateful to the Treasury for providing me with a preliminary version of these data and the documentation. Given the preliminary nature of the dataset, the figures presented in this paper may be subject to revision.

¹¹ In the New Zealand dataset, output is measured by value added. In the U.S. data, output is measured as gross output and we construct a measure of value added. Hence, all aggregates are on a value-added basis, but the lack of gross output for New Zealand means that certain adjustments calculated by Basu, Fernald, and Shapiro (2001) are not calculated for New Zealand. An important difference in measurement between the U.S. and New Zealand data concerns the source of industry output. In the United States, these data come from the income side. In New Zealand, they are based on production. The theory under which the measures are constructed mandates that income and product side measures should yield the same answers, though in practice they might be quite different owing both to measurement issues and departures from the assumption of the theory.

II. Estimates of Productivity Growth: Cycle versus Technology

This section presents some estimates of total factor productivity growth using the framework and data discussed in the previous section.

A. United States

Productivity growth in the United States increased sharply around 1995. From 1973 through 1995, output per worker grew 1.4 percent per year. This rate of growth has averaged 2.6 percent per year since then. For various subperiods, Table 1 shows these rates of productivity growth. It also shows the various adjustments and corrections to yield adjusted total factor productivity, i.e., the growth in technology.

The increase in the rate of total factor productivity growth since 1995 has also been substantial. It increased one percentage point per year, from 0.3 percent per year in 1973 through 1995 to 1.3 percent per year from 1996 through 2003. Between these two periods, there was a decrease in the growth of labor, a slight decrease in the contribution of labor quality to growth, and an increase in the contribution of capital per worker to growth.

The cyclical adjustments for these periods are relatively modest. The adjustment cost correction adds 0.1 percentage point to adjusted TFP growth in the 1973 to 1995 period and 0.2 percentage point in the 1996 to 2002 period, when investment was stronger. Note that the adjustment affects the estimates even in steady state owing to the underlying assumption that adjustment costs are a function of gross investment.

The utilization correction is zero in steady state and indeed averages zero for the 1973 to 1995 period. For the 1995 to 2002, cyclical factors lead unadjusted TFP to understate the growth in technology because of the recession of 2001.

The net result of the corrections is that adjusted TFP growth shows a more pronounced increase after 1995 than unadjusted TFP growth. Both cyclical factors and the high level of investment lead the uncorrected data to understate the pace of technological progress during the sample.

The subperiods shown in the right-hand side of Table 1 illustrate better how the correction operate. In 1995 through 2000, the adjustment cost correction is very sizeable because of the investment boom during this period. Cyclical factors were slightly expansionary. Since 2000, fixed investment has collapsed, so adjustment costs are pulling down the estimate of technology. That is, the usual amount of investment is not taking place. Hence, factors of production are devoting an unusually high fraction of their time to making observed output, so measured productivity overstates technology.

Utilization tells the opposite story. Utilization fell sharply in the recession, leading current productivity, but not technological progress, to decelerate sharply.

Since 2001:3, the trough of GDP, there has been a very sharp increase in the pace of technological progress according to these estimates. As discussed in the introduction, income has recovered from its trough, but employment languishes. The TFP calculations confirm that there appears to be a genuine rapid increase in the pace of technological progress.

B. New Zealand

In New Zealand, a somewhat different pattern of productivity and technology growth emerges in the results displayed in Table 2. For 1992 to 2002, I estimate that adjusted TFP grew at 1.0 percent per year. This rate compares favorably to the 1973 to 1995 period in the United States, which includes the period of the productivity slowdown after 1973, but is substantially slower than the U.S. performance in the second half of the 1990s. Note, moreover, that the New Zealand figures omit two steady state adjustments. There is no adjustment for labor quality owing to lack of data. If the pace of labor quality growth were the same as in the United States, that would take about 1/4 of a percentage point off the estimate of rate of technological progress.

The New Zealand estimates also do not include a correction for adjustment cost. If one is willing to apply the U.S. adjustment cost parameter to New Zealand, one can estimate this correction.¹² Average growth in investment (market sector business investment) times the U.S. coefficient of 0.035 yields an adjustment cost correction for New Zealand of -0.1 , the same value as in the U.S. for the 1973 to 1995 period. This adds 0.1 to the estimate of the rate of technological progress derived from adjusted TFP. Thus, on a comparable basis with the figures for the United States in Table 1, adjusted TFP growth in New Zealand was about 0.8 percent per year from 1992 to 2002.

Cyclical factors are important for particular years. See Figure 1 for the annual estimate of TFP growth with and without the cyclical adjustment. The gap was

¹² The parameter is “structural” in the sense of being based on the underlying technology, so there is a case for applying the U.S. parameter to different countries. Yet, technologies can differ, so before these results are highlighted, the adjustment cost parameter should be estimated for New Zealand.

slightly positive on average for the period, accounting for a 0.1 percentage point per year correction for the whole sample. The correction is, however, is larger recently, so measured productivity is overstating the pace of technological progress recently owing to there being a relatively hot economy.

