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Does the Gap Model Work in Asia?

Prepared by David T. Coe and C. John McDermott[1]

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Abstract

There is considerable evidence from industrial countries that the output gap is an important determinant of inflation. We examine whether the gap model also works in developing, newly industrializing, and industrial Asian economies. Our output gaps are based on a new nonparametric estimation procedure for trend output that does not require an arbitrary specification of the degree to which the data are smoothed. We test simple versions of the gap model in which the change in inflation is related to the output gap, as well as to the money supply and the terms of trade. We conclude that the gap model works very well in almost all of the Asian economies we study.

JEL Classification Numbers:
E31,O53

[1]We thank Bankim Chadha, Douglas Laxton, Alexander Hoffmaister, and other Fund colleagues for comments, and Claire Adams for research assistance. The question in the title was asked by Michael Mussa.

DOES THE GAP MODEL WORK IN ASIA?

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Summary

It is generally accepted that inflation is closely related to the pace of economic activity. The most common formulation of the "gap model" is that there is a level of output--potential or trend output--that is consistent with a stable rate of inflation. There is considerable empirical support for the gap model from a large number of studies for industrial countries, but scant evidence for developing countries. This, together with the fact that many developing or newly industrializing economies in Asia have sustained very rapid growth during the past one or two decades, and some have recently had to address the problem of overheating, raises the question of whether the gap model is relevant for Asia.

This paper presents some evidence on this issue for a group of 13 developing, newly industrializing, and industrial Asian economies. The research strategy minimizes judgmental input, and a new nonparametric methodology, which is more data-driven than alternative methods, is used to estimate trend output and output gaps. The results indicate that the gap model works very well in almost all of the economies studied. The only exceptions are Thailand and China, where there is no evidence that the estimated output gap has any impact on inflation. In India, the output gap is an important determinant of inflation when included with a measure of the broad money supply. Thus, the developing, newly industrializing, and industrial economies of Asia are not different from the industrial countries of North America and western Europe.

I. Introduction

It is generally accepted that inflation is closely related to the pace of economic activity. The most common formulation is that there is a level of output--referred to as potential or trend output--that is consistent with a stable rate of inflation. In this formulation of the "gap model," the change in inflation will be related to the level of the output gap, defined as actual minus potential output: inflation will tend to rise if the gap is positive, it will tend to fall if the gap is negative, and it will remain stable if the gap is zero. An alternative version of the gap model focuses on the change in the gap rather than the level of the gap. In this case, the change in inflation will be related to the change in the output gap, implying that the level of inflation will tend to remain stable so long as the level of the gap is unchanged. The gap model is also commonly applied to wage inflation--the Phillips curve--in which case the relevant "gap" is between the actual rate of unemployment and the natural rate of unemployment (or the nonaccelerating rate of unemployment, the NAIRU).

The gap model has proven to be a useful tool for policy analysis since economic policies will generally have direct impacts on the gap. Monetary and fiscal policies, for example, will affect actual output, while structural policies will affect potential output. Inflation will, of course, also depend on other factors. Changes in import prices, indirect taxes, inflation expectations, and labor market policies and institutions that affect wage formation can all have direct impacts on inflation. Although variables such as these are usually incorporated into most empirical models, the output or the unemployment gap remains at the center of almost all inflation models (Nickell, 1988; Masson, Symansky, and Meredith, 1990; Chadha, Masson, and Meredith, 1992).

There is considerable empirical support for one or both versions of the gap model from a large number of studies for industrial countries.[2] There have, however, been only a few empirical studies of the gap model for developing countries.[3] This, together with the fact that many developing or newly industrializing economies in Asia have sustained very rapid growth during the past one or two decades, and some have recently had to address the problem of overheating, raises the question of whether the gap model is relevant for Asia. The purpose of this paper is to present some evidence on this issue for a group of 13 developing, newly industrializing, and industrial Asian economies: Australia, China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, New Zealand, the Philippines, Singapore, Taiwan Province of China, and Thailand. This group includes the rapidly growing and, at least in some cases, relatively high inflation economies of east and southeast Asia. To be as evenhanded as possible, we adopt a research strategy designed to minimize judgmental input. In the next section we discuss a new nonparametric estimator for trend output and present

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[2]See, for example, IMF (1991), OECD (1994), and Bryant *et al.* (1988).

[3]An exception is Andersen (1991) and IMF (1995). Singh (1996) discusses output gaps and inflation and other indicators of overheating in Asian economies. Agenor (1995) presents a survey of theoretical and empirical studies on labor markets in developing countries.

estimates of the output gap. Empirical tests of the gap model are presented in Section III. Section IV concludes.

II. Output Gaps

To test the gap model, it is first necessary to estimate potential or trend output in order to define the gap between actual and potential output. This means that any test of the gap model is a joint test of the estimated gap and of the impact of the gap on inflation. Unfortunately, estimating trend or potential output is more an art than a science. There are many different approaches, and no one method is trouble free (Adams and Coe, 1990; Giorno *et al.*, 1995). One general approach is to estimate a production function and then calculate potential output as the level of output that would obtain if all factors of production were fully utilized (IMF, 1991; OECD, 1994). This structural approach has the advantage of explicitly identifying the sources of output growth. In practice, however, these studies commonly focus on capital and labor, with total factor productivity, typically an important source of growth, left largely unexplained.

A less structural, much simpler, approach is to use some type of univariate smoothing technique to define trend output. The most popular is the Hodrick-Prescott (1980) filter. In this paper, we use a new nonparametric method to estimate trend output that has the important advantage that the degree of smoothing is determined by the data. By contrast, the Hodrick-Prescott filter and other smoothing techniques require the user to specify an arbitrary smoothing parameter. In effect, this smoothing parameter determines the size of the data "window" used to calculate the trend: the larger the window, the smoother will be the trend; the smaller the window, the more the trend will resemble the actual data.[4] Based on U.S. data, Kydland and Prescott (1990) suggest smoothing parameters of 1600 for quarterly data and 100 for annual data. These smoothing parameters have, to a large extent, become the industry standard, even for countries where the business cycle may be substantially different than in the United States. The absence of statistical criteria to guide the choice of the smoothing parameter is problematic since the estimated trends will depend importantly on the value of this parameter.

The technique used here determines the size of the data window through a statistical procedure that is asymptotically optimal in the sense that a global error criterion is minimized, thus ensuring that the degree of smoothing is consistent with the cyclical properties of the data. Since the degree of smoothing is determined on statistical grounds and does not require the specification of an arbitrary smoothing parameter or data window size, different researchers analyzing the same data will obtain the same trend estimates. In the appendix, the method we use to estimate trend output and output gaps is described and compared with estimates obtained with a Hodrick-Prescott filter.

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[4]In a simple moving average, the size of the window is the number of lags over which the data are averaged.

Real GDP and its estimated trend are displayed in the left panels of Figure 1 (note that the scales differ). The GDP data, as well as the data used in the next section, are from the IMF's *International Financial Statistics*. For China, we also estimate trend output based on new estimates of real national income from Hu and Khan (1996), which are available for a much longer time period than GDP. Like other univariate estimates, our estimated trends have the property that their average value over the sample period is the same as the average value of actual GDP. The estimated trend at the beginning and the end of the sample may be biased by the absence of data prior to and beyond the sample period. To at least partially solve this problem, we (i) exclude the first two years of the estimated trends and (ii) extend the GDP data two years beyond the last year shown in the figure using the projections from the May 1996 *World Economic Outlook*, and then exclude these two years of the estimated trends. The fact that the estimated trends are most uncertain for the most recent period, a problem that is common to all centered smoothing techniques, limits their usefulness as an operational tool for practical policy implementation purposes.

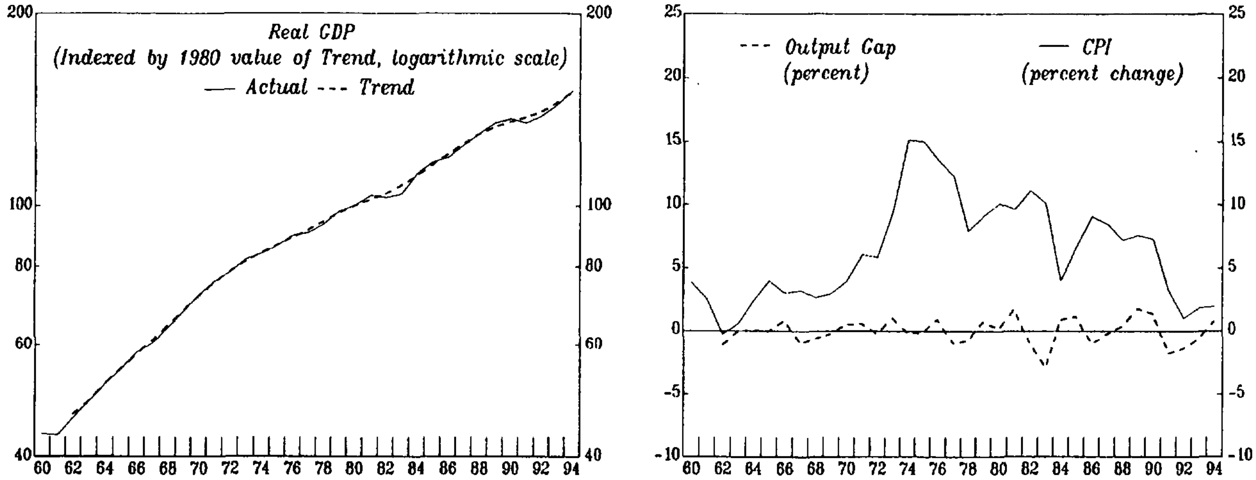
There are a number of notable features in the development of actual output. The first is the contrast between the majority of countries that have experienced remarkably rapid increases in real output and Australia, India, Japan, New Zealand, and the Philippines where increases in output have been much more modest (Table 1). The second is that GDP appears to have accelerated since 1970 in some of the high-growth economies while growth has declined in most of the low-growth countries. The third is that growth has been sustained remarkably well since the mid-1960s, with only a few examples of stagnant or negative growth.

