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## An Investigation of Output Variance Before and During Inflation Targeting

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## An Investigation of Output Variance Before and During Inflation Targeting

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## Abstract



Since Taylor estimated a trade-off between inflation and output variance, it has been widely accepted that efforts to keep the inflation rate "too low and stable" will likely result in relatively larger output fluctuations. Following the generalized reduction in inflation variance in the 1990s, that concern was rekindled. This study estimates whether conditional output variance has changed in a sample of 12 countries. With the possible exception of Canada, there is no evidence of an increase in output variance. Either output variance has not changed (i.e., in Korea and Singapore) or has fallen (i.e., in Australia and New Zealand).

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# I. Introduction

In 1979, Taylor argued that while there is no *long-run* trade-off between inflation and output average *levels*, there is a long-run trade-off between inflation and output *variance*. Taylor (1994) explained the rationale for this trade-off in an intuitive way. The discussion was cast, however, in terms of the variance of inflation and the variance of *short-run* divergences of output from potential (henceforth, output variance will refer to the variance of output around its potential). The inflation/output variance trade-off implies that efforts to keep the inflation rate "too low and stable" will result in relatively larger output and employment fluctuations. Since Taylor's seminal work, a myriad of papers has addressed the inflation/output variance trade-off both theoretically and empirically, and a consensus seems to have been reached, at least among central bankers, on the existence of a short-run inflation/output trade-off.[2]

In the 1990s, central banks in many countries moved away from conducting monetary policy on the basis of intermediate targets, such as the growth of monetary aggregates or exchange rates, and embraced some form of inflation targeting. This monetary policy change has been accompanied by a reduction in inflation and inflation variance.[3] The reduction in inflation and inflation variance, however, seems more generalized as it has also been observed in other countries that have not explicitly adopted inflation targeting frameworks.[4] Given the apparent generality of the phenomenon, figures 1 and 2 show 4-year moving average standard deviations of CPI inflation between 1975 and 2000 in six non-inflation targeters and six inflation targeters.[5] As a result, and mindful of Taylor's trade-off, some observers have argued against trying to stabilize inflation "too much." They have been influential in the formulation and implementation of monetary policy as well as in the design of monetary policy frameworks (e.g., Svensson, 2000 and 2001). The inflation/output trade-off seems particularly relevant for inflation targeting countries as a key characteristic of inflation targeting frameworks is the need to decide on the level and the variance of inflation that are going to be targeted (Leiderman and Svensson, 1995). In general, the level of targeted inflation as well as its variance (often reflected by a band around the target level of inflation) have been lower than their historical values.[6]

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[2] For a summary of the discussion on the trade-off, see Clarida et al (1999).

[3] The mean and the variance of inflation are positively correlated because the distribution of price changes tends to be non-normal.

[4] This observation has prompted some observers to downplay the role of inflation targeting frameworks in reducing inflation (e.g., Dueker and Fischer, 1996, and Lee, 1999). For an alternative interpretation, see Nadal-De Simone (2001).

[5] Three-year moving average standard deviations convey the same impression.

[6] Chile, for instance, has been targeting inflation since 1991. In the period through 2000, the central bank targeted a declining end-year annual inflation level, and in 2001 started targeting

(continued)

This paper does not try to estimate the short-run trade-off between inflation and output variance. Instead, departing from the observation that inflation variance has fallen in the last decade in many countries, it starts shedding some light into the issue of whether that fall in inflation variance has been accompanied by an increase in output variance. The evidence on output variance can inform the debate on the actual effect of reducing inflation variance because it refers to a range of countries that are quite different in terms of their economic structure, the shocks to which they are exposed, and the approaches they have followed to achieve their inflation objectives. Given the decade-long experience with inflation targeting, this evidence should matter for the design of monetary policy frameworks. This empirical evidence can also provide a starting point for stochastic simulations of output behavior at relatively lower levels and variances of inflation.

Therefore, this study estimates output conditional variance for a sample of six non-inflation targeters and six inflation targeters during the period 1976-2000. It uses a set of time-varying parameter models that allow for the variance of the shock to the cyclical component (and also to the trend component) of output to depend on the state of the economy. The main conclusion is that there is some evidence that the decline in inflation variance has not been accompanied by an increase in output variance, with the possible exception of Canada. Either output variance in the 1990s has not changed (i.e., Korea and Singapore) or has fallen (i.e., in Australia and New Zealand).

Next section discusses some methodological issues and the models of output behavior estimated. Section III describes the data used and discusses the results of the estimations. Section IV concludes the paper.

## II. The Models of Output Behavior

At least three major methodological problems have to be tackled in studying the behavior of output. First, we need a model to describe the interaction between nominal and real variables; however, there is no agreement in the profession on this issue.[7] Second, we need to account for the transition between policy regimes (an issue virtually ignored in the literature). Third, we need to allow for the possibility that the shift to an inflation-targeting regime or structural changes in some countries in the sample alter the trade-off between inflation and output variability.

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inflation within a band of 2 to 4 percent as measured by the CPI (this compares with an average inflation of about 38 percent in the 1970s and about 21 percent in the 1980s). The level and the width of the band recognize, among other factors, the short-run downward rigidity of prices, and an implied short-run inflation/output variance trade-off (Banco Central de Chile, 2000).

[7] See McCallum (1997). On the other hand, agreement among modelers is quite often not matched by sufficient attention to how well the models fit the data (Sims, 2001).