Even correcting for cyclical factors, the pattern of technological progress is very different in New Zealand than the United States. Since 1996, there has been a slowdown in the rate of technological progress in New Zealand instead of the increase seen in the United States and elsewhere.

Though there is not evidence of an acceleration in productivity growth in New Zealand in the later half of the 1990s, there is evidence that performance in the 1990s compares favorable to the previous two decades. Calculations by the Treasury make this point for labor productivity. Razzak (2003), using a variety of econometric techniques, finds evidence that performance in the 1990s was better than the past.

Hence, New Zealand is not currently suffering the very poor performance that Prescott and Kehoe have classified as great depression. Yet, given that previous poor performance leaves the level of New Zealand productivity behind that of other countries, growth at rates comparable to world norms will not lead to a catch up of the level of New Zealand's productivity.

C. Understanding the differences between the rates of technological change

This subsection presents some informed speculation about why New Zealand has a lower rate of technological progress and a different pattern than seen in the United States.

1. Data issues

One possible explanation for the differential growth rates between the U.S. and New Zealand could be measurement problems. For example, Diewert and Lawrence (1999) suggest that measurement of financial services accounts for some of the difference between the performance of Australia and New Zealand. Yet, for measurement to explain the differences in growth rates would require systematically different rates of bias in price measurement or other systematic differences across countries. New Zealand shares with all nations the challenges of measuring economic performance, especially where there are improvements in quality or other structural changes in the economy. My impression is that there is not a strong case that measurement problems are systematically worse in New Zealand than elsewhere. Certainly, as Diewert and Lawrence suggest, some sectors are poorly measured. On the other hand, New Zealand's economy is relatively commodity-intensive and there is a case that commodity output is easier to measure than manufactured goods and services. A study by Gibson and Scobie (2002) suggests that New Zealand has substantial quality-adjustment biases in its price indexes, but these biases are similar to those found for the United States using the same methodology [Hamilton (2001), Costa (2001)].

This is not to say there are not substantial areas where economic measurement in New Zealand should be improved. Some of these are discussed below.

2. Make versus use of new technology

Much of the increase in the pace of technological progress in the United States arose from increases in the efficiency of making information technology and

telecommunications equipment. Some researchers (e.g., Gordon (2000)) have suggested this effect accounts for all of the increase in the pace of technological progress. My reading of the data is that about half the improvement in the pace of aggregate technological progress in the United States comes from the production of IT and telecommunications goods.

New Zealand is not a major producer of these goods. Hence, it is not surprising that the acceleration in technology has not affected New Zealand's productivity. This observation is not meant to suggest that New Zealand should jump on the IT-producing bandwagon. That horse has left the barn. There is now substantial excess capacity in this industry, and an overhang of its output from the 1990s boom. Moreover, experience here and elsewhere suggests it is very hard to make successful policy choices about the composition of output.

Different countries appear to have had different experiences in the impact of information technology on productivity despite similarities in the update of new technology. For Australia, Simon and Wardrop (2002) find that IT uptake did give a boost to productivity despite the fact that Australia, like New Zealand, is not engaged in the production of IT equipment. In contrast, Basu, Fernald, Oulton, and Srinivasan (2003) find no effect of IT on productivity in the United Kingdom.

3. Geography and size

Geography and size are factors affecting New Zealand's performance. I am not in a position to assess how much these affect the level of New Zealand's performance. Surely there are costs related to transport. Moreover, the small size of the market mandates that New Zealand be an active and free participant in world markets.

Looking forward, New Zealand should focus on a number of natural advantages. Continued reduction in transportation costs will allow more tourists to enjoy the varied and distinct resources of your country.

More generally, New Zealand has several advantages.

- Asia will continue to be a center of growth, so New Zealand's relative proximity is an advantage.
- English is likely to continue to be the leading commercial language.
- Education will be a growing export industry.
- Distance will matter less as the industrial mix continues to shift from goods to services.
- New Zealand's time zone creates opportunities to provide back-office services in a global setting.

More generally, new econometric techniques are available to measure returns to scale. In the U.S., the evidence is that returns to scale are close to constant. There are good theoretical arguments for constant returns in the long run.¹³ Research on the New Zealand economy should be undertaken to assess the degree of returns to scale in its industry. I am skeptical, however, that it will find that increasing returns represent a speed limit to growth.¹⁴

¹³ See Basu, Fernald, and Shapiro (2001) for a discussion and reference.

¹⁴ New Zealand has a very high fraction of small firms and self-employed individuals. I would look to explanations from the tax system before returns to scale in explaining this phenomenon.

4. Speed of adjustment

New Zealand can look forward to a process of catching up to world levels of productivity provided it stays the course of its economic reforms. Yet, the process can be quite slow.