Given these features of actual output developments, the estimated trends are relatively smooth. The data window--the number of years of data used to define the trend--is typically 7 to 9 years, although it is only 3 years for Thailand and as long as 14 years for China based on national income (see the first column of Table 1). The size of the data window tends to be inversely related to the growth of output and positively related to the volatility of output growth (cf. Figure 1). The different sizes of the data windows indicate that it would be inappropriate to arbitrarily apply the same degree of smoothing to the GDP data for all economies.

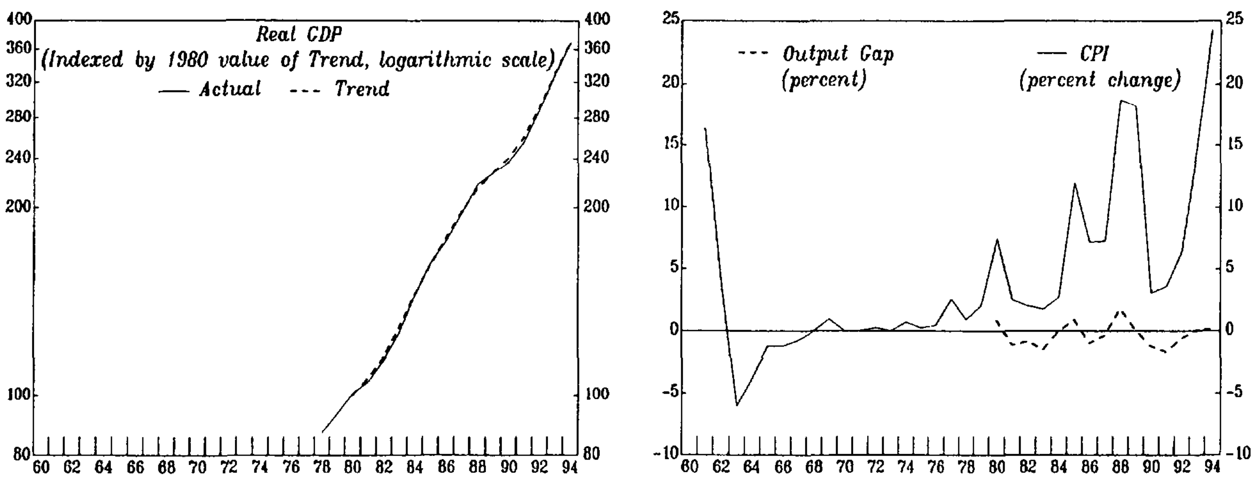
The output gaps implied by actual output and the estimated trends are displayed in the right panels of Figure 1; the gap is defined as actual output minus trend output as a percent of trend output. The estimated output gaps are typically in the range of ± 3 percent. The largest estimated output gaps are negative 5 percent in Hong Kong in the mid-1970s and the Philippines in the mid-1980s, and ± 10 percent in China in the 1960s based on real national income. Except for a few years in the mid-1980s, real output growth has been remarkably stable since the mid-1970s in Malaysia, Singapore, and Thailand, and hence the calculated output gaps are relatively small. As discussed in the Appendix, our estimated trends are less smooth than those obtained from the Hodrick-Prescott filter, and hence our calculated output

Figure 1. Output Gaps and Inflation

Australia



China



China

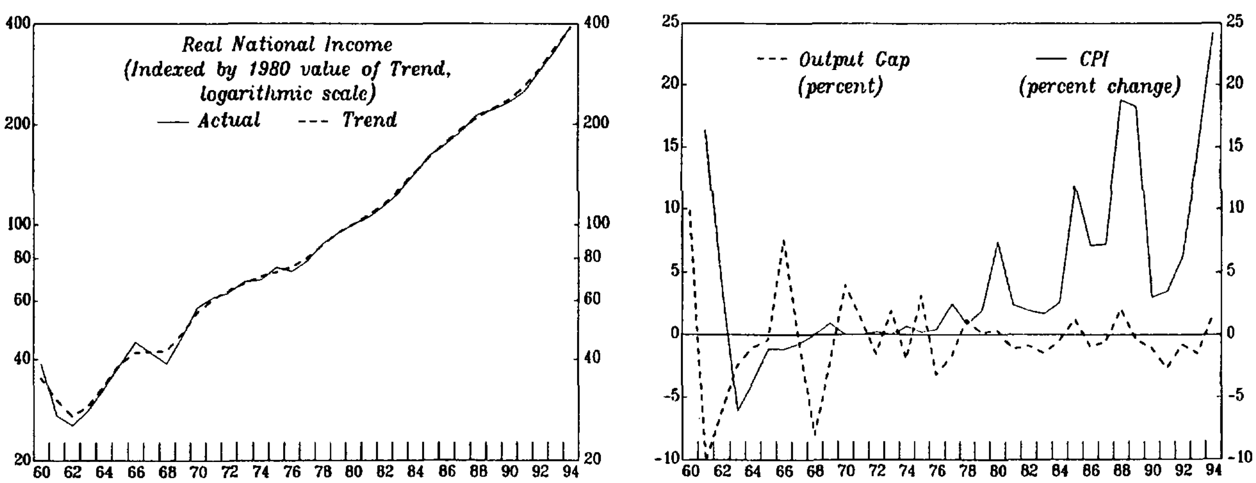
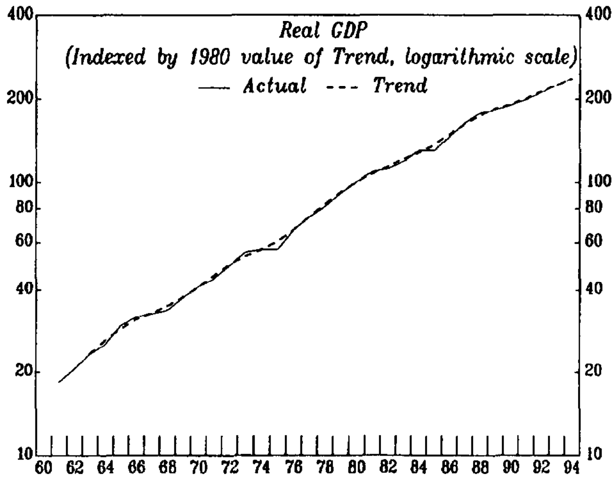
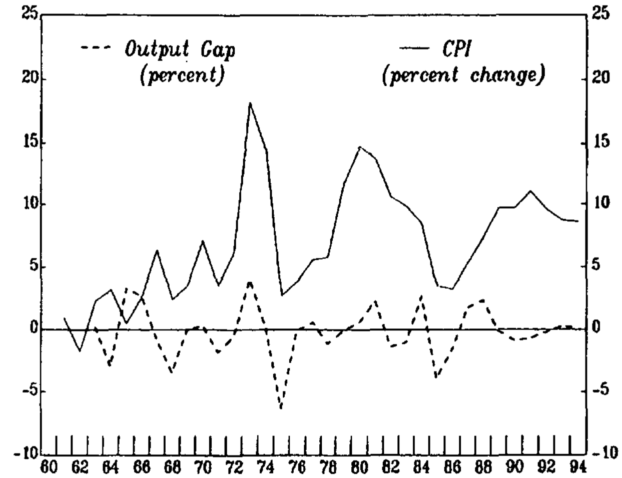


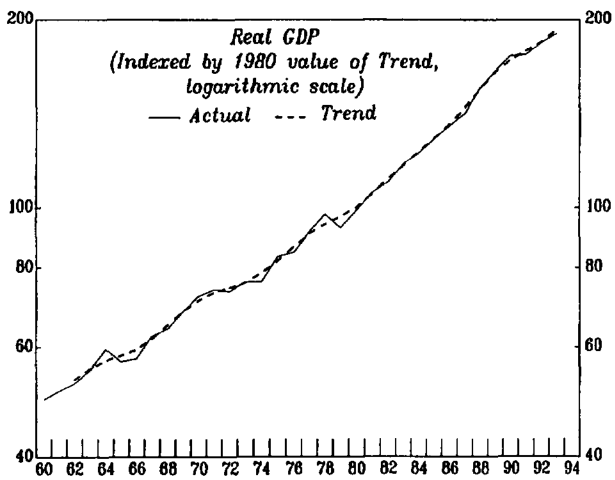
Figure 1. Output Gaps and Inflation (continued)