To deal with the first problem, we will consider two alternative models of real output behavior. The first one is a model proposed by Friedman (1964, 1993) and based on the empirical regularity already observed by Keynes (1936). Observing real output behavior, Keynes noted that: "the substitution of a downward for an upward tendency often takes place suddenly and violently, whereas there is, as a rule, no such sharp turning point when an upward is substituted for a downward tendency." In a related observation, Friedman argued that the amplitude of a real output contraction is strongly correlated with the succeeding expansion but the amplitude of an expansion is not correlated with the amplitude of the succeeding contraction. Moreover, he observed that output could not exceed a ceiling level determined by the resources and the technology available to the economy but that occasionally output is plucked downward by a recession. Those two regularities are referred to henceforth as Friedman's "plucking model."[8] They imply that real output fluctuations are asymmetric and recessions are transitory.[9] The second, alternative, model of output behavior is a restricted version of the first model, assuming constant output variance (both for the trend and the cyclical components) in normal times and in recessions.

Business cycle asymmetries such as the one suggested by Keynes and Friedman have been studied in the literature (e.g., Neftcy, 1984, Hamilton, 1989, DeLong and Summers, 1986, Sichel, 1993, Diebold, Rudebusch and Sichel, 1994, Razzak, 2001). Goodwin and Sweeney (1993) apply Friedman's correlation method to a set of eight OECD countries. They find that although there is weak support for the asymmetry hypothesis, there is substantial support for the proposal that the output ceiling plays a major role in business cycle fluctuations. Recently, Kim and Nelson (1999) estimated formally for the first time the importance of downward shocks and tested successfully Friedman's plucking hypothesis for the United States.

The second issue is that, with few exceptions, the empirical literature assumes that economic agents learn about the new regime immediately, thus ignoring that there is a period of transition between policy regimes (Clarida et al, 1999). Studies usually assume that there is no parameter uncertainty, and/or uncertainty about the distribution of future random shocks. As a result, output losses that normally accompany a disinflation period (i.e., a transition) under conditions of imperfect credibility tend to be confused with the eventual output losses that result from the inflation/output trade-off once the regime has been in place for a "long period of time."[10]

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[8] The model is different from real business cycle models in that output shocks in the latter are always permanent.

[9] There is a thriving literature that looks at the problem from the employment viewpoint. For example, Caballero and Hammour (1994) find that job destruction is more cyclically responsive than job creation, and that while job creation is symmetric around its mean, job destruction is highly asymmetric. This may suggest that the output behavior asymmetries noted by Friedman are smoothed out through the asymmetry in the job creation process.

[10] This concept is taken from Sargent (1987), chapter XVII.

To allow for the possibility that parameters change, this study will use time-varying parameters (to capture the learning process of economic agents).[11] It will also allow for changes both in the conditional and in the unconditional variance of output so that shocks to output may have different variance depending on what state the economy is when the shock occurs (Kim 1993a and 1993b). It is expected that this approach will help reduce the importance of a precise determination of the starting date of inflation targeting regimes (and also take account of structural changes that occurred in several countries during the sample period).

Finally, as pointed out by Cecchetti and Ehrman (2000), if the trade-off (frontier) between inflation and output variability is stable, a move to inflation targeting would be a move along that trade-off line to a point where inflation is less variable but output is more variable. However, it is also possible that a shift to an inflation-targeting framework acts as a commitment device and, via increasing the credibility of policymakers, help to achieve both *lower inflation variance and lower output variance.*[12] If the trade-off is stable, time-varying parameter models are not necessary; if the trade-off is instead unstable, time-varying parameter models become one way of taking care of that instability.

This study will proceed in two steps. First, Friedman's model of the business cycle will be estimated for 12 countries, six of which started implementing some form of inflation targeting during the 1990s. Second, a restricted version of the plucking model that assumes a constant output variance in normal times and in recession will also be estimated. The models will be used to explore the behavior of output variance before and during inflation targeting. Comparisons across countries as well as over time for the same country will be made.

Consider the unobserved components model of the log of real GDP $(y_t)$. Fluctuations of $y_t$ are decomposed into a trend component $(T_t)$ and cyclical component $(C_t)$:

$$y_t = T_t + C_t. \tag{1}$$

Friedman (1993) suggested that the potential output (the "ceiling maximum feasible output") could be approximated by a random walk with all sorts of disturbances including the technological disturbances:

$$T_t = g_t + T_{t-1} + v_t \tag{2}$$

[11] Wong (2000) found that the response of output and the price level to monetary shocks was quite variable in the U.S. in the sample period 1959:1-1994:12 and suggests using time-varying parameter models to study the effects of monetary policy on output and prices.

[12] Section 4.2.2 in Clarida et al (1999) suggests this point. See also Bernanke and Mishkin (1997).

$$g_t = g_{t-1} + w_t \qquad (3)$$
$$w_t \sim N(0, \sigma_w^2) \qquad (4)$$
$$v_t \sim N\left(0, \sigma^2{}_{v,S_t}\right) \qquad (5)$$
$$\sigma_{v,S_t}^2 = \sigma_{v0}^2(1 - S_t) + \sigma_{v1}^2 S_t \qquad (6)$$
$$S_t = 0 \text{ or } 1, \qquad (7)$$

where the stochastic trend component $T_t$ is subject to two kinds of shocks: shocks to its level $v_t$, and shocks to its growth rate $w_t$. Thus, equations (2)–(3) allow for productivity shocks.

Equations (5)–(6) allow for the possibility that the variance of shocks to the level of $y_t$ be different depending on whether the economy is in normal times ($S_t = 0$) or in recession times ($S_t = 1$) (equation 7). To account for that, $S_t$ is assumed to evolve according to a first-order Markov process:

$$P_r\left[S_t = 1 \middle| S_{t-1} = 1\right] = p \qquad (8)$$
$$P_r\left[S_t = 0 \middle| S_{t-1} = 0\right] = q. \qquad (9)$$

$S_t$ depends on its previous state.