- Cross-county evidence suggests that rates of convergence, though positive, are quite slow. Catch up time is measured in decades, not years.
- Catch up requires supernormal capital accumulation. Extra output can only be sustained with extra investment.
- Increased labor flows into New Zealand recently also require investment.
- Investment in housing, though beneficial for consumption, will not add to industrial productivity.

In recent years, New Zealand has had a business investment rate that is somewhat higher than its longer-term average, but it has not been supernormal. Moreover, in the 1990s, other countries, notably the United States, were investing at unprecedented levels. Hence, especially given the high level of net migration recently, the rate of investment in New Zealand is not high enough to accommodate an acceleration in productivity.

III. Public Policy and the Pace of Technological Progress

A. Monetary policy and Growth Gambles¹⁵

The view of the U.S. Federal Reserve about whether the surge in productivity in the 1990s and the related increase in stock market values was sustainable underwent a

¹⁵ This section and the appendix are based on work in progress with Yuriy Gorodnichenko.

significant shift. In December 1996, Alan Greenspan gave his famous irrational exuberance speech, which was widely taken as skepticism about values that stock market had then reached.¹⁶ Had the Fed remained skeptical about the acceleration of productivity and the very high levels of the stock market in the late 1990s, its policy might have been very different than it was. There was, however, a shift in Greenspan's thinking. For example, in a speech in September 1998 at the Berkeley Business School, he takes note of the increase in productivity and investment and implies that the market is at least in part responding to it. Significantly, he links this performance to the surprising lack of inflation despite the booming economy:

The question posed for this lecture of whether there is a new economy reaches beyond the obvious: Our economy, of course, is changing everyday, and in that sense it is always "new." The deeper question is whether there has been a profound and fundamental alteration in the way our economy works that creates discontinuity from the past and promises a significantly higher path of growth than we have experienced in recent decades.

The question has arisen because the economic performance of the United States in the past five years has in certain respects been unprecedented. Contrary to conventional wisdom and the detailed historic economic modeling on which it is based, it is most unusual for inflation to be falling this far into a business expansion.¹⁷

The assessment that the Fed had a new view of the real economy and its prospects for inflation need not be inferred from speeches. Mechanical projections of inflation based on historical relationships with real variables indicated that inflation would be forecast to increase substantially. Yet, the Fed pursued a relatively

¹⁶ The text of the speech refers to balance sheet effects of the stock market and does not confront directly the question of whether there was sufficient economic growth to sustain the stock market values.

<http://www.federalreserve.gov/boarddocs/speeches/1996/19961205.htm>

¹⁷ <http://www.federalreserve.gov/boarddocs/speeches/1998/19980904.htm>

expansionary monetary policy, e.g., it was cutting rates in the fall of 1998 even though the unemployment rate was the lowest it had been for decades and an expansion that started in 1992 continued to be sustained.

Figure 2 shows actual and forecast inflation for the United States based on a conventional Phillips curve where the equilibrium unemployment is recalculated using data through 1995 using a version of the method of Staiger, Stock, and Watson (1997, 2001). Hence, the forecasts take into account the best estimate of the NAIRU as of the beginning of the period of the productivity acceleration. The figure shows forecast over 12-quarter horizons of 1996:4, 1997:4, and 1998:4.¹⁸ Looking ahead from ends of 1996 and 1997, one would have expected much more inflation based on this historical relationship than was realized. It is in the context of these very substantial favorable inflation surprises and of the accumulating evidence that there was a sustainable improvement in the productive capacity of the economy that the Fed pursued what looked at the time like a very expansionary policy in 1998 and into 1999.

Why did inflation expectations not increase in line with the mechanical projections in Figure 2? One possibility is that the public and the Central Bank believed that the trend rate of growth of the economy had increased and therefore that nominal variables could increase faster than previously without setting off inflation. But because of slow adjustment, both of prices and of quantities, the economy cannot jump costlessly to a new equilibrium. The Appendix sketches a simple and standard model for examining the evolution of the economy if the growth rate of potential is

believed to have shifted. It considers two policy regimes, one where only deviations of output and inflation from their target enter the objective function and one where there is also a price-level target. The model has standard ingredients: (i) a central bank that chooses inflation to minimize the present discounted value of deviations of weighted average of inflation, output, and possibly the price level from targets and (ii) output that is determined by a forward-looking Phillips curve. The central bank is fully credible given its objective function, the public knows the objective function, and the central bank and the public share the same expectations about all variables.

Consider the following experiment. Suppose the economy is initially in steady state. At time zero, the central bank believes that trend growth of potential output has increased permanently. The public shares this perception. The bank raises its target path for output to equal its new estimate of the trend. In fact, the growth rate has not changed at all. After two periods, the central bank and the public both realize the mistake, so the central bank revises down its target for output.

