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Hong Kong Inflation Dynamics:
Trend and Cycle Relationships with the U.S. and China

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Abstract

This paper analyzes trend and cycle movements of Hong Kong inflation. The empirical model is an unobserved components model that is consistent with the New Keynesian Phillips curve and is estimated using Hong Kong, U.S., and China inflation and output data. The model decomposes Hong Kong inflation into a stochastic trend and a stationary cycle component that is driven by domestic as well as U.S. and China output gaps. The output gaps are treated as latent variables, thus a byproduct of estimating the empirical model are measures of the output gaps for Hong Kong that are consistent with the New Keynesian Phillips Curve. Empirical results suggest minor evidence that Hong Kong and U.S. inflation rates are related in the long-run, as permanent price shocks from the U.S. have minimal effects on Hong Kong trend inflation movements. Over the short-run horizon, Hong Kong price movements are heavily driven by both the domestic output gap as well as external forces. The U.S. and China output gap has opposite effects on the cycle component of Hong Kong inflation, with the coefficients on the China output gap twice as large as those on the U.S. are.

Keywords: Inflation, New Keynesian Phillips Curve, Output Gap, Trend Inflation, Unobserved Components Model

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1. Introduction

Inflation modeling is an important topic in macroeconomics, because being able to understand and predict inflation plays a central role in monetary policy analysis. Recently, the approach to modeling inflation using two components, trend and cycle, has become an appealing way to study the inflation process. Within this framework, changes to the trend component are driven by permanent shocks and correspond to long-horizon forecasts of inflation. Shocks to the cycle component are transitory and generally arise from short-run fluctuations in aggregate demand. Policymakers closely monitor movements in trend inflation as it indicates the future course of inflation excluding short-term noise. At the same time, knowledge about the driving forces behind cyclical movements can help to improve near-term inflation forecasts, as well as deliver an improved understanding about the monetary policy transmission mechanism.

In recent work, a popular method for studying inflation trend and cycle movements is to model the inflation process as an unobserved components (UC) model. For example, Stock and Watson (2007) propose a univariate UC model with stochastic volatilities that decomposes U.S. inflation into a trend component that follows a driftless random walk, and a stationary white noise component. H08 proposes a UC model for U.S. inflation that is consistent with a reduced form Phillips curve, with lags of inflation replaced by a driftless random walk. Lee and Nelson (2007) and Kim et al. (2012) consider estimating a UC model of inflation consistent with the New Keynesian Phillips curve (NKPC). In this context, trend inflation corresponds to long-horizon forecasts of inflation and the cycle component is driven by current and future forecasts of the real activity measure. Modeling inflation dynamics in this way gives the estimated trend and cycle components more economic content than a univariate UC model which is a decomposition based purely on statistical properties.

Thus far, the majority of studies that estimate UC models for inflation limit the driving variables behind trend and cycle components to domestic ones. This paper extends the UC model of Kim et al. (2012) to account for external factors as well, and applies the model to study Hong Kong inflation dynamics. The case of Hong Kong is particularly interesting for at least three reasons. First, the direction of trend inflation is usually assumed to be driven by domestic monetary policy. For example, in the U.S., the usual approach is to attribute movements in trend inflation to changes in the Federal Reserve Bank's implicit inflation target (see Ireland, 2007; Cogley and Sbordone, 2008). However, Hong Kong relinquished control of its monetary policy by adopting the Linked Exchange Rate System in October 1983. To establish stability and confidence in the economy, Hong Kong fixed its currency at a rate of 1 HKD to 7.80 U.S. dollars, leaving little room for the conduct of discretionary monetary policy. Accordingly, Hong Kong trend inflation may be heavily reliant on external factors such as U.S. trend inflation movements.

Second, inflation in a country under a currency board arrangment such as Hong Kong is believed to be highly dependent on external forces. Moreover, Hong Kong is a small open economy that engages in substantial amounts of international trade which could lead to volatile price movements. While these swings may originate from many sources, it is often understood that shocks from the U.S. and Mainland China are largely responsible in shaping the macroeconomic landscape of Hong Kong, as these two countries are Hong Kong's leading trading partners and investors. As mentioned earlier, the economy of Hong Kong is tied to some degree to the U.S. via the Linked Exchange Rate System. As for China, the close geographic proximity and the return of Hong Kong to Chinese sovereignty in 1997 has led to tight economic integration between Hong Kong and the Mainland through activities in trade, FDI, tourism, and financial markets. While these factors have an important influence on Hong Kong's price movements, the transmission mechanism is less well understood. The UC framework developed in this paper can help to shed some light on this issue.