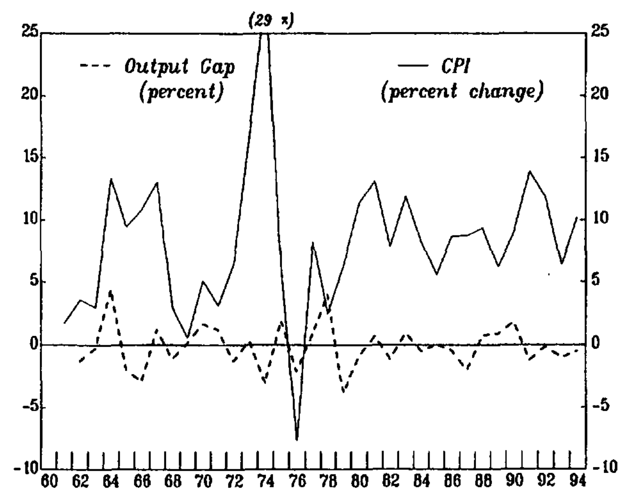
Hong Kong



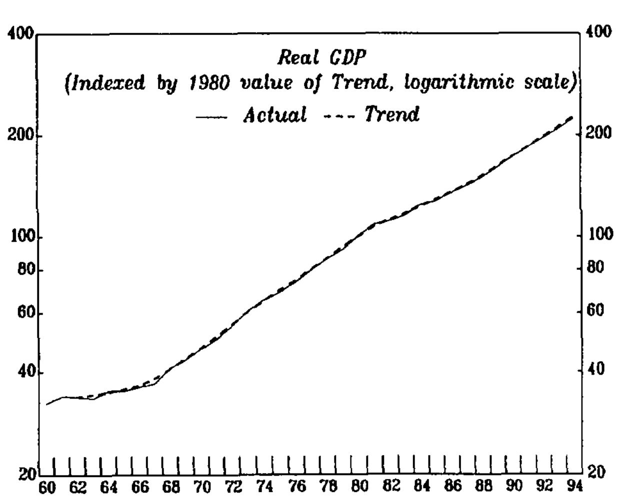


India





Indonesia



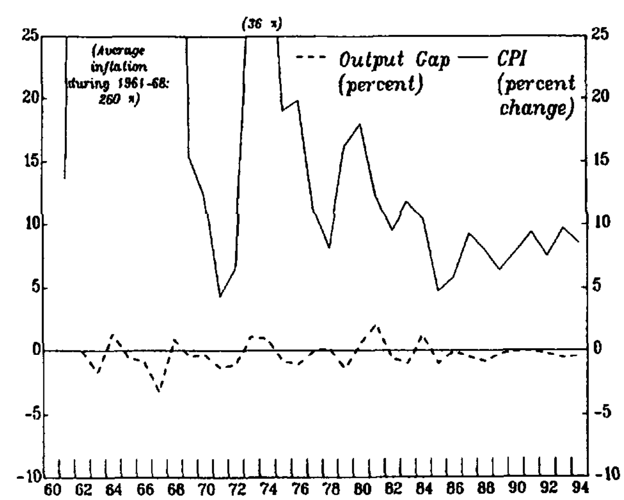
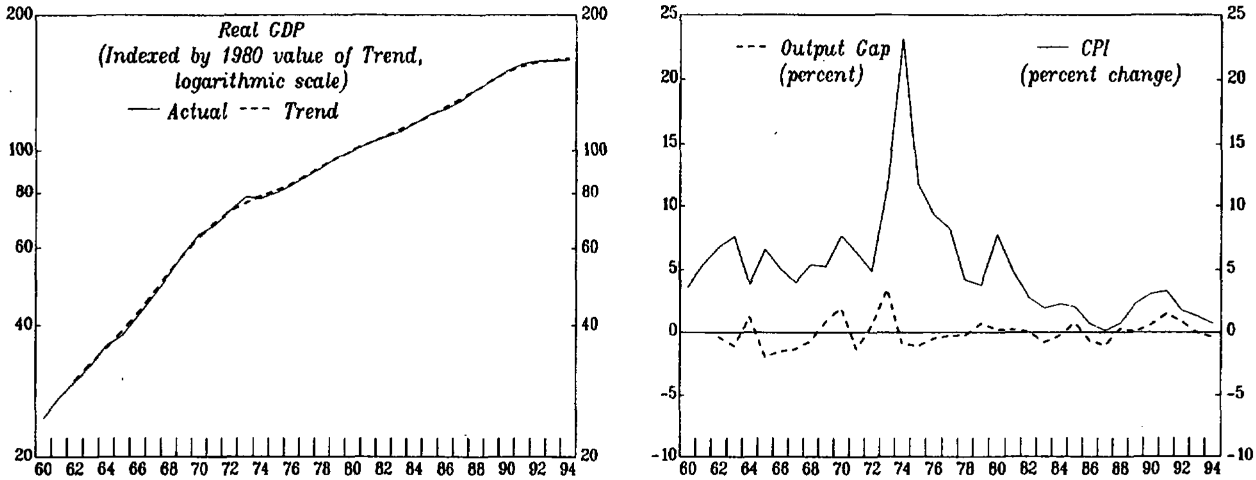
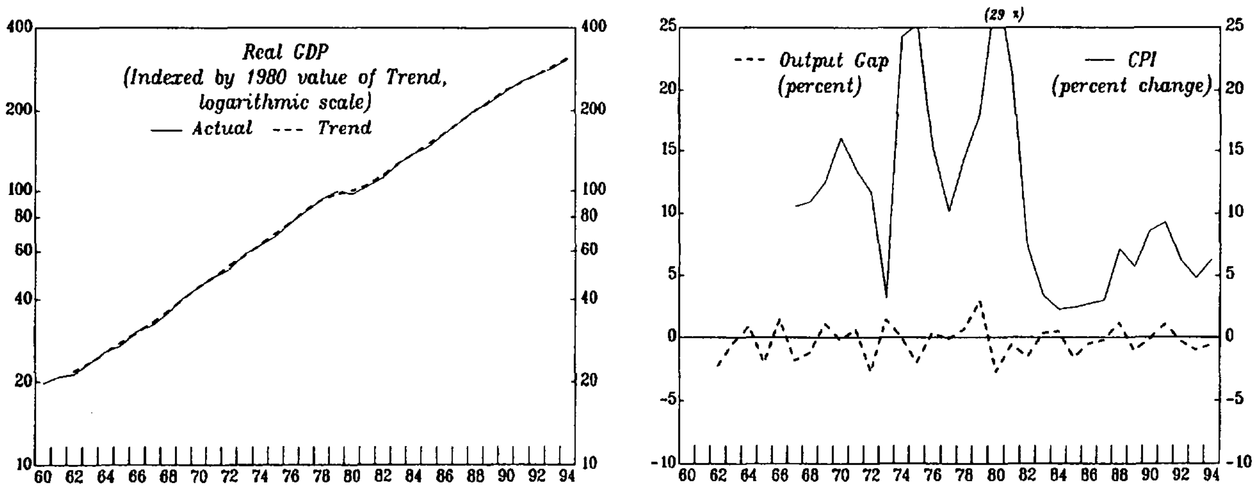


Figure 1. Output Gaps and Inflation (continued)