To allow for asymmetric deviations of $y_t$ from its trend, the cyclical component is assumed to be subject to two types of shocks:

$$C_t = \theta_1 C_{t-1} + \theta_2 C_{t-2} + u_t^* \qquad (10)$$
$$u_t^* = \pi_{s_t} + u_t \qquad (11)$$
$$\pi_{s_t} = \pi S_t, \pi < 0 \qquad (12)$$
$$u_t \sim N\left(0, \sigma^2{}_{u,S_t}\right) \qquad (13)$$
$$\sigma_{u,S_t}^2 = \sigma_{u0}^2(1 - S_t) + \sigma_{u1}^2 S_t, \qquad (14)$$

where $\pi_t$ is an asymmetric, discrete shock, which depends upon the unobserved variable $S_t$, and $u_t$ is the usual symmetric shock. During normal times $S_t = 0$, and so $\pi_{S_t} = 0$; therefore, the economy is near its potential or trend output. During the recession times, $S_t = 1$, and the economy is hit by a transitory negative shock $(\pi_{s_t} = \pi < 0)$. Temporary disturbances are plucking down real GDP. Equations (13) and (14) allow for the possibility that the variance of the symmetric shock $u_t$ is different during the normal and the recession times.

The model of output behavior usually used the literature views economic fluctuations as symmetric movements around a stochastic trend. One model of that kind is Clark's (1987), which is a restricted version of the plucking model, the restrictions being $\pi = 0, \sigma^2_{v0} = \sigma^2_{v1}$, and $\sigma^2_{u0} = \sigma^2_{u1}$. Both the unrestricted plucking model as well as its restricted (Clark's) version will be estimated.

## III. Data Analysis and Estimation Results

### A. Data Analysis

The non-inflation targeting countries considered in this study are: two large economies (the United States and Japan); two economies that are part of the European Union (France and the Netherlands), and two small open economies (Korea and Singapore). The set of countries that started introducing inflation-targeting in the 1990s (and for which there are enough data points to allow a reasonable econometric analysis) comprises Australia, Canada, Chile, New Zealand, Sweden, and the United Kingdom.[13] Although some debate surrounds the date in which those countries adopted inflation targeting, it can be said that New Zealand adopted an inflation targeting framework in 1990, and Canada in 1991. Chile started announcing decreasing annual inflation targets in 1991, and adopted an inflation-targeting framework in 2000. The United Kingdom adopted an inflation targeting framework in 1992, and Australia and Sweden in 1993.

The quarterly real GDP data are from International Financial Statistics (IFS) for all countries except Japan, New Zealand, and Singapore, for which national sources were used due to significant differences between them and IFS. The sample lengths (see column 2 of table 1) depend on the availability of data for each country. The data used in the estimations are in natural logarithms. The seasonal component of all the series was removed using X-11.

The series were tested for the presence of unit roots using the modified Dickey-Fuller t-test ($DFGLS^{\tau}$) proposed by Elliott, Rothenberg, and Stock (1996), a point-optimal invariant test which has a substantially improved power when an unknown mean or trend is present in the data.[14] Table 1 shows that the null of a unit root with a constant and a linear trend cannot be

[13] The list of countries that currently have some form of inflation targeting also includes the Czech Republic, Poland, Israel, South Africa, and Brazil, but they have not been considered in this study because they all started inflation targeting after 1998 (see e.g., Schaechter et al, 2000). Spain and Finland did inflation-targeting during the early 1990s, but they abandoned it to join the European Union.

[14] The lags used in the unit-root tests are chosen using the Schwarz Information Criterion and checking that the residuals are white noise using the Box and Pierce Q statistics.

rejected for any country with the exception of Singapore.[15] Real GDP changes for all countries are stationary.

## B. Estimation Results

The plucking model and Clark's model were formulated in state-space form and estimated using Kim's approximate maximum likelihood estimator (Kim, 1994) based on the prediction error decomposition produced by a Kalman filter. The only restrictions used in estimating the plucking model were that the probability values "p" and "q" lie between 0 and 1, and that the variances are positive; Clark's model was estimated with the restriction that the variances are positive.

Tables 2.1 and 2.2 present the estimation results for the whole sample period.[16] Coefficients significant at the 95 percent confidence level carry an asterisk and those significant at the 90 percent confidence level carry two asterisks. A number of features are worth noticing. First, the likelihood ratio tests (LR) at the bottom of table 2.2 for the hypotheses that $\pi = 0, \sigma^2_{v0} = \sigma^2_{v1}$, and $\sigma^2_{u0} = \sigma^2_{u1}$ reject them at the 99 percent confidence level for most countries (97.5 percent for France and 95 percent for Canada). The restrictions taken together are not statistically significant only for Chile.

Second, with the exception of Canada, Korea, New Zealand, and Singapore, the sum of the autoregressive coefficients for the transitory component of output falls when asymmetry is accounted for, i.e., the sum of the autoregressive coefficients $\theta_1$ and $\theta_2$ (see equation (10)) tends to be lower in the plucking model than in Clark's model (as Kim and Nelson, 1999, found for the United States). This has the important practical implication that output shocks could be erroneously considered as permanent (or persistent) when estimated output behavior is restricted to be symmetric when in fact it is asymmetric.[17]

Third, the transitory cyclical component of the plucking model is affected by an asymmetric discrete shock $\pi_{St}$ and a symmetric continuous shock $u_t$. The asymmetric shock is significant for Canada, Chile, Korea, the United Kingdom, and the United States.[18] It is negative,

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[15] For Singapore, the Phillips-Perron test with a constant and a trend was also run. As the test did not reject the null of unit root, the country was kept in the sample.

[16] Estimation results for the sample restricted to 1990:4 are available upon request.

[17] This tends to validate Perron's (1990) claim that standard unit root tests are biased toward nonrejection of the null of a unit root when the data generating process is stationary with a switching mean.