Figure 3 shows the behavior of output, inflation, and the price level under two possible central bank objectives. In the first (solid line), the central bank puts no weight on the price level. In this case, shocks can have a permanent effect on the price level. In the second (line with dots), the central bank puts some weight on the price level, so the price level will eventually return to its target path following a shock.

In the first two periods, when the growth in potential output is believed to have increased, there is a boom. The central bank creates inflation because output is

¹⁸ Updating the estimate of the NAIRU for each successive year has only a modest effect on the forecasts. The decomposition of inflation surprises into NAIRU

perceived to be below potential and there is a corresponding boom in output. Notice that price level commitment greatly damps the movement of inflation, but only somewhat attenuates the effect on output. Likewise, in period three when it is discovered that potential has not increased, price level commitment damps the negative movement in inflation.

While these considerations do not prove that the Fed successfully anchored expectations with an element of price level commitment in the 1990s, they are consistent with that story. Since private agents believed that the Fed would undo errors, a gamble that sustainable growth had increased had only a muted impact on inflation and inflation expectations.

Is New Zealand in a similar position to take a growth gamble with monetary policy? I think the answer is no. First, there is no evidence here that the sustainable rate of growth has increased. Hence, the Reserve Bank could not credibly undertake a policy that had a higher growth target. Second, though Reserve Bank has an inflation target that is both transparent and credible, it does not have a price level target. In particular, since there is no commitment to stay on average near the center of the inflation bands, the operation of policy may admit a drift in the price level. In the present context, the first point, that there is no evidence of an increase in the trend growth rate of the economy, settles the issue: There is no case for monetary policy taking a growth gamble regardless of the details of the policy rule. But looking ahead, were evidence to appear that New Zealand were enjoying with a lag some of the acceleration in trend output evidenced in the U.S. data, then a monetary policy

surprises and other surprises needs to be investigated further.

aiming to accommodate this increase in trend should insure itself against negative growth rate surprises by committing to reverse errors should they occur.

B. Economic Growth and Government Policy

What can government do to affect the rate of growth of potential output? The analysis in the first section focused on the role of technological progress in determining the rate of growth of output, output per worker, and in wages. There is little evidence that government policy aimed at affecting the growth rate can have beneficial effects, and many efforts at targeting policy toward growth—particularly in specific industries or sectors—are counterproductive.

Monetary policy, in particular, has no ability to systematically raise the rate of output growth on average. Efforts to do so will only lead to inflation in the long run. Moreover, efforts by central banks to push output above its sustainable level are typically followed by recessions as the central bank acts to reverse earlier errors in policy.

Monetary policy must, however, be based on an assessment of the potential growth rate for the economy. The simulation discussed the previous section illustrates this point. Monetary policy must be predicated on a forecast for the sustainable path of output. Hence, the central bank has important estimation and communications problems. It needs to have an estimate of the sustainable rate of output growth. It must convey this estimate to the public. Yet, it must convey its estimate of the sustainable rate of growth without giving the impression that it is a direct object of its policy.

The best policies to promote growth are ones that New Zealand is already largely pursuing: stable and transparent monetary policy, a simple and non-distorting tax system, the lowest marginal tax rates possible consistent with balancing the government budget, deregulation of economic activity. There is considerable frustration in New Zealand that its growth performance has not been better in light of the policy reforms over the last decade and a half. Reforms are likely to take a substantial amount of time to change aggregate performance.¹⁹ More to the point, consider the counterfactual where the reforms had not taken place. New Zealand citizens currently enjoy a substantially greater variety and quality of goods and services than previously. Business can operate much more efficiently. Moreover, the reduction in tax distortions, regulatory barriers, and barriers to financial transactions has certainly made it much easier to operate a business. Had the previous barriers been in place, New Zealand would be poorly situated to take part in the increasingly interdependent world marketplace.

Government should avoid intervening on behalf of specific industries or groups, because such interventions are often driven by political or interest-groups considerations rather than promoting general well-being or increasing economic efficiency. Even well-meaning government interventions are often behind the curve and contrary to what an efficient marketplace would deliver.

Does this mean that government has no role in promoting growth apart from having stable monetary policy, low tax rates, balanced budgets, and limited regulation? Not quite. Effective government interventions should instead be focused

¹⁹ For example, Bandyopadhyay (2002) constructs a model where skill shortages can arise endogenously from reform and create a bottleneck that impairs their impact on

in areas where there is a clear government purpose owing to an externality or market failure. Consider several such areas.

1. Providing information

Collection of data and provision of information certainly is the quintessential public good. There are important areas where New Zealand's system of economic statistics should be improved. New Zealand lacks official measures of productivity. Statistics New Zealand has done important work recently in building toward a capability of measuring total factor productivity, e.g., by its work on capital stock statistics. Academics, the Treasury, and consultants have worked on constructing productivity measures.