Japan



Korea



Malaysia

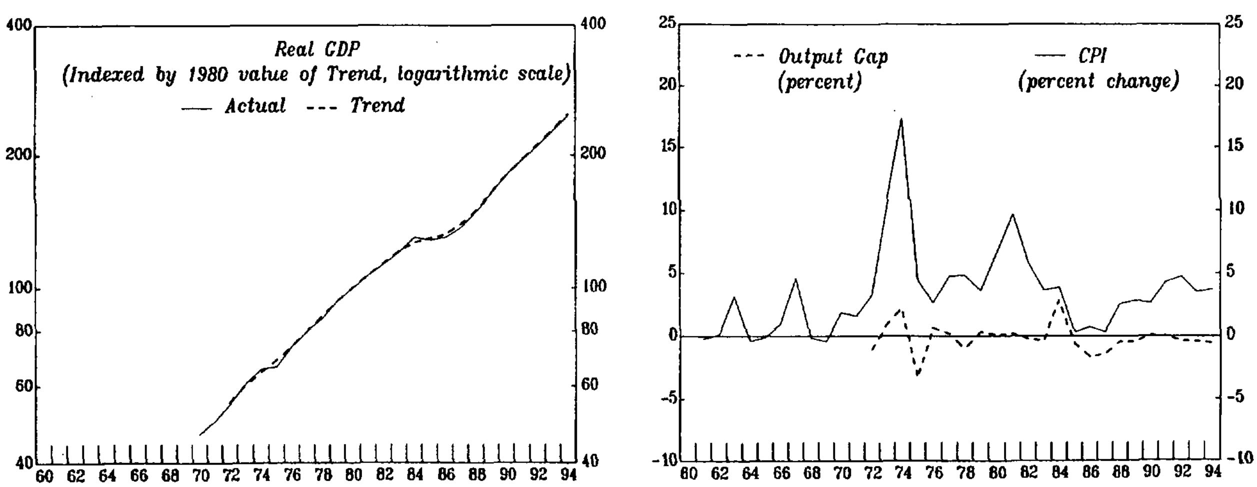
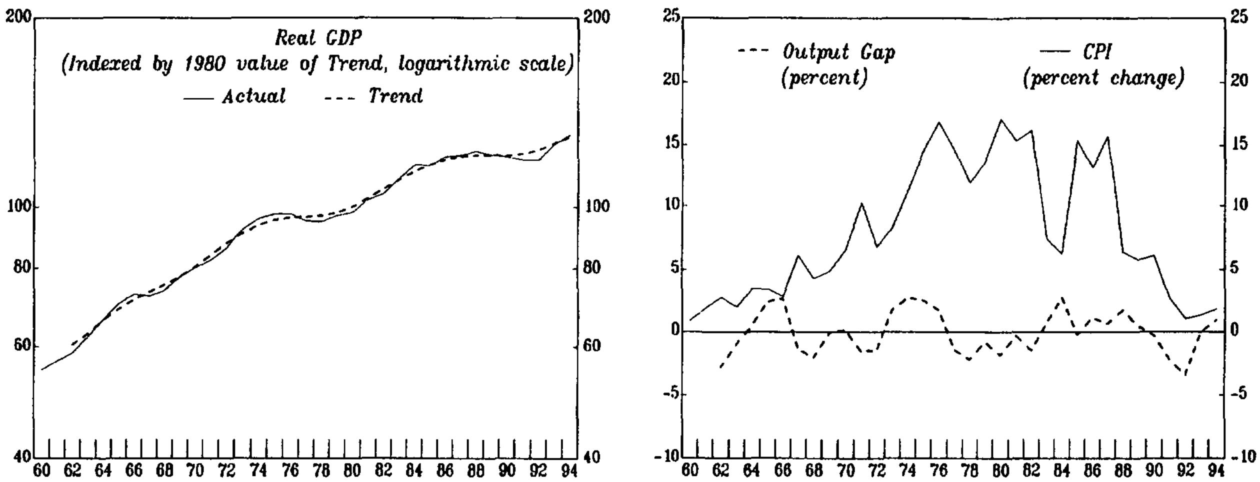
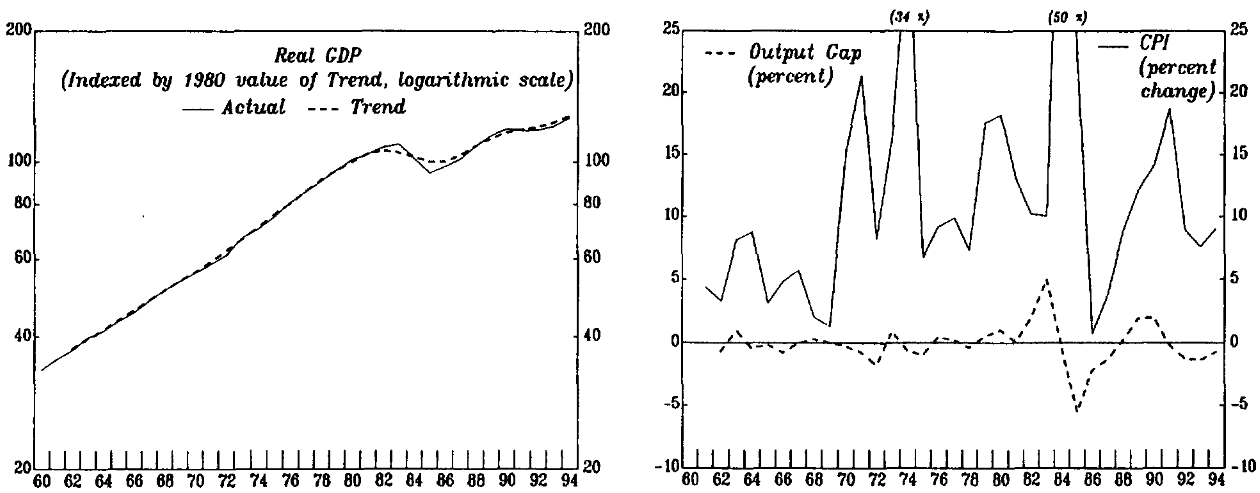


Figure 1. Output Gaps and Inflation (continued)

New Zealand



Philippines



Singapore

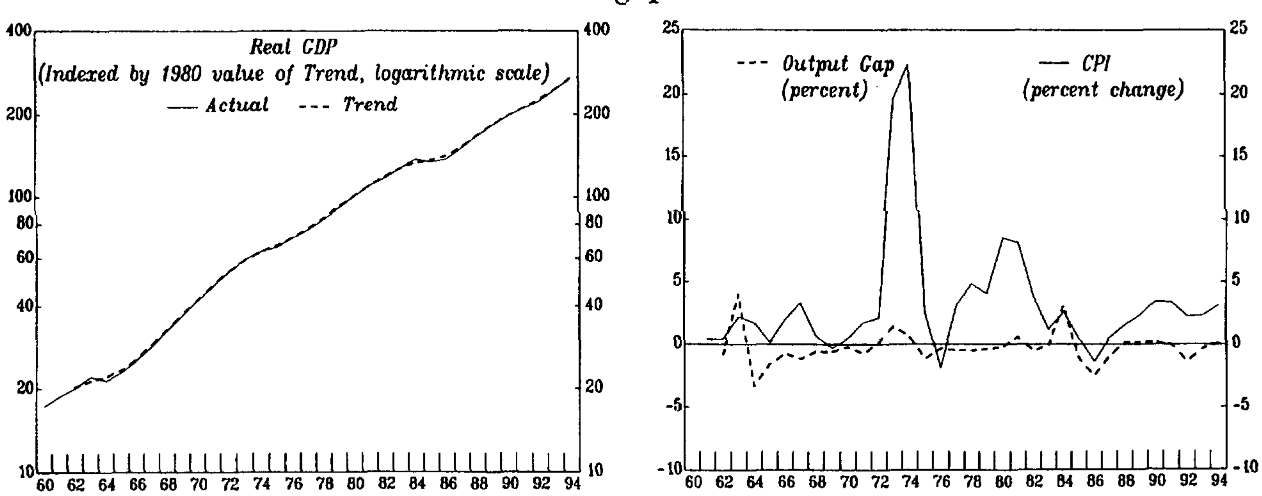
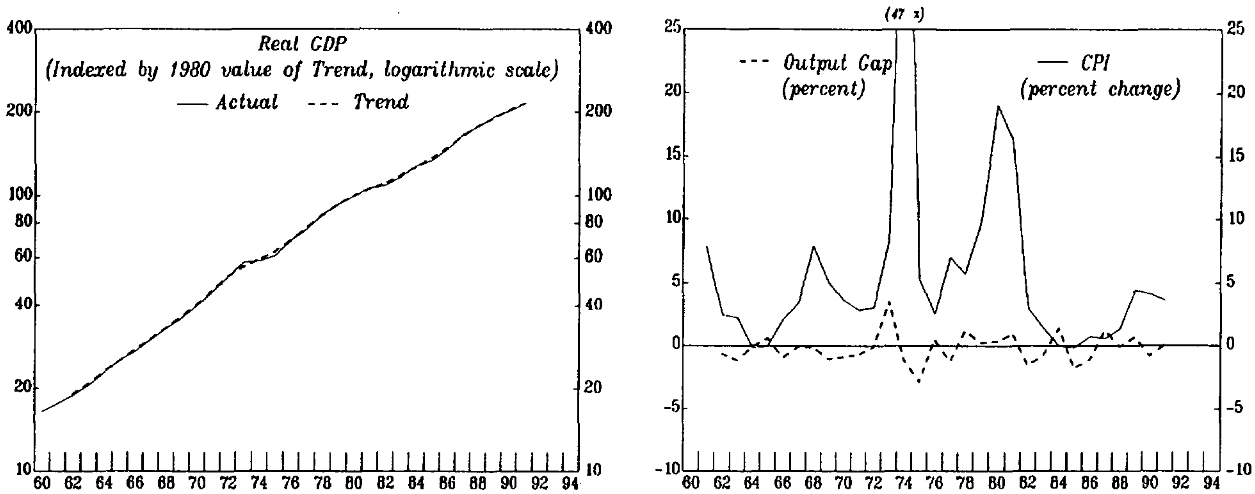


Figure 1. Output Gaps and Inflation (concluded)