[18] The estimated coefficient for the United States is very similar to the result of Kim and Nelson (1999).

as expected, whenever it is significantly different from zero, except for the United Kingdom.[19] For those countries, the data seem to confirm Friedman's view that the economy is most of the time at potential, and it is plucked down from time to time.[20] Except for Korea, the asymmetric discrete shock $\pi_{St}$ to the transitory part of output seems to be more important than the symmetric shock $u_t$. At least one component of the symmetric variance of the transitory component is significant except for the Netherlands, New Zealand, United Kingdom, and the United States. Finally, the variance of the transitory component associated with recession times ($\sigma^2_{u1}$) was smaller than the variance of the transitory component associated with the normal times ($\sigma^2_{u0}$) more frequently within the sample.

Once a negative transitory shock hits the economy, its effects decay relatively fast with the exception of Canada and possibly Singapore (as Kim and Nelson, 1999, found for the United States). This is indicated by relatively low values for the sum of the estimated parameters $\theta_1$ and $\theta_2$ for all other countries.

Fourth, with the sole exception of Japan, all economies are affected by significant shocks to their trend components, either during normal times, $\sigma^2_{v0}$, or during recessions times, $\sigma^2_{v1}$. In contrast to the variance of shocks to the cyclical component of output, there is no obvious pattern in terms of the relative importance of the variance of shocks to output trend in normal times and in recession times.

Finally, there does not seem to be a pattern in the influence of accounting for asymmetry on the significance of the variance of the shock to the trend growth component $\sigma^2_w$. The shock to the trend growth component becomes statistically significant when asymmetry is taken into account for France and the United States. The variance of the shock to the trend growth component is significant in both models for Chile, Japan, the Netherlands, and the United Kingdom (it is not significant in all other cases). As Kim and Nelson (1999) found for the United States, however, the variance is always a small value.[21]

Tests for serial correlation of the forecast errors and squared forecast errors for the whole sample are presented in tables 3.1 and 3.3 for the plucking model and Clark's model, respectively; the tests for the sample restricted to 1990:4 are presented in tables 3.2 and 3.4. Adopting a conservative stance in model selection, the tests for serial correlation suggest that the plucking model is a good representation of Canadian output behavior and that Clark's model is

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[19] It is not immediately obvious how to interpret the results for the United Kingdom.

[20] The Kalman filter estimates of potential output are available upon request.

[21] Technically speaking, the plucking model and Clark's model require that real GDP be I(2). However, if the variance of the shock to the trend growth component is not statistically different from zero or it is very small, this should not pose a major misspecification problem. The models were not estimated restricting growth to have zero variance.

instead a good representation of output behavior for Australia, Korea, New Zealand, and less so for Singapore.[22] In what follows, tests that compare output variance estimates between the whole sample period and the sample restricted to 1990:4 will refer only to those countries for which either the plucking model or Clark's model are a reasonable representation of the data, Canada for the former and Australia, Korea, New Zealand, and Singapore for the latter.

The comparison of output variance using the plucking model before and also during inflation targeting in Canada can be done using the results of table 4. The table shows the estimates of the output variance associated with the *transitory symmetric components* $\sigma^2_{u0}, \sigma^2_{u1}$ for the whole sample period and for the sample period restricted up to 1990:4. It also shows the estimated *asymmetric component* $\pi$. The F tests indicate that the inclusion of the 1990s produces a significant increase in the estimated Canadian output variance which results from the symmetric component. This is associated with normal times, however, and not with periods of recession induced, say, by the disinflation policy required to reach lower inflation rates and inflation variances.[23]

Table 5 reports the results of the estimates of Clark's model for the whole sample period and for the sample restricted up to 1990:4. The F tests indicate that the inclusion of the 1990s produces a significant fall in the estimated output variance for Australia and New Zealand, while the estimated output variance is not statistically different for Korea and Singapore. Given the good fit of Clark's model of output for Australia and New Zealand (including the absence of serial correlation), there is some evidence that the reduction in inflation variance in both countries during the 1990s was not associated with an increase in output conditional variance.

## IV. Conclusions

The objective of this study is to investigate the behavior of the conditional variance of output fluctuations around its potential level. The sample of countries comprises six countries that do not do inflation targeting and six countries that introduced inflation targeting during the 1990s. The sample period varies across countries depending on data availability.

Two models of output behavior are estimated: 1) Friedman's plucking model, and 2) Clark's model. The plucking model assumes that output cannot exceed a ceiling level determined by the resources and the technology available to the economy but that occasionally output is plucked downward by a recession. The model allows for asymmetric shocks to the trend

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[22] Estimates of the plucking model with the restriction that $\sigma_{u0} = \sigma_{u1}$ did not reduced serial correlation. Results are available upon request.

[23] The variance of the *trend component* of Canadian output associated with normal times is also higher in the whole sample than in the restricted sample. Results are available upon request.

component and to the cyclical component of output. Clark's model is a restricted version of the plucking model in which it is assumed that there is no asymmetry in output behavior either in its trend component or in its cyclical component. Both models of output are put in state-space form and are estimated using the Kalman filter.

The plucking model fits the data well for Canada. Clark's model is a good representation of the data for Australia, Korea, New Zealand, and less so for Singapore. Taking only those countries into account, it seems difficult to argue that when unconditional inflation variance fell in the 1990s, there was a corresponding significant increase in conditional output variance. The plucking model estimates a significant increase in conditional output variance for Canada, but this is associated with normal rather than with recession times. On these grounds, it seems difficult to identify an inflation/output variance trade-off in the usual sense of the concept.

According to Clark's model, there was a significant *fall* in the estimated conditional variance of output in two countries, i.e., Australia and New Zealand. In Korea and Singapore, the estimated variances were not statistically different in the whole sample and in the sample estimated up to 1990:4. Given the good fit of Clark's model of output for Australia and New Zealand, there is some evidence that the reduction in inflation variance in both countries during the 1990s was not associated with an increase in output variance.