Last, despite the economic influence that China has exerted on the rest of the world, its macroeconomic variables and linkages with its trading partners is an under-studied topic. In this paper, the output gaps in the empirical model are treated as latent variables, thus a byproduct from estimation is a measure of China's unobserved output gap. There are a number of authors that attempt to measure China's output gap using UC approaches such as Genberg and Pauwels (2005), but the majority of work relies on within-country relationships and Chinese data alone. By exploiting the macroeconomic linkages between Hong Kong, the U.S., and China, information in Hong Kong and U.S. data may help to deliver a more accurate measure of China's output gap.

The rest of this chapter is organized as follows. Section 2 briefly describes the characteristics of Hong Kong's inflation dynamics as well as the related literature. The model specification is outlined in Section 3, and Section 4 discusses the empirical findings. Section 5 concludes.

2. Literature Review

Since the establishment of the currency board arrangement in 1983, consumer price inflation in Hong Kong has varied substantially. Figure 1 plots headline inflation as calculated from the consumer price index (CPI), together with CPI inflation excluding rental components, and underlying CPI inflation which strips out the impact of one-off government relief measures. As shown, Hong Kong experienced high inflation for most of the 1980s and 1990s. Then, it underwent a six-year prolonged period of deflation starting in 1998 which may have been spurred by events such as the Asian Financial Crisis and the integration with Mainland China. Since mid 2004 Hong Kong inflation has been rising, albeit with a slight dip due to the recession. Rising global food prices along with a number of other factors such as rising energy prices, the appreciation of the renminbi, and the weakening U.S. dollar may be responsible for this increase in headline inflation. However, it can also be inferred from Figure 1 that the rise in the rental component has been a main driver in the overall increase in headline CPI inflation during the recent period as well.

In the literature, the New Keynesian Phillips curve (NKPC) is often the preferred model used to analyze the inflation process. In the baseline NKPC, monopolistically competitive firms exhibit forward-looking behavior in an environment of sticky prices. Accordingly, current inflation is postulated to depend on expected future inflation and a measure of marginal cost or real economic activity such as the output gap. However, it is well-known that this so-called purely forward-looking NKPC has difficulty in explaining the high degree of persistence observed in inflation data. Therefore, the baseline NKPC is often augmented to include a backward-looking component or a lagged inflation term to help fit the data, resulting in a NKPC of hybrid form. The inclusion of this backward-looking term is somewhat ad hoc but is often justified by the existence of price-indexation or rule-of-thumb price-setting behavior (see Gali and Gertler, 1999; Christiano et al., 2005).

In the case of Hong Kong, inflation dynamics are often studied using an open-economy hybrid NKPC, as the economy relies heavily on international trade. The open-economy NKPC is an extension of the standard model, where pricing decisions are allowed to depend on external sector macrovariables such as fluctuations in the multilateral terms of trade, or imported intermediate goods (see Clarida et al., 2002; Gali and Monacelli, 2005). The few studies that have estimated open-economy Phillips curves for Hong Kong report evidence supporting the empirical relevance of the model. For example, using the instrumental variable approach, Genberg and Pauwels (2005) find that the Phillips curve can provide a good description of movements in Hong Kong inflation. They find that using either the output gap, a unit labor cost gap or a specification of marginal cost, including unit labor cost and import input cost as the driving variable for inflation, yields similar results. They also report that both backward and forward-looking components are important in the NKPC. Liu and Tsang (2008) also employ a Phillips curve model to study Hong Kong domestic inflation but they focus on analyzing the pass-through effect of exchange rate movements to Hong Kong domestic inflation. They find that although the degree of exchange-rate pass through is high in Hong Kong compared to OECD averages, domestic factors are also very important in explaining Hong Kong inflation dynamics and can even dominate external factors in the medium run.

Recent studies have tried to gain a better understanding of trend and cycle movement in Hong Kong inflation. For example, Leung et al. (2009) use various methods such as the exclusion method and statistical methods such as the principal components analysis to extract trend inflation movements from the data. Ha et al. (2002) estimate a backward-looking Phillips curve augmented by an error-correction term to relate Hong Kong's inflation to that of the U.S. and China in the long-run, and the output gap, import prices and property prices in the short-run. They find that U.S. inflation explains 92% of Hong Kong's long-run price movements whereas, in the short run, lags of the output gap, import prices, and property prices are important. Cheung and Yuen (2002) also find long-run price movements in Hong Kong to be tied to the U.S. via cointegration tests, and using a Vector Error Correction (VEC) model, that in the short-run, U.S. inflation has a significant impact on Hong Kong inflation with a lag of two years. Ha and Fan (2002) use a panel of city-level commodity prices in Hong Kong, Beijing, Shanghai, Guangzhou and Shenzhen to examine price convergence between Hong Kong and Mainland China. They find that price convergence with the Mainland may be responsible for less than a quarter of deflation in Hong Kong, whereas domestic cyclical conditions play a larger role.