Taiwan Province of China



Thailand

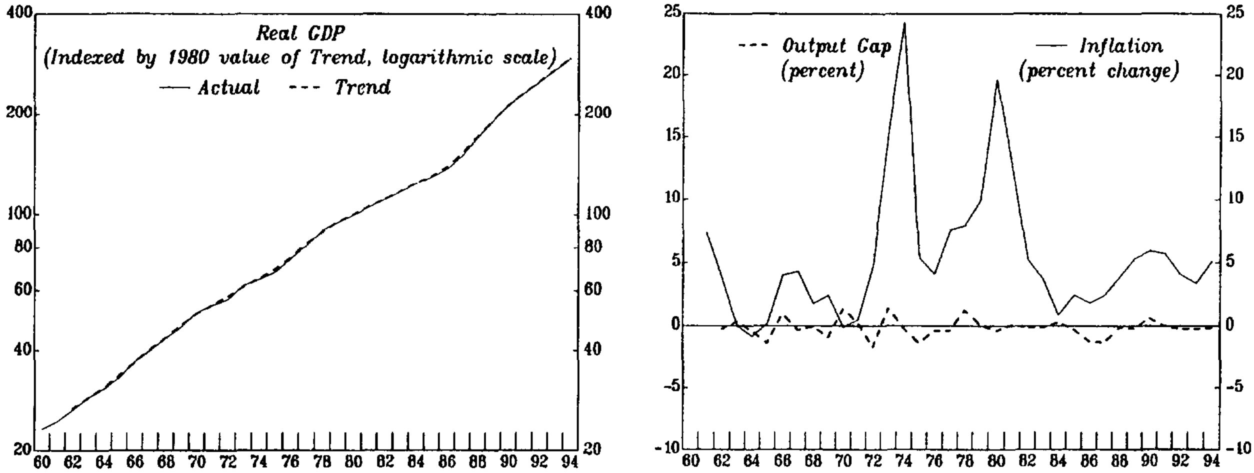


Table 1. Output and Prices
(Average annual growth rates)

	Data window (years)	Full Sample 1/			1970s			1980s			Early 1990s 1/		
		GDP			GDP			GDP			GDP		
		Actual	Trend	CPI	Actual	Trend	CPI	Actual	Trend	CPI	Actual	Trend	CPI
Australia	11	3.8	3.7	6.4	3.4	3.4	10.5	3.2	3.1	8.1	2.5	2.7	2.0
China – GDP	7	9.5	9.8	4.3	7.7 1/	...	1.5	9.0	9.2	7.5	11.7	11.3	12.2
– National Income	8	7.6	7.5		5.9	6.2		8.8	8.9		14.1	13.3	
Hong Kong	9	8.2	7.8	6.9	9.5	9.4	8.7	6.6	6.7	8.2	5.8	5.5	9.5
India	9	4.3	4.3	8.1	3.3	3.5	8.2	5.9	5.6	8.9	3.6	4.2	10.6
Indonesia	9	5.9	6.1	70.6	8.0	7.9	17.5	5.5	5.6	8.6	6.8	6.9	8.8
Japan	10	5.7	5.4	5.2	4.5	4.7	9.1	4.1	4.1	2.1	1.5	1.7	1.7
Korea	8	8.5	8.7	10.9	8.3	8.5	16.5	9.2	8.9	6.4	7.1	7.2	6.7
Malaysia	8	7.2	7.1	3.5	8.0	7.8	6.0	6.0	6.0	3.2	8.4	8.6	4.1
New Zealand	14	2.6	2.4	8.2	2.1	2.2	12.5	2.1	2.0	10.8	2.0	1.7	1.7
Philippines	11	4.0	3.9	11.7	6.1	6.0	14.9	1.7	1.6	14.6	1.6	2.3	11.1
Singapore	8	8.5	8.5	3.3	9.1	9.1	6.7	7.1	7.0	2.3	8.4	8.4	2.8
Taiwan Province of China	8	8.5	8.5	5.6	9.7	9.6	11.1	7.2	7.3	3.2	6.6	6.4	3.8
Thailand	3	7.8	7.8	5.5	6.8	7.0	10.0	7.9	7.8	4.4	8.3	8.5	4.6

1/ Data refer to the years shown in Figure 1.

gaps are generally smaller.[5] In the next section, we test the extent to which our estimates of the output gap explain inflation developments in 13 Asian economies.

III. Testing the GAP Model

Annual rates of inflation are displayed in the right panels of Figure 1, together with the estimated output gaps. In most countries, inflation has been volatile, with spikes of 25 to 50 percentage points not uncommon, particularly during the 1970s and early 1980s. Many, although not all, of these inflation spikes appear to be associated with smaller spikes in the output gaps. Periods of relatively high inflation in the 10-15 percent range are not unusual, and Indonesia experienced a sustained period of very high inflation in the 1960s. Except for China and Hong Kong, inflation has generally been lower--below 5 percent in Japan, Malaysia, Singapore, Taiwan Province of China, and Thailand--and more stable since the mid-1980s. In China, by contrast, inflation has risen substantially since the mid-1980s; and this is also true, albeit to a lesser extent, in Hong Kong. Except for China, Phillips-Perron (1988) unit root tests indicate that inflation, as well as the change in inflation, is stationary.

To assess the importance and significance of the visual evidence of a relationship between inflation and the estimated output gaps, we estimate the following simple specification of the gap model:

$$MODEL\ 1: \qquad \Delta\pi_t = \alpha_1 + \sum_{i=0}^{\Upsilon} \beta_{1i} GAP_{t-i} + \epsilon_{1t}$$

where $\pi_t = 100(CPI_t/CPI_{t-1} - 1)$, $GAP_t = 100(GDP_t - GDP_t^{TR})/GDP_t^{TR}$, ϵ is a stochastic disturbance term, and Δ is the first-difference operator. We include a constant to avoid imposing the constraint that the noninflationary level of the output gap is exactly zero. Model 1 can be derived from a simple inflation-expectations-augmented Phillips curve with adaptive expectations:

$$\pi_t = \alpha_1 + \pi_t^e + \sum_{i=0}^{\Upsilon} \beta_{1i} GAP_{t-i} + \epsilon_{1t} \qquad with \qquad \pi_t^e = \pi_{t-1}$$

where π_t^e is inflation expectations at time t. The assumption of adaptive expectations greatly simplifies the modeling of inflation expectations allowing us to focus on the role of the output gap as a determinant of the change in inflation.

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[5]King and Rebelo (1993) and Cogley and Nason (1995) argue that the Hodrick-Prescott filter over smooths and tends to add spurious cycles in the resulting output gaps.

The coefficients on the gap variable can be interpreted as semi-elasticities that give the percentage point change in inflation implied by a 1 percentage point output gap. We estimate equations with only the contemporaneous value of the gap variable and with up to five lagged values (Υ=5) of the gap variable, using the Schwarz (1978) information criterion to determine the preferred lag length. For given estimates of trend output, this estimation procedure requires no judgement on our part to select the preferred specification. Our test of the gap model is simply an F-test that the β_{1i} are jointly significantly different from zero--that is, that the output gap is a significant determinant of the change in inflation--and that $\sum\beta_{1i} \geq 0$.

It is important to note that Model 1 encompasses both the level and the change versions of the gap model discussed in the introduction. The change version of the gap model is:

$$MODEL\ 2: \qquad \Delta\pi_t = \alpha_2 + \sum_{i=0}^{\Upsilon} \beta_{2i}\Delta GAP_{t-i} + \epsilon_{2t}$$

which is a special case of Model 1 with the constraint that the coefficients on the level of the gap alternate in sign, with each pair equal in absolute value, implying that they sum to zero, that is that $\beta_{11} = -\beta_{10}$, $\beta_{13} = -\beta_{12}$, and so on. Model 1 also encompasses specifications that allow both the level and the change in the gap to affect inflation, in which case some of the estimated coefficients would be negative, but their sum would be positive.

The estimation results for Model 1 are summarized in panel A of Table 2. The estimated lags are short: only the contemporaneous value of the gap enters 6 of the equations, with the rest having 1 or 2 lags except for China (GDP based).[6] The F-tests indicate that the level of the gap, whether included contemporaneously or with lags, is a significant determinant of the change in inflation in all economies except China (national income based), India, and Thailand. For New Zealand and the GDP- based gap for China, the gap has a significant impact on the change in inflation but the sum of the estimated coefficients on the gap variables is negative, although in the case of New Zealand it is almost zero. The estimated elasticity of the change in inflation with respect to the gap is largest for Indonesia, Taiwan Province of China, and Korea, reflecting the relatively high rates of inflation compared to the small estimated output gaps for these economies. For the economies where the estimated coefficients are significant, the level of the output gap explains one-fourth to one-half of the total variance in the *change* in inflation over the sample period.

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[6]The estimated equations for China suffer from a number of problems. The GDP-based gap variable is available for 14 years, which only leaves about 7 degrees of freedom if 5 lags are included. The national-income-based gap variable, on the other hand, covers the pre-reform period when many prices where not market determined.