A country with a growth agenda, should, however, have an official program to measure the determinants of economic growth. Accordingly, Statistics New Zealand should make it a priority to construct official estimates of labor productivity and total factor productivity at industrial and aggregate levels. Having reliable estimates of productivity is not simply a matter of making calculations based on currently collected data.

The Stats New Zealand, in tandem with other agencies around the world, needs to continue to work to improve the quality of price measurements, especially in regards to making adjustments for changes in quality of goods and services, and changes in outlets where they are sold.

Productivity calculations depend critically on the income side of the accounts. Statistics New Zealand should improve income-side measures.

productivity.

Use of administrative data rather than surveys can improve the quality of data and reduce respondent burdens. Recent research has suggested avenues for making effective use of scanner data for measuring prices and for adjusting prices for changes in quality (see Feenstra and Shapiro, 2003). These data can also be used to estimate sales. Administrative data from tax agencies can play an important role in estimating income and in imputing output. Advances in information processing technology will make use of administrative data more effective. The small size of New Zealand may make it easier to the statistical agency to cooperate with firms in setting up systems to use administrative data.

Productivity measurements are typically based on measures of changes in labor input adjusted for changes in quality of labor. These calculations are based on surveys that simultaneously measure employment, hours, wages, and education. These data are simultaneously available from the census, but not on higher-frequency surveys. Employment surveys should be designed with the objective of providing the necessary data for a productivity statistics. Work by Trinh, Gibson, and Oxley (2003) have taken the first step in doing a labor-quality adjustment by constructing human capital measures for New Zealand using existing data. The next step in their research will be to incorporate these data into productivity measurement. This work will fill an important gap in New Zealand data.

Statistics New Zealand is doing important work to improve measurement of capital. These data are essential to creating the capital services series necessary to do productivity measurement.

2. Infrastructure

There is evidence that physical infrastructure investments by the government can raise productivity. For example, the U.S. interstate highway system evidently raised productivity (see Fernald (1999)). I am not suggesting that a network of four-lane superhighways would be appropriate in New Zealand, but infrastructure investments appropriate to the geography and industries of New Zealand could be productive.

3. Education

There is also evidence that high levels of education attainment contribute to economic growth. General-purpose skills, such as those provided by a good university education, are increasingly important in the changing economy. New Zealand has an admirable record in literacy and had very substantial increases in university attendance. These are policies that should show sustained, long-term benefits in economic performance.²⁰

4. Tax policy

As discussed earlier, additional capital accumulation will be required if New Zealand is to grow faster. Reducing the taxation on the returns to investment and saving is one effective lever for promoting capital accumulation. The theory of optimal taxation suggests that capital should be taxed at a relatively low rate. Many countries implement policies to reduce the tax rate on capital. For example, the U.S. Congressional Budget Office estimates that the effective marginal tax rate in the U.S.

on capital is half that of on labor. New Zealand's current tax system is more neutral with respect to the taxation of capital income.

IV. Summary

The United States has enjoyed since 1995 an increase in the rate of productivity growth driven largely by an increase in the rate of technological progress. Even if this growth rate cannot be sustained, this improvement in technology should lead to a sustained increase in the level of productivity capacity.

New Zealand has not had a similar improvement in technology. There is no scope for monetary policy to affect the rate of productivity advance. Yet, monetary policy must be calibrated based on the best forecast of economic growth. Moreover, monetary policy should follow rules that will lead to good outcomes even when forecasts of economic growth prove to be wrong.

More generally, the scope for public policy to affect growth rates is quite limited. The best pro-growth policies are quite generic: low and non-distorting taxes, limited taxation of capital income, efficient regulation, investment in infrastructure, and openness to the world economy. Efforts to target growth by stimulating particular industries typically fail because the political system is ill-suited to locate efficient investments.

²⁰ New Zealand faces special challenges in the market for human capital. Many of its skilled graduates find jobs, especially early in careers, in other countries. International security concerns recently have damped this trend.

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APPENDIX

We assume that the central banker cares about the deviation of output, price level, and inflation from target values. The first two variables are state variables, while inflation is the only control (instrument) at the central baker's disposal. To formalize trade-off between achieving targets, we assume that the central banker has a quadratic loss function representing relative weights of the goals:

$$\min E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(w_y (y_t - y_t^*)^2 + w_p (p_t - p_t^*)^2 + w_\pi (\pi_t - \pi_t^*)^2 \right) \right\}$$

where y_t is output, p_t is the price level, and π_t is inflation. The starred variables represent desired, or targeted values. The w_i are the weights of the variables.

Optimal policy is invariant to normalization of weights in the loss function. Hence, we normalize weights so that they sum up to one:

$$\begin{aligned} w_y &= (1 - \omega_p)(1 - \omega_\pi) \\ w_\pi &= (1 - \omega_p)\omega_\pi \\ w_p &= \omega_p \end{aligned}$$

where ω_p, ω_π are relative weights on price level gap and inflation, respectively.