3. Model Specification

Consider the following New Keynesian Phillips curve:

$$\pi_t = E_t(\pi_{t+1}) + kx_t + \eta_t \tag{1}$$

where $E_t(.)$ refers to expectations formed conditional on information up to time t, π_t is current inflation, k is the slope of the Phillips curve, and x_t is the output gap, defined as the difference between actual and potential output. As explained in Kim et al. (2012), η_t may be serially correlated if the backward-looking component or additional leads of inflation beyond $t+1$ are important in the NKPC[1].

The NKPC above can be iterated forward and expressed as:

$$\pi_t = \lim_{j\to\infty} E_t(\pi_{t+j}) + k\sum_{j=0}^{\infty} E_t(x_{t+j}) + \tilde{z}_t, \tag{2}$$

where $\tilde{z}_t = \sum_{j=0}^{\infty} E_t(\eta_{t+j})$. Since a number of studies such as Henry and Summers (2003) and Gerlach and Peng (2006) fail to reject the null of a unit root for the Hong Kong inflation process, it is appropriate to interpret $\lim_{t\to\infty} E_t(\pi_{t+j})$ as the Beveridge and Nelson stochastic trend which follows a driftless random walk. The remaining terms, $k\sum_{j=0}^{\infty} E_t(x_{t+j}) + \tilde{z}_t$, is the stationary cycle component of inflation, also known as the inflation gap. Note that in theory, $\tilde{z}_t$ would be driven by backward-looking or additional forward-looking price dynamics, as explained above. However, empirically, $\tilde{z}_t$ could also be influenced by a variety of other macroeconomic factors. For the case of a small open economy such as Hong Kong, fluctuations in terms of trade, import prices, and property price movements as well as exchange rate variability could all be relevant in explaining movements in $\tilde{z}_t$.

[1] To illustrate this point, consider the following widely estimated hybrid NKPC:

$$\pi_t = (1-\alpha)E_t(\pi_{t+1}) + \alpha\pi_{t-1} + kx_t + \eta_t, \ \ 0 \le \alpha < 1,$$

which can be rewritten as (1) with $\eta_t = \alpha(\pi_{t-1} - E_t(\pi_{t+1}))$. It then follows that if $\alpha > 0$, η_t may be serially correlated. The above model is a hybrid NKPC that hinges upon the assumption that inflation is stationary, and a serially correlated η_t term is often interpreted as evidence of important backward-looking price-setting dynamics. However, as shown in Cogley and Sbordone (2008), additional leads of inflation beyond $t+1$ may enter the NKPC if inflation is assumed to have a unit root. Thus, in the presence of stochastic trend inflation, serial correlation in η_t may not necessarily stem from backward-looking price-setting dynamics. Rather, serial correlation in η_t may serve as a spurious proxy for additional forward-looking elements.

This paper is particularly interested in investigating how the U.S. and China output gaps affect $\tilde{z}_t$ movements.

Following Kim et al. (2012), (2) can be written as the following UC model for inflation:

$$\pi_t = \tilde{\pi}_t + k\sum_{j=0}^{\infty} E_{t-1}(x_{t+j}) + z_t, \quad (3)$$

$$\tilde{\pi}_t = \tilde{\pi}_{t-1} + e_t, \quad (4)$$

$$z_t = \varepsilon_t. \quad (5)$$

In (3) above, notice that the expectational element of the infinite sum term is now based on information up to time $t-1$ for feasible estimation of the model. In this case, $z_t = \tilde{z}_t + (\sum_{j=0}^{\infty} E_t(x_{t+j}) - \sum_{j=0}^{\infty} E_{t-1}(x_{t+j}))$, thus z_t may be correlated with x_t. As mentioned above, z_t may be serially correlated due to the importance of backward-looking or additional forward-looking elements in the NKPC. However, when the model is estimated with Hong Kong inflation data, the fit of the model during the time period studied is best when z_t is modeled as a white noise process. Note that this implies that a purely forward-looking NKPC can explain Hong Kong inflation data well.