Table 2. Testing the GAP Model

	Lag length	*GAP* coefficients sum	*GAP* coefficients signs	F-test	R^2
A. *MODEL 1*					
Australia	1	1.231	++	5.092**	0.253
China - GDP	4	-4.344	+--+-	11.042**	0.917
- national income	0	0.484		2.739	0.081
Hong Kong	0	0.979		18.554**	0.382
India	0	0.156		0.061	0.002
Indonesia	2	10.713	+++	2.666*	0.229
Japan	2	0.570	++-	9.241**	0.498
Korea	1	3.497	++	6.506**	0.361
Malaysia	0	1.651		12.068**	0.365
New Zealand	2	-0.142	-+-	4.434**	0.322
Philippines	2	0.894	-+-	8.950**	0.499
Singapore	0	1.064		3.854*	0.111
Taiwan Province of China	1	6.069	++	8.829**	0.404
Thailand	0	1.017		1.051	0.033
B. *MODEL 2*					
Australia	1	0.617	-+	7.229**	0.325
China - GDP	5	-13.876	+-----	2.453	0.880
- national income	0	-0.021		0.009	0.000
Hong Kong	3	2.912	++++	9.174**	0.605
India	1	-0.846	--	1.524	0.098
Indonesia	0	1.056		0.411	0.013
Japan	1	1.402	++	13.950**	0.482
Korea	0	-0.756		2.721	0.098
Malaysia	0	1.044		11.226**	0.360
New Zealand	1	0.323	-+	7.077**	0.321
Philippines	1	2.415	-+	13.863**	0.489
Singapore	1	1.870	++	3.816**	0.208
Taiwan Province of China	1	3.443	++	7.726**	0.373
Thailand	0	0.399		0.381	0.012

** (*) indicates reject the null hypothesis that the gap variables jointly have no effect on the change in inflation at the 5 (10) percent significance level.

Except for China (GDP based), Japan, New Zealand, and the Philippines, there are either no lags on the gap variable or the signs of the estimated coefficients are all positive. This suggests that, based on our criterion for determining the number of lags in Model 1, the change in inflation is related to the level rather of the change in the output gap. For Japan and the Philippines, there are positive and negative estimated gap coefficients, but their sum is positive suggesting that both the level and the change in the output gap may be relevant. Estimation results with the constraints implied by Model 2 are presented in panel B of Table 2.[7] The estimated equations for Model 2 are nested in Model 1 for Korea, the Philippines, New Zealand, and Japan; an F-test rejects the constraints implied by Model 2 only for Korea.[8] Thus, for Japan, New Zealand, and the Philippines the data suggest that the change specification works as well as or better than Model 1. Indeed, for New Zealand the unconstrained estimation results for Model 1 are virtually identical to the constrained results for Model 2. For most of the other countries, either Model 1 or Model 2 appears to be broadly consistent with the data. There is no evidence that the change in the output gap is an important determinant of the change in inflation for China, India, or Thailand, which is consistent with the results obtained from Model 1.

We now extend Model 1 to allow the money supply and the terms of trade to have an impact on the change in inflation in addition to the level or the change in the output gap. In most inflation models, the money supply does not directly affect inflation, but instead has an indirect effect through the output gap. The money supply could, of course, affect inflation expectations and thereby have a direct impact on inflation over and above the effect of the output gap. Moreover, a measure of the money supply adjusted for secular movements in the velocity of money may be better able to explain inflation developments than the estimates of the output gap presented above. To test this, we construct a measure of the real money gap analogous to our measure of the output gap: $MGAP_t = 100(M2_t - M2_t^{TR})/(M2_t^{TR})$, where $M2$ is broad money from *International Financial Statistics* and $M2_t^{TR}$ is estimated by the same method used to estimate trend output. Adding this measure of the money gap to Model 1 gives:[9]

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[7]For Australia and New Zealand, the negative sign on the contemporaneous change in the output gap may reflect that the CPI contains a component that is directly related to mortgage interest rates. In this case, the initial effect of a tightening of monetary policy that raised interest rates and reduced actual output and the output gap could be an increase inflation.

[8]The models are nested only if the lags implied by the Schwarz information criterion in Model 2 are one less than the lags in Model 1, since the first difference specification of Model 2 incorporates a lag in each gap variable. Non-nested J-tests, which are discussed in Kennedy (1993) pp. 88-90, for Model 1 indicate that the change specification of Model 2 is not rejected for any country, while the same tests for Model 2 indicate that the level specification of Model 1 is rejected, albeit only marginally, for Australia and Hong Kong.

[9]The estimation results discussed below are largely unchanged if *MGAP* is defined instead as

(continued...)

$$MODEL\ 3: \qquad \Delta \pi_t = \alpha_3 + \sum_{i=0}^{\Upsilon} \beta_{3i} GAP_{t-i} + \sum_{i=0}^{\Upsilon} \gamma_{3i} MGAP_{t-i} + \epsilon_{3t}$$

We use the same procedure to select lag lengths, but constrain both the output and the money gap measures to enter with the same number of lags.

The estimation results for Model 3 are presented in Table 3.[10] The most striking result is for India, where the levels of both the output gap and the money gap are very significant determinants of the change in inflation, explaining fully two-thirds of the variance of the change in inflation. This is in sharp contrast to Model 1 where the output gap alone was not significant and explained virtually nothing. The level of the money gap is also important in

Table 3. Testing the GAP Model with Money

	Lag length	*GAP* coefficients sum	*GAP* coefficients F-test	*MGAP* coefficients sum	*MGAP* coefficients F-test	Model F-test	Model R^2
MODEL 3							
Australia	1	1.269	4.485**	-0.134	0.219	2.523*	0.265
Hong Kong	1	0.929	7.455**	-0.710	5.295**	8.583**	0.569
India	2	2.286	3.400**	4.051	12.406**	7.862**	0.672
Indonesia	1	1.858	2.557*	1.468	1.676	2.498*	0.312
Japan	2	0.455	7.445**	-0.044	0.707	4.829**	0.537
Korea	1	3.327	4.977**	0.362	0.101	3.049**	0.367
Malaysia	0	1.598	9.808**	0.092	0.117	5.838**	0.369
New Zealand	2	-0.046	7.113**	0.384	4.852**	5.558**	0.572
Philippines	2	0.608	3.341**	-0.728	0.829	4.804**	0.546
Singapore	0	1.163	4.329**	-0.437	1.091	2.424*	0.143
Taiwan Province of China	1	7.552	10.529**	-1.175	1.637	5.450**	0.476
Thailand	0	0.826	0.666	0.565	0.973	1.012	0.063

** (*) indicates reject the null hypothesis that the gap variables jointly have no effect on the change in inflation at the 5 (10) percent significance level.

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[9](...continued)
the difference between the growth of the money supply and the growth of its trend.

[10]We do not report results for China for the reasons noted in a previous footnote.

Hong Kong, but with a negative sign, and in New Zealand. For the other economies, adding the money gap makes little difference to the significance or size of the estimated coefficients on the output gap compared with Model 1 except for Indonesia where the estimated coefficient is substantially smaller. There is no evidence that either measure of the output or the money gap is a significant determinant of the change in inflation in Thailand.

We also estimated the gap model with the percent change in the terms of trade included in addition to the output and money gap variables. This allows, for example, commodity price shocks or exchange rate changes to have direct effects on inflation. In general, the terms of trade variable was not significant and had little impact on the size or significance at the gap variable. The exceptions were Korea and Japan, where terms of trade growth was significant (for Korea, the output gap became insignificant) when added to Models 1 and 2; and Japan and New Zealand where terms of trade growth was significant when added to Model 3 (for New Zealand the output gap became insignificant).

Diagnostic tests indicate that the residuals from the regressions in Models 1-3 are essentially white noise, suggesting the absence of significant specification errors. Both the Breusch-Godfrey test for autoregressive errors and the Engle test for autoregressive conditional heteroskedasticity were not significant at the 5 percent level for any country in any of the three models. The Breusch-Pagan test for heteroskedasticity was significant at the 5 percent level in all models for Taiwan Province of China and in Model 2 for Indonesia.[11]

In summary, the estimation results indicate that the output gap is an important determinant of the change in inflation for all of the economies in our sample except China and Thailand. For China, the failure of the gap model may reflect the relatively few observations since the implementation of economic reforms; for Thailand, the failure of the gap model partly reflects that output has grown so steadily since the mid-1970s that the estimated gap is very close to zero for much of the sample period (cf. Figure 1). For the other economies, Model explains an average of 34 percent of the variance of the change in inflation over the full sample period; while for India, Model 3, which includes a measure of the money gap, explains 67 percent. Given that the dependent variable is the second difference of the price level, the goodness of fit of the estimated equations is relatively high. Figure 2 presents the actual and predicted change in inflation for the most recent five years based on our estimates of Model 1 and, in the case of India, Model 3. Although the estimated gap models do a pretty good job of predicting the change in inflation for some economies, there are a number of examples where they perform poorly. Other factors, including changes in indirect taxes, import prices, as well as random shocks, are also important, and in many cases more important than the output gap.