As suggested by Cecchetti and Ehrman (2000), it may very well be that a growing and widespread concern for price stability (within which to inscribe the adoption of inflation targeting frameworks by several countries) has moved economies to a combination of both lower inflation variance and lower, or similar, output variance than in the past. Alternatively, it is also possible that there has been less cost-push inflation during the late 1980s and the 1990s such that the reduction in inflation has not been in general accompanied by an increase in output variance.[24]

A natural extension of this research would involve analyzing the structure of serial correlation in the standardized forecast errors so as to extend the plucking model or Clark's model to account for that feature. Also, a simultaneous estimation of inflation and output variance would be useful to increase the robustness of the results presented in this study.

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[24] Clarida et al (1999) show that under discretionary monetary policy, there is a short-run trade-off between inflation and output variability to the extent that cost-push inflation is present. This result was originally emphasized by Taylor (1979).

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Table 1. Elliot, Rothenberg, and Stock Test for Unit Roots for Real GDP [a]

Statistics for $\rho = 0$

| Countries | Period | Levels Lags | Levels DFGLS $^{\tau}$ | Change Lags | Change DFGLS |
|---|---|---|---|---|---|
| Australia | 70:1–00:3 | 4 | -2.10 | 3 | -5.38* |
| Canada | 70:1–00:3 | 1 | -1.23 | 1 | -5.51* |
| Chile | 80:1–00:4 | 1 | -1.48 | 1 | -4.93* |
| France | 70:1–00:3 | 2 | -1.38 | 1 | -4.92* |
| Japan | 80:1–00:3 | 3 | -1.02 | 2 | -3.53* |
| Korea | 70:1–00:3 | 1 | -1.79 | 1 | -6.51* |
| Netherlands | 77:1–00:3 | 1 | -0.69 | 4 | -2.61 [b] |
| New Zealand | 77:2–00:3 | 1 | -2.57 | 1 | -3.60* |
| Singapore | 75:1–00:4 | 3 | -3.02* | 3 | -4.33* [c] |
| Sweden | 70:1–99:4 | 1 | -2.12 | 1 | -9.21* |
| United Kingdom | 70:1–00:2 | 3 | -2.78 | 1 | -6.60* |
| United States | 70:1–00:2 | 1 | -2.49 | 1 | -5.05* |

[a]/ Real GDP is deseasonalized and measured in natural logarithms. Lags are determined according to Schwarz information criterion and checking that the residuals are white noise. The DFGLS $^{\tau}$ has a null of unit root with a constant and a linear trend. The 5 percent critical value is -2.89.

[b]/ The statistic value was -4.08* for the change in GDP growth for the Netherlands rejecting the nul of unit root at the 5 percent confidence level.

[c]/ The Phillips-Perron $\tau$ statistic with constant and trend was -2.08 which did not reject the nul of unit root. The Phillips-Perron n $\left(\hat{\rho}-1\right)$ statistic with constant and trend was -8.54 which did not reject the nul of a unit root. The value of the statistics for GDP growth were -7.93 and -82.54, respectively, rejecting the nul of a unit root for Singapore real GDP growth in both cases.

## Table 2.1: Plucking Model

| Parameters | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{vo}$ | 0.0068 * (0.0006) | 0.0049 * (0.0009) | 0.0048 (0.0060) | 0.0050 * (0.0011) | 0.0005 (0.0016) | 0.0000 (0.0000) | 0.0029 * (0.0008) | 0.0111 * (0.0013) | 0.0152 * (0.0035) | 0.0099 * (0.0009) | 0.0048 * (0.0004) | 0.0076 * (0.0006) |
| $\sigma_{v1}$ | 0.0001 (0.0014) | 0.0022 * (0.0009) | 0.0092 * (0.0018) | 0.0000 (0.0000) | 0.0000 (0.0010) | 0.0350 * (0.0052) | 0.0085 (0.0059) | 0.0339 * (0.0160) | 0.0031 (0.0024) | 0.0073 * (0.0028) | 0.0501 ** (0.0272) | 0.0107 * (0.0013) |
| $\sigma_{w}$ | 0.0000 (0.0000) | 0.0000 (0.0000) | 0.0020 * (0.0006) | 0.0008 * (0.0004) | 0.0017 * (0.0006) | 0.0000 (0.0000) | 0.0014 * (0.0009) | 0.0000 (0.0003) | 0.0000 (0.0000) | 0.0000 (0.0000) | 0.0015 * (0.0005) | 0.0011 * (0.0005) |
| $\theta_1$ | 0.6597 * (0.1792) | 1.5413 * (0.0864) | 0.4914 * (0.0971) | 1.2719 * (0.1920) | 0.6740 * (0.2637) | 1.0735 * (0.1343) | 0.4745 ** (0.2692) | 0.6585 * (0.1575) | 1.5591 * (0.1809) | -0.2381 (0.3141) | 1.2019 * (0.0748) | 1.3589 * (0.1093) |
| $\theta_2$ | 0.0274 (0.0587) | -0.5686 * (0.0867) | -0.0604 * (0.0239) | (0.4044) * (0.1272) | 0.1881 (0.1178) | -0.1644 (0.1301) | 0.0752 (0.1848) | 0.1412 ** (0.0811) | -0.6077 * (0.1410) | -0.0142 (0.0374) | -0.3611 * (0.0449) | -0.4616 * (0.0742) |
| $\pi$ | -0.0111 (0.0112) | -0.0112 * (0.0015) | -0.0385 * (0.0042) | 0.0036 (0.0024) | 0.0029 (0.0041) | -0.0074 * (0.0036) | 0.0078 (0.0072) | 0.0186 (0.0158) | 0.0017 (0.0026) | 0.0003 (0.0033) | 0.0361 * (0.0090) | (0.0125) * (0.0032) |
| $\sigma_{uo}$ | 0.0000 (0.0002) | 0.0033 * (0.0011) | 0.0088 * (0.0028) | 0.0031 * (0.0015) | 0.0042 * (0.0010) | 0.0099 * (0.0009) | 0.0000 (0.0006) | 0.0000 (0.0000) | 0.0070 ** (0.0037) | 0.0000 (0.0011) | 0.0000 (0.0002) | 0.0011 (0.0022) |
| $\sigma_{u1}$ | 0.0181 * (0.0052) | 0.0000 (0.0000) | 0.0000 (0.0037) | 0.0022 * (0.0006) | 0.0134 * (0.0039) | 0.0000 (0.0000) | 0.0056 (0.0065) | 0.0000 (0.0002) | 0.0047 * (0.0017) | 0.0145 * (0.0031) | 0.0000 (0.0065) | 0.0000 (0.0003) |
| p | 0.6244 * (0.2867) | 0.6362 * (0.0683) | 0.8025 * (0.1028) | 0.8997 * (0.0852) | 0.7476 * (0.1874) | 0.8702 * (0.0693) | 0.9204 * (0.0582) | 0.6685 ** (0.3995) | 0.8947 * (0.0658) | 0.9553 * (0.0506) | 0.5006 * (0.0079) | 0.9613 * (0.0361) |
| q | 0.9682 * (0.0248) | 0.9715 * (0.0212) | 0.8991 * (0.0481) | 0.9431 * (0.0468) | 0.9099 * (0.0592) | 0.9513 * (0.0280) | 0.9771 * (0.0253) | 0.9670 * (0.0299) | 0.9114 * (0.0677) | 0.9808 * (0.0204) | 0.9902 * (0.0101) | 0.9875 * (0.0181) |
| log likelihood | 333.2700 | 355.1822 | 160.0733 | 389.5318 | 213.0896 | 265.2629 | 278.9841 | 221.3986 | 236.6853 | 279.5374 | 357.0525 | 393.9784 |