To complete the description of this optimization problem we need laws of motion for the state variables. Price level gap evolves according to a very simple rule. Define p_t^* as log targeted price level at time t . Suppose further that optimal inflation rate π_t^* is constant. Then targeted price level evolves according to

$$p_{t+1}^* = p_t^* + \pi^*$$

since, $p_{t+1} = p_t + \pi_{t+1}$. Then the gap between actual and targeted price level, $p_t - p_t^*$, changes as

$$p_{t+1} - p_{t+1}^* = (p_t + \pi_t) - (p_t^* + \pi_t^*) = (p_t - p_t^*) + \pi_t - \pi_t^*$$

Note that any deviation of actual inflation π_t from desired inflation has a permanent effect on price level gap $p_t - p_t^*$. Unless the central banker decides to revert to the targeted price level, the gap does not disappear over time. For example, any positive price level gap can be eliminated only at the cost of restrictive monetary policy (disinflation or deflation, i.e. $\pi_t < \pi_t^*$) with a likely slowdown in the economy.

Unlike price level gap, the output gap is derived from the optimization problem of the private sector. We simplify the role of the private sector in this model as we adopt the consumption-based Euler equation from Clarida et al (1999, p. 1691) in somewhat less general form:

$$y_t - y_t^N = \theta \cdot (y_{t-1} - y_{t-1}^N) + \alpha \cdot (\pi_t - E_t \pi_{t+1}) + \varepsilon_t$$

where $E_t \pi_{t+1}$ is expected inflation of period $t+1$ at period t , y_t^N is the natural level of output. For simplicity we assume that $y_t^N = y_t^*$, i.e. central banker targets natural level or growth rate of output. Note that agents are forward-looking in terms of inflation.

In sum, the optimization problem is

$$\min E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left((1-\omega_p)(1-\omega_\pi)(y_t - y_t^*)^2 + (1-\omega_p)\omega_\pi(\pi_t - \pi_t^*)^2 + \omega_p(p_t - p_t^*)^2 \right) \right\}$$

subject to

$$p_t - p_t^* = p_{t-1} - p_{t-1}^* + \pi_t - \pi_t^*$$

and

$$y_t - y_t^* = \theta \cdot (y_{t-1} - y_{t-1}^*) + \alpha \cdot (\pi_t - E_t \pi_{t+1}) + \varepsilon_t$$

where ε_t is the output disturbance and $E_t \pi_{t+1}$ is expected inflation of period $t+1$ conditional on information set at time t .

To get some numerical results, we consider the following calibration. We assume that $\beta = 0.9$, $\alpha = 0.5$, $\theta = 0.9$, $\omega_\pi = 0.5$. If we consider price level commitment case we set $\omega_p = 1/3$, otherwise $\omega_p = 0$. Without loss of generality we set $\pi^* = p^* = 0$. Note that a permanent change in output is represented by a change in y_t^* . In contrast, temporary change is captured by ε_t . The model is solved using the Anderson-Moore (1985) algorithm.

Table 1
Growth in Productivity and Technology: United States
(percent per year)

	1973:1- 1995:3	1995:3- 2002:3	1995:3- 2000:2	2000:2- 2001:3	2001:3- 2002:3
Labor productivity	1.4	2.6	2.6	0.5	5.2
Hours	1.7	1.0	2.1	-1.2	-1.8
<i>Contribution of:</i>					
labor quality	0.3	0.2	0.2	0.3	0.3
capital per worker	0.8	1.1	1.2	1.2	0.6
Total factor productivity	0.3	1.3	1.4	-0.9	4.4
Adjustment cost correction	-0.1	-0.2	-0.4	0.2	0.2
Utilization correction	0.0	-0.3	0.1	-1.7	-0.3
Adjusted total factor productivity	0.5	1.8	1.6	0.7	4.5