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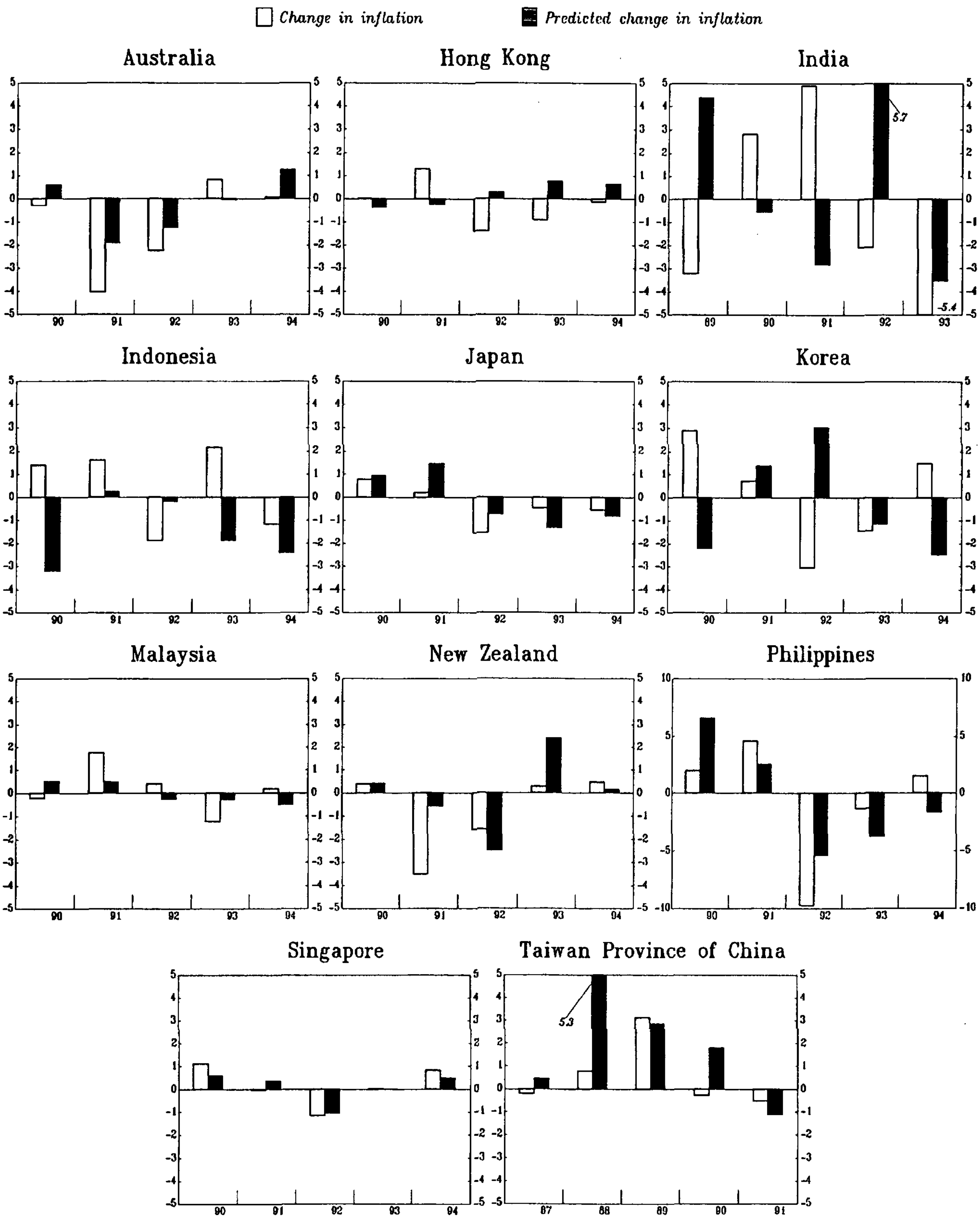
[11]Engle (1984) discusses these and other diagnostic tests. When the Indonesian sample was restricted to exclude the inflationary period of the 1960s, the tests for heteroskedasticity were no longer significant while the tests for the significance of the estimated coefficients on the output and money gap variables were unchanged.

Figure 2. Actual and Predicted Changes in Inflation

(In percentage points)



The predicted change in inflation is based on Model 1 except for India, which is based on Model 3.

IV. Conclusions

Double-digit rates of growth are not uncommon in Asia. The fact that some rapidly growing economies, such as Singapore, Taiwan Province of China, and Thailand, have been able to sustain high rates of growth while keeping inflation relatatively low, while others have experienced relatively high rates of inflation, raises the question of the relevance of the gap model for Asia. To answer this question as neutrally as possible, we have presented a new procedure to estimate trend output that allows the data to determine the degree of smoothing rather than requiring the researcher to specify this arbitrarily. We then used the output gaps implied by the estimated trends to test a number of versions of the gap model. As discussed in the Appendix, the output gaps implied by our estimates of trend output generally perform better than estimates based on a Hodrick-Prescott filter.

The answer to the question posed in the title to the paper is clear: the gap model works very well in almost all Asian economies. The output gap is a significant determinant of the change in inflation in 11 of the 13 economies we study. The only exceptions are Thailand and China, where there is no evidence that our estimate of the output gap has any impact on the change in inflation. In India, the output gap is an important determinant of the change in inflation when included with a measure of the broad money gap. In New Zealand, the change in inflation is more closely related to the change in the output gap than to the level of the output gap; both the level of and the change in the output gap appear to be important in a number of countries, including Japan and the Philippines. For most economies, the output gap remains a significant determinant of inflation when other determinants of inflation, such as changes in the money supply or in the terms of trade, are also included in the estimated equations.

There are a number of obvious and closely related policy implications. The first is that accelerating prices are, in general, an indication of an overheating economy. The second implication is that reductions in inflation will generally require the implementation of restrictive macroeconomic policies that temporarily reduce the growth of real output. Although the gap model generally does a relatively good job of explaining changes in inflation, it is clear that other factors such as changes in indirect taxes and random stocks are also important. Moreover, estimates of the output gap are inevitably most uncertain for the most recent period. Thus, a third implication is that while estimates of the output gap can be a useful tool for policy analysis, they need to be used in conjunction with other indicators and analyses for practical policy implementation purposes. In this regard, the developing, newly industrializing, and industrial economies of Asia are not different from the industrial countries of North America and western Europe.

Appendix: A Nonparametric Regression Method for Estimating Trends and Gaps

This appendix outlines a new nonparametric regression estimation method to estimate output trends and output gaps without the need to specify the functional form of the trend in the underlying output series or the degree of smoothing applied to the data.[12] A GAUSS program to implement the method is available from *cmcdermott@imf.org*.

The estimation is performed in the spirit of the classical decomposition that splits output into two components, trend output and an output gap, denoted by

$$y_t = m(t) + y_t^*$$

where y_t is output, $m(t)$ is trend output, t is a time trend, and y_t^* is the output gap. A typical method of estimating the function $m(t)$ is to regress output on a known parametric form such as $\beta_0+\beta_1 t$. However, modeling trends in economic data often requires more complex functions, usually involving higher order polynomials. The aim of nonparametric regression estimation of $m(t)$ is to approximate an unknown trend function arbitrarily closely, given a large enough sample. It is not necessary to specify the functional form of $m(t)$, although it is necessary to assume that the trend has an adequate number of derivatives so that it is smooth relative to y_t^*. Consequently, using nonparametric regression to estimate $m(t)$ allows truly flexible functional forms to be considered.

There are a large number of nonparametric regression estimates. We use the Nadaraya-Watson estimator $\hat{m}_h(t)$ of $m(t)$ which has the form

$$\hat{m}_h(x) = \frac{T^{-1}\sum_{t=1}^{T} K_h(x-t/T)y_t}{T^{-1}\sum_{t=1}^{T} K_h(x-t/T)}$$

where $K_h(u)=h^{-1}K(u/h)$, h is the bandwidth parameter, T is the sample size, and $K(u)$ is a kernel with support [-1,1] that satisfies $\int K(u)\,du = 1$. The bandwidth parameter determines the size of the data "window" used to calculate the smoothed trend series while the kernel determines the distribution of the weights, which can be thought of as the shape of the data window. For a simple moving average, the shape of the kernel is rectangular. We use the Epanechnikov kernel, defined as

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[12] Although the nonparametric regression literature is dominated by asymptotic theory results, nonparametric regression have been used to estimate consumption and production functions, Phillips curves, and forecasting equations for exchange rates and stock market returns; see Härdle (1990) and Ullah and Vinod (1993).

$$K(u) = 0.75(1-u^2)I(|u| \leq 1)$$

where $I(|u| \leq 1)$ is the indicator function. This is a commonly used parabolic shaped kernel function that minimizes the mean squared error of all twice-differentiable functions m. In practice the choice of kernel is not critical since the mean squared error properties of alternative kernals are almost identical. For example, the Epanechnikov kernel is only 6 percent more efficient than the rectangular shaped kernel.