Table 2.2: Clark's Model

| Parameters | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{vo}$ | 0.0076 * | 0 | 0 | 0.0043* | 0.0001 | 0 | 0.0001 | 0.0119 * | 0.0103* | 0.0100 * | 0 | 0.0050 * |
| | -0.0011 | 0 | -0.0001 | -0.0006 | -0.0004 | 0 | -0.0012 | -0.0035 | -0.0016 | -0.0014 | 0 | -0.0008 |
| $\sigma_{v1}$ | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| $\sigma_{w}$ | 0.0001 | 0 | 0.0023* | 0 | 0.0015 * | 0.0002 | 0.0010 * | 0 | 0 | 0 | 0.0025 * | 0 |
| | -0.0002 | 0 | -0.0007 | 0 | -0.0006 | -0.0003 | -0.0005 | 0 | -0.0001 | 0 | -0.0006 | 0 |
| $\theta_1$ | 1.3666 * | 1.4858 * | 0.8673* | 1.5318* | 0.5482 * | 0.9455* | 0.8381 * | 1.0670 * | 1.5889* | -0.2085 | 0.6101 * | 1.5142 * |
| | -0.1074 | -0.0359 | -0.1377 | -0.0348 | -0.1314 | -0.0319 | -0.1201 | -0.2749 | -0.0658 | -0.1957 | -0.1205 | -0.0174 |
| $\theta_2$ | -0.4669 * | -0.5289 * | -0.1615 | -0.5745* | 0.3103 * | -0.0125* | -0.0119 | -0.2862 ** | -0.6312* | -0.0109 | 0.2582 * | -0.5732 * |
| | -0.0734 | -0.0333 | -0.1244 | -0.0299 | -0.1087 | -0.0029 | -0.0206 | -0.1471 | -0.0523 | -0.0204 | -0.033 | -0.0132 |
| $\pi$ | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| $\sigma_{uo}$ | 0.0044 * | 0.0068 * | 0.0153* | 0.0033* | 0.0078 * | 0.0203* | 0.0064 * | 0.0069 | 0.0076* | 0.0079 * | 0.0063 * | 0.0056 * |
| | -0.0015 | -0.0005 | -0.0015 | -0.0007 | -0.0008 | -0.0015 | -0.0006 | -0.0051 | -0.0018 | -0.0015 | -0.0006 | -0.0008 |
| $\sigma_{u1}$ | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| P | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| q | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| log likelihood | 323.8562 | 350.8 | 156.2106 | 384.6328 | 205.5587 | 241.5818 | 261.802 | 215.3077 | 229.3973 | 266.7818 | 330.3255 | 374.236 |
| LR | 18.83 * | 8.76* | 7.73 | 9.80* | 15.06 * | 47.36 * | 34.36 * | 12.18* | 14.58 * | 25.51 * | 53.45 * | 39.48 * |

## Table 3.1 Plucking Model
## Residual Analysis - Whole Sample

| Statistics | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standardized forecast errors, DF = 10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 25.35 * | 8.95 | 38.17* | 14.69* | 15.96 * | 9.50 | 30.52 * | 13.08 | 10.05 | 22.22 * | 16.78 * | 79.81* |
| Q (16) | 32.56 * | 15.57 | 92.11* | 26.83* | 27.17 * | 20.58 | 40.59 * | 16.46 | 16.83 | 40.91 * | 35.43 * | 113.90* |
| Q (24) | 43.81 * | 30.01 | 114.14* | 44.06* | 32.98 | 26.56 | 50.99 * | 38.78* | 38.71* | 54.13 * | 39.48 * | 122.64* |
| Squared standardized forecast errors, DF=10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 22.56 * | 6.13 | 10.27 | 13.05 | 3.84 | 14.72 * | 16.02 * | 5.33 | 8.54 | 40.24 * | 5.33 | 28.49* |
| Q (16) | 33.16 * | 13.93 | 21.76 | 20.73 | 11.21 | 23.58 * | 35.51 * | 11.55 | 27.67* | 50.63 * | 19.69 | 46.56 * |
| Q (24) | 37.04 * | 25.29 | 36.28 * | 43.02* | 15.00 | 26.57 | 37.55 * | 19.25 | 31.21 | 58.49 * | 30.38 | 51.57 * |