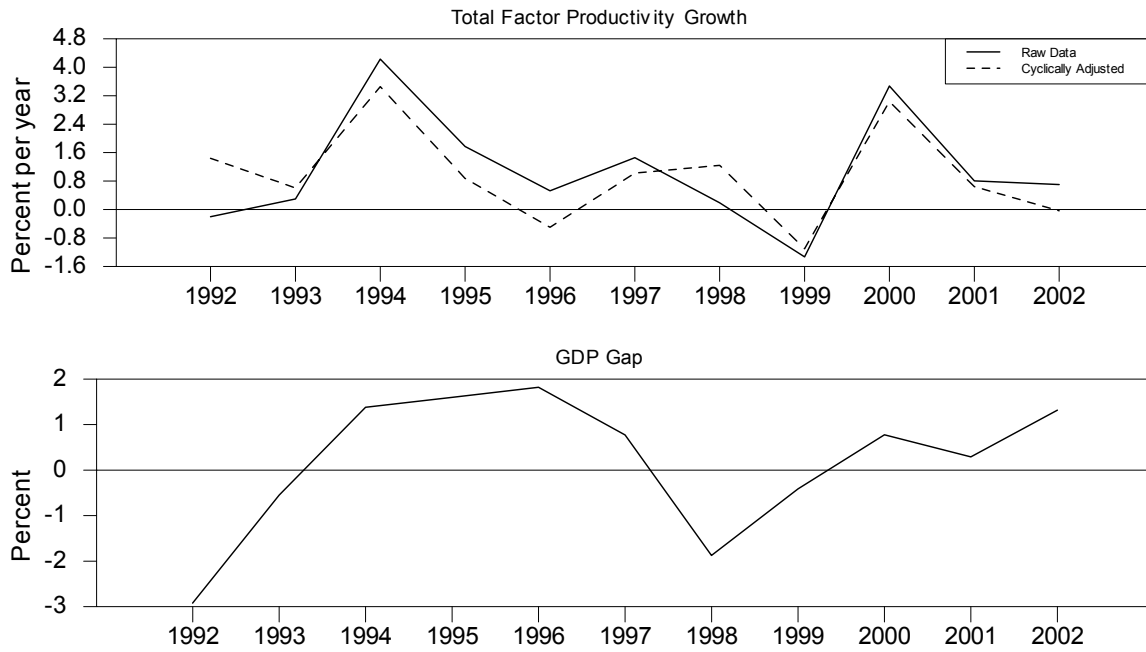
Figures may not add up because of rounding.

Table 2
Growth in Productivity and Technology: New Zealand
(percent per year)

	1992-2002	1992-1995	1996-2002
Labor Productivity	1.3	1.0	1.5
Output	3.1	3.4	3.0
Hours	1.8	2.4	1.5
Capital	2.0	1.0	2.6
<i>Contribution of capital per hours</i>	0.1	-0.7	0.6
Total factor productivity	1.1	1.5	0.8
Utilization correction	0.1	-0.1	0.2
<u>Adjusted total factor productivity</u>	<u>1.0</u>	<u>1.6</u>	<u>0.6</u>
Memo: GDP Gap	0.2	-0.1	0.4

Figures may not add up because of rounding.