The accuracy of kernel smoothers as estimators of m is a function of the kernel K and the bandwidth h, with the latter being the most important. We use a data dependent bandwidth selection procedure that minimizes quadratic error measures for the regression. There are three main types of such procedures: (i) cross-validation, (ii) penalizing functions, and (iii) plug-in methods. The first two methods are asymptotically optimal in the sense that they minimize mean squared errors without reference to the smoothness of m, although in practice all three methods yield similar estimates of h for a given data set. We use the cross-validation or leave-out method, which is based on regression smoothers in which one, say the jth, observation is left-out

$$\hat{m}_{h,j}(j) = T^{-1}\sum_{t \neq j} W_{ht}(j)y_t$$

where $W_{ht}(x) = K_h(x - t/T)/[T^{-1}\sum_{t=1}^{T} K_h(x - t/T)]$. With these modified smoothers, we define the cross-validation function

$$CV(h) = T^{-1}\sum_{j=1}^{T} [Y_j - \hat{m}_{h,j}(j)]^2$$

The cross-validation function is constructed over a dense grid of h values, with h chosen such that this function is at the minimum. This is called the least squares cross-validation estimate of h. This method validates the ability to predict $\{y_j\}_{j=1}^{T}$ across the subsamples $\{(t, y_t)\}_{t \neq j}$.

The procedure outlined above is very similar to the Hodrick-Prescott (HP) filter. The HP filter is based on an adjusted least squares method, where the adjustment is based on a roughness penalty. Formally the HP filter is the solution to the following minimization problem

$$min_g \sum_{t=1}^{T} (y_t - g(t))^2 + \lambda \int g''(x)^2 \, dx$$

where *g(t)* is trend output and λ denotes a smoothing parameter. The smoothing parameter λ represents the rate of exchange between residual error and roughness of the curve g, where the roughness is measured by the term $\int g''(x)^2\, dx$. Silverman (1984) shows that there is an equivalence between such a filter and a kernel smoother with the kernel defined as

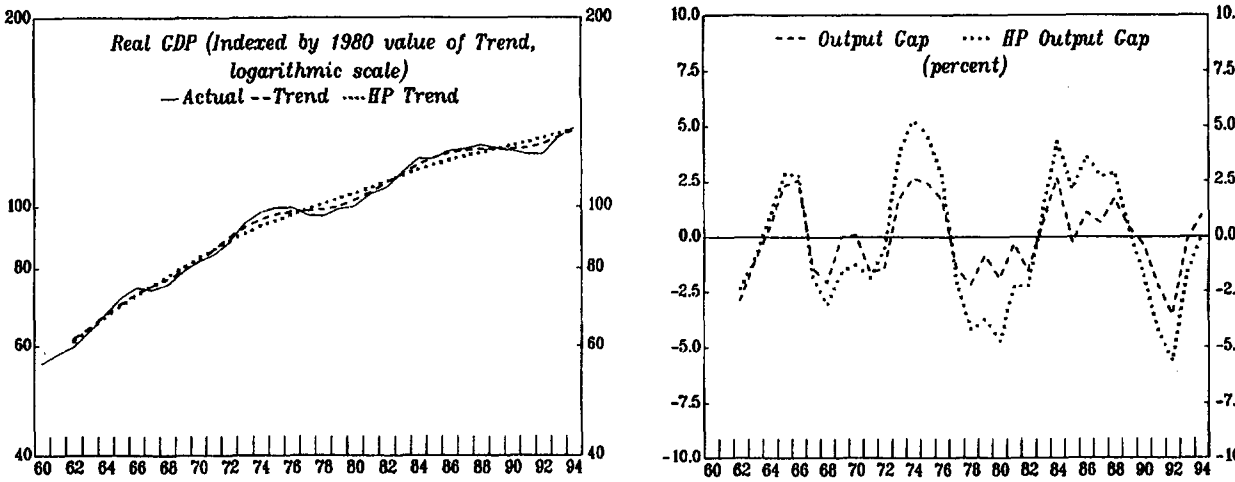
$$k(u) = 0.5 exp\left(\frac{-|u|}{\sqrt{2}}\right) sin\left(\frac{-|u|}{\sqrt{2}} + \frac{\pi}{4}\right)$$

The effective bandwidth or "window" size in the HP filter varies in relation to the curvature of trend output, unlike the fixed bandwidth of the kernel smoother.

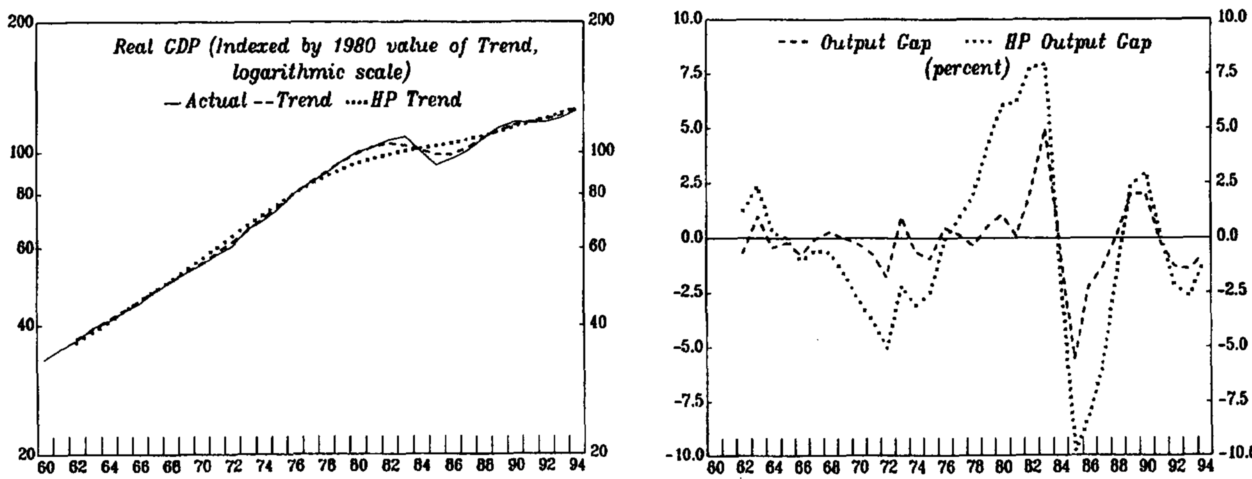
The estimated trends from the nonparametric regression method are compared to the estimated trends from the HP filter in Figure 3 for New Zealand, the Philippines, and Singapore. Compared with the nonparametric kernel smoother, the HP filter results in smoother trends and correspondingly more volatile output gaps . When the HP-based output gap is used in Model 1 in place of the kernel smoother, the size of the estimated coefficients on the HP-based output gap variables is smaller due to the larger swings in the output gaps. In addition, more lags are required on the gap variables because of higher levels of serial correlation in the residuals. Even with the additional lags, however, the model's explanatory power does not increase and diagnostic tests showed significant serial correlation problems for a number of countries. These results suggest that estimated trends and output gaps based on the nonparametric kernel smoother do a better job of explaining inflation developments than do estimates based on the Hodrick-Prescott filter.

Figure 3. Output Gaps

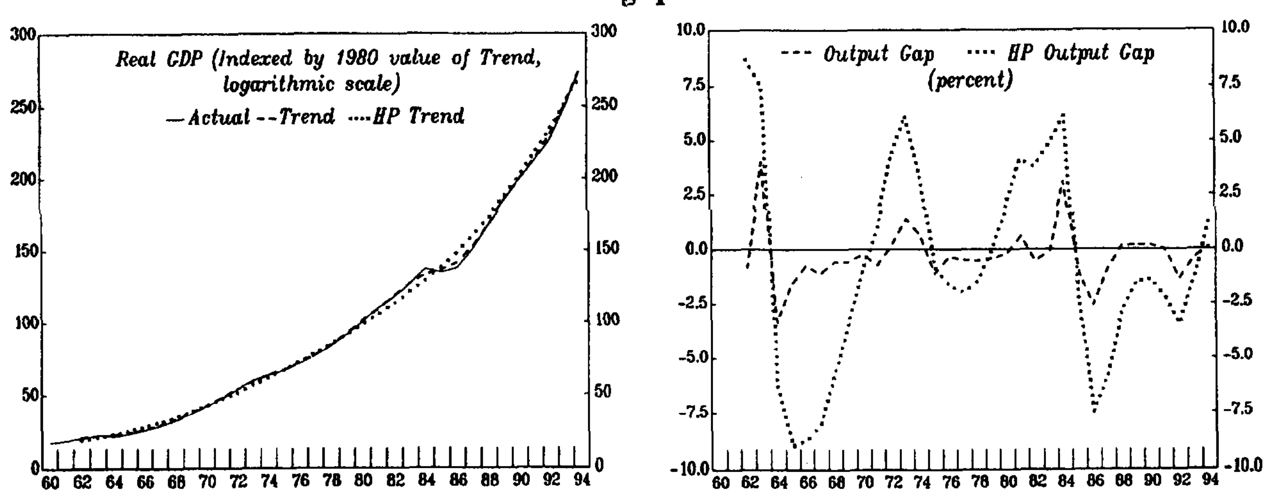
New Zealand



Philippines



Singapore



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