Table 3.2 Plucking Model
Residual Analysis - Up to 1990:Q4

| Statistics | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standardized forecast errors, DF = 10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 41.29* | 9.82 | 6.92 | 14.49* | 22.50* | 12.39 | 10.16 | 12.77 | 14.63* | 22.51* | 14.00* | 10.26 |
| Q (16) | 46.11* | 14.36 | 33.94* | 22.93 | 51.86* | 17.45 | 27.36* | 23.79* | 23.60* | 41.81* | 31.69* | 32.76* |
| Q (24) | 60.56* | 48.27* | n.a. | 85.10* | n.a. | 25.40 | 36.54* | 58.16* | 35.94* | 63.88* | 36.79* | 51.77* |
| Squared standardized forecast errors, DF=10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 33.08* | 5.84 | 12.86 | 6.47 | 12.29 | 7.97 | 9.46 | 2.66 | 5.57 | 29.62* | 3.14 | 5.12 |
| Q (16) | 58.15* | 16.83 | 46.37* | 9.36 | 18.32 | 18.60 | 17.44 | 6.69 | 17.21 | 45.70* | 13.62 | 16.92 |
| Q (24) | 75.20* | 41.86* | n.a. | 11.94 | n.a. | 25.07 | 28.96 | 44.14* | 35.16* | 62.50* | 27.07 | 31.16 |

Table 3.3 Clark's Model
Residual Analysis - Whole Sample

| Statistics | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standardized forecast errors, DF = 10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 9.35 | 10.24 | 6.76 | 17.42* | 13.37* | 6.52 | 8.61 | 12.36 | 11.48 | 24.03 * | 10.25 | 14.19 |
| Q (16) | 16.30 | 17.12 | 25.62 * | 28.96* | 24.86* | 14.29 | 24.67 * | 16.76 | 18.65 | 40.15 * | 27.30 * | 37.37 * |
| Q (24) | 23.81 | 28.62 | 47.78 * | 52.06* | 32.47 | 20.54 | 34.07 * | 34.66 * | 35.98* | 55.00 * | 32.14 | 51.32 * |
| Squared standardized forecast errors, DF=10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 13.82 * | 20.68 * | 6.22 | 11.11 | 4.92 | 4.64 | 19.03 * | 4.38 | 8.58 | 35.10 * | 23.97 * | 13.79* |
| Q (16) | 19.17 | 35.65 * | 14.73 | 22.06 | 10.47 | 6.39 | 36.34 * | 10.90 | 23.66* | 45.10 * | 32.35 * | 30.91 * |
| Q (24) | 23.50 | 70.34 * | 24.53 | 30.86 | 13.66 | 10.49 | 38.09 * | 13.52 | 31.05 | 55.21 * | 34.49 * | 39.24 * |

Table 3.4 Clark's Model
Residual Analysis - Up to 1990:Q4

| Statistics | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standardized forecast errors, DF = 10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 6.54 | 7.18 | 5.55 | 14.80* | 17.71* | 7.71 | 6.83 | 10.87 | 13.55* | 23.18* | 6.31 | 11.97 |
| Q (16) | 13.05 | 13.61 | 53.72* | 25.63* | 48.04* | 16.16 | 25.10* | 20.15 | 22.12 | 42.61* | 19.63 | 33.51* |
| Q (24) | 18.58 | 31.74 | n.a. | 60.31* | n.a. | 25.71 | 37.03* | 37.35* | 39.47* | 62.15* | 25.19 | 49.42* |
| Squared standardized forecast errors, DF=10 | | | | | | | | | | | | |
| Q-Statistics | | | | | | | | | | | | |
| Q (8) | 10.38 | 13.30 | 21.12* | 5.16 | 8.88 | 5.40 | 7.13 | 4.02 | 4.82 | 20.22* | 13.34 | 6.28 |
| Q (16) | 18.95 | 33.50* | 52.66* | 15.36 | 34.52* | 12.94 | 15.55 | 7.30 | 10.48 | 31.15* | 17.74 | 14.16 |
| Q (24) | 26.76 | 73.93* | n.a. | 31.56 | n.a. | 20.92 | 26.81 | 15.42 | 13.01 | 43.59* | 18.66 | 23.44 |

## Table 4: Output Variance from Plucking Model

| | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter: | σu0 | | | | | | | | | | | |
| Whole sample | 0.0000 | 0.0033 | 0.0088 | 0.0031 | 0.0042 | 0.0090 | 0.0000 | 0.0000 | 0.0070 | 0.0000 | 0.0000 | 0.0011 [a] |
| Sample until 1990:4 | 0.0058 | 0.0000 | 0.0099 | 0.0049 | 0.0014 | 0.0000 | 0.0013 [a] | 0.0001 [a] | 0.0000 | 0.0173 | 0.0000 | 0.0092 |
| $F^b$ | n.a. | n.a. | 1.13 (24,60) | 1.59 * (103,60) | 3.00 * (63,24) | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Parameter: | σu1 | | | | | | | | | | | |
| Whole sample | 1.13 | 0.0000 | 0.0000 | 0.0022 | 0.0134 | 0.0000 | 0.0056 | 0.0000 | 0.0047 | 0.0145 | 0.0000 | 0.0000 |
| Sample until 1990:4 | (24,60) | 0.0000 | 0.0000 | 0.0000 | 0.0030 | 0.0347 | 0.0057 | 0.0000 | 0.0050 | 0.0047 | 0.0000 | 0.0011 |
| $F^b$ | 1.02 (99,60) | n.a. | n.a. | n.a. | 4.47 * (63,24) | n.a. | n.a. | n.a. | 1.06 (44,80) | 3.09 * (98,60) | n.a. | n.a. |
| Parameter: | Π | | | | | | | | | | | |
| Whole sample | -0.0011 [a] | -0.0112 | -0.0385 | 0.0036 [a] | 0.0029 [a] | -0.0074 [a] | 0.0078 [a] | 0.0186 [a] | 0.0017 [a] | 0.0003 [a] | 0.0361 | -0.0125 |
| Sample until 1990:4 | -0.0086 [a] | -0.0108 | -0.0182 | -0.0246 | -0.0097 | 0.0130 [a] | -0.0003 [a] | 0.0105 [a] | 0.0044 [a] | 0.0039 [a] | 0.0351 | 0.0055 |