Figure 1
Total Factor Productivity and the Cycle: New Zealand



Note: Cyclical adjustment using GDP gap

Figure 2
Forecasts of Inflation Based on a Phillips Curve: United States

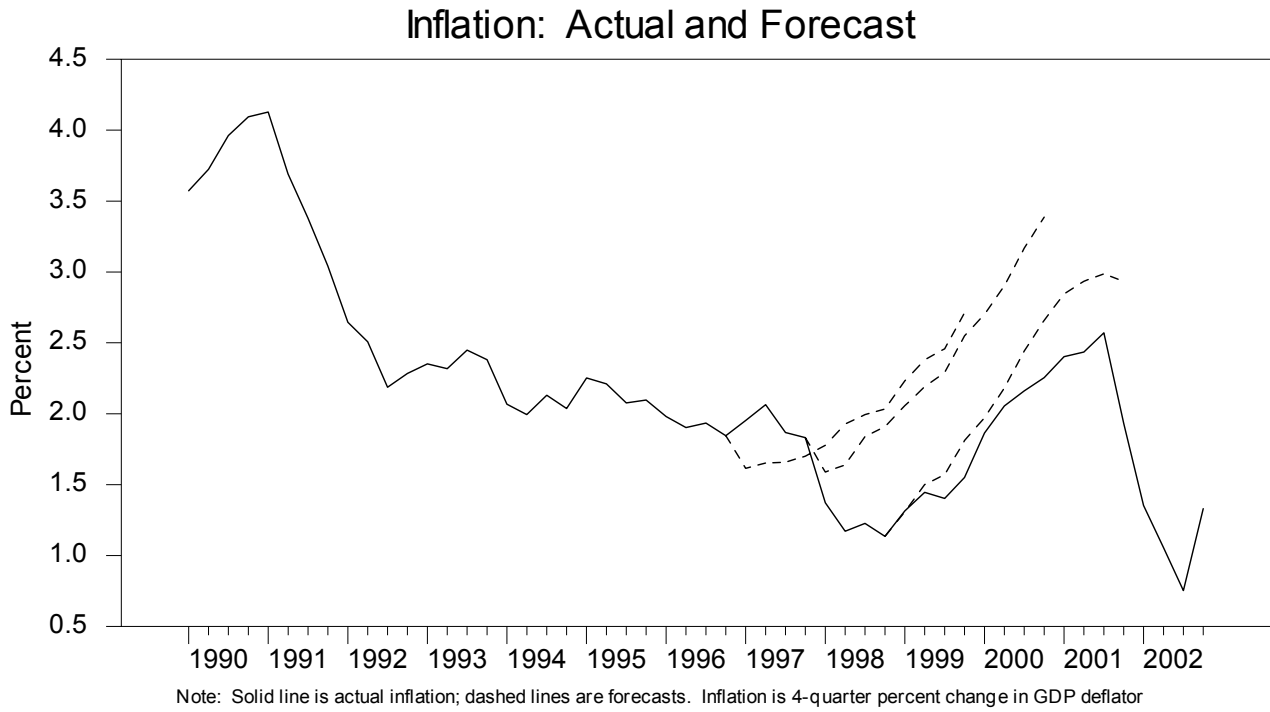
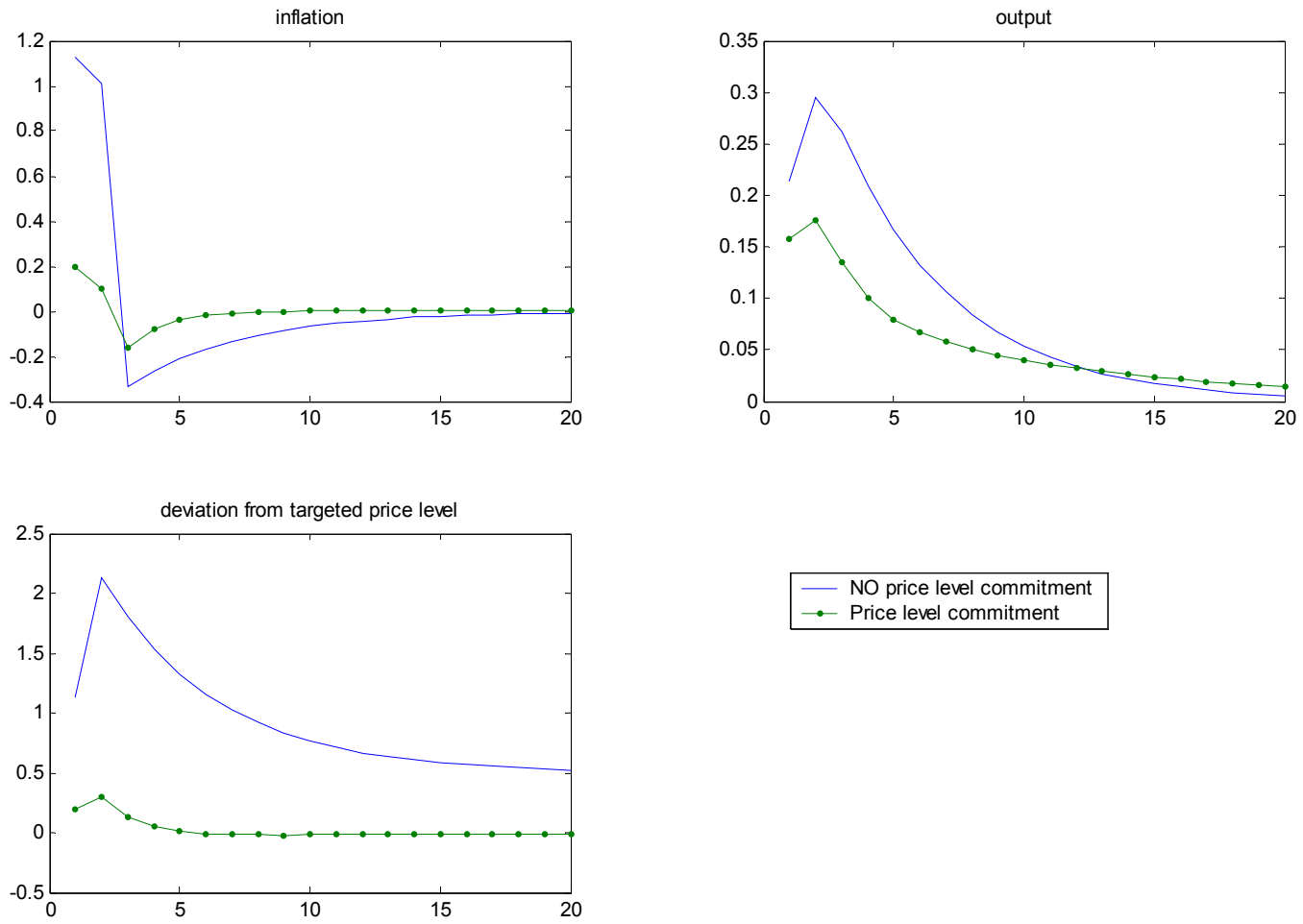


Figure 3
Response to a Perceived Change in the Growth Rate
with and without a Central Bank Price Level Commitment



Note for Figure 3. Both the public and the central bank expect an increase in the potential growth rate at time zero. At time two, they discover that they were mistaken and that potential growth was always at the original level. Policy is credible. In one case, keeping the *price level* stable is in the central banks objective. In the other, it puts no weight on price-level stability.