## Table 5. Output Variance from Clark's Model

| Parameters | Australia | Canada | Chile | France | Japan | Korea | Netherlands | New Zealand | Singapore | Sweden | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole sample | 0.0044 | 0.0068 | 0.0153 | 0.0033 | 0.0078 | 0.0203 | 0.0064 | 0.0069 [a] | 0.0076 | 0.0079 | 0.0063 | 0.0056 |
| Sample until 1990:4 | 0.0073 | 0.0065 | 0.0186 | 0.0053 | 0.0071 | 0.0207 | 0.0082 | 0.0156 | 0.0077 | 0.0161 | 0.0080 | 0.0069 |
| F[b] | 1.66 * (60,99) | 1.05 (99,60) | 1.22 (20,60) | 1.61 * (64,103) | 1.10 (63,24) | 1.02 (60,99) | 1.28 (36,75) | 2.26 * (37,76) | 1.01 (80,40) | 2.04 * (96,60) | 1.27 (98,60) | 1.23 (72,110) |

[a] Not significant different from zero.

[b] Degrees of freedom are in parenteses.

Figure 1. Standard Deviation of CPI Inflation, 4 Year Moving Average, 1975 - 2000

Non-Inflation Targeters

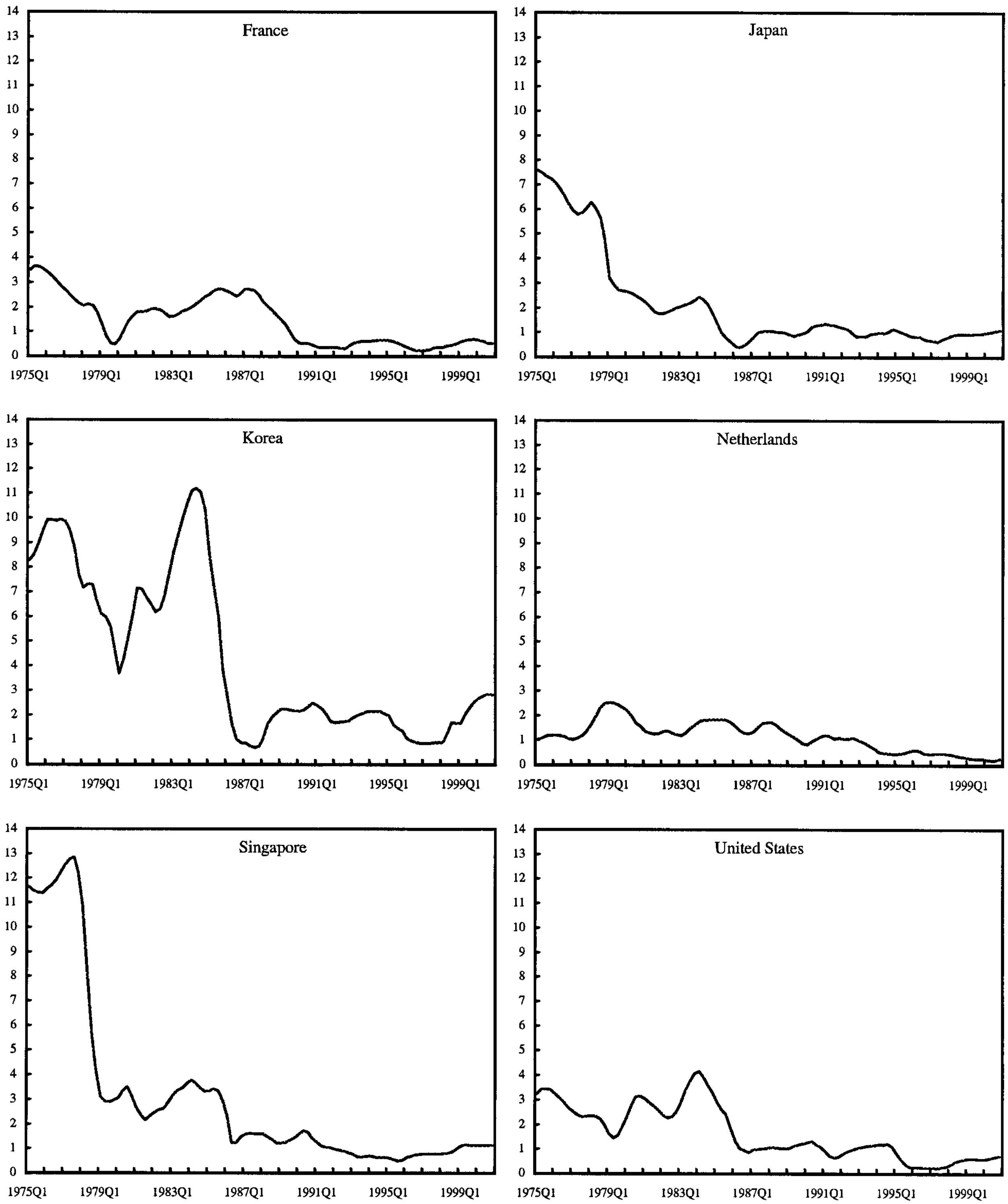

Figure 2. Standard Deviation of CPI Inflation, 4 Year Moving Average, 1975 - 2000

Inflation Targeters