In dealing with the unobserved output gap x_t, Kim et al. (2012) assume that the U.S. output gap is an observed process as measured by the Congressional Budget Office's (CBO) measure of the output gap. For the case of Hong Kong, there is less of an established measure for the output gap. Hence, the output gap in the UC model for Hong Kong is treated as an unobserved variable and is extracted from the following UC model for output:

$$y_t = \tau_t + x_t, \quad (6)$$

$$\tau_t = \mu + \tau_{t-1} + w_t, \quad (7)$$

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + v_t. \quad (8)$$

The above model follows Harvey (1985) and Clark (1987), in which equilibrium output y_t is decomposed into a stochastic trend component τ_t and a cyclical component x_t which corresponds to the output gap. The output trend and cycle components are assumed to be uncorrelated. In estimating the full UC model as described by (3)-(8), shocks to the output gap v_t in (8) are allowed to be correlated with ε_t in (5) with correlation coefficient $\rho_{\varepsilon v}$. Note that the unobserved output gap x_t backed out from the full UC model will be consistent with the NKPC, and its movements are influenced not only by information contained in its own lags, but also by information in inflation and trend output growth.

The UC model denoted by (3)-(8) is henceforth referred to as the one-country model. Its corresponding state-space model can be written as follows:

Measurement equation

$$\begin{bmatrix} \pi_t \\ y_t \end{bmatrix} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} \tilde{\pi}_t \\ z_t \\ \tau_t \\ x_t \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} k\sum_{j=0}^{\infty} E_{t-1}(x_{t+j}) \\ 0 \end{bmatrix}, \tag{9}$$

$$\left(\Pi_t = H\beta_t + \tilde{Z}_t\right)$$

Transition equation

$$\begin{bmatrix} \tilde{\pi}_t \\ z_t \\ \tau_t \\ x_t \\ x_{t-1} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \mu \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \phi_1 & \phi_2 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \tilde{\pi}_{t-1} \\ z_{t-1} \\ \tau_{t-1} \\ x_{t-1} \\ x_{t-2} \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} e_t \\ \varepsilon_t \\ w_t \\ v_t \end{bmatrix}, \tag{10}$$

$$\left(\beta_t = \tilde{\mu} + F\beta_{t-1} + RU_t, \quad U_t \sim i.i.d.N(0,Q)\right)$$

$$Q = \begin{bmatrix} \sigma_e^2 & 0 & 0 & 0 \\ 0 & \sigma_\varepsilon^2 & 0 & \sigma_{\varepsilon v} \\ 0 & 0 & \sigma_w^2 & 0 \\ 0 & \sigma_{\varepsilon v} & 0 & \sigma_v^2 \end{bmatrix},$$

where $\sigma_{\varepsilon v} = \rho_{\varepsilon v}\sigma_\varepsilon\sigma_v$. Note that $\sum_{j=0}^{\infty} E_{t-1}(x_{t+j})$ in the measurement equation can be calculated as:

$$\sum_{j=0}^{\infty} E_{t-1}(x_{t+j}) = \tilde{e}_4'(I_5 - F)^{-1}\beta_{t|t-1}, \tag{11}$$

where $\tilde{e}_4' = \begin{bmatrix}0 & 0 & 0 & 1 & 0\end{bmatrix}$ and $\beta_{t|t-1} = E(\beta_t \mid I_{t-1})$.

To investigate how Hong Kong's inflation dynamics may be affected by external factors from the U.S. and China, the one-country model is extended to the following three-country model:

<u>NKPC for Hong Kong:</u>

$$\pi_{1,t} = \tilde{\pi}_{1,t} + k_1 \sum_{j=0}^{\infty} E_{t-1}(x_{1,t+j}) + z_{1,t}, \tag{12}$$

$$\tilde{\pi}_{1,t} = \beta\tilde{\pi}_{2,t-1} + (1-\beta)\tilde{\pi}_{1,t-1} + e_{1,t}, \tag{13}$$

$$z_{1,t} = \gamma_1 x_{2,t-1} + \gamma_2 x_{2,t-2} + \gamma_3 x_{3,t-1} + \gamma_4 x_{3,t-2} + \varepsilon_{1,t}, \tag{14}$$

$$y_{1,t} = \tau_{1,t} + x_{1,t}, \tag{15}$$

$$\tau_{1,t} = \mu_1 + \tau_{1,t-1} + w_{1,t}, \tag{16}$$

$$x_{1,t} = \phi_{1,1} x_{1,t-1} + \phi_{1,2} x_{1,t-2} + v_{1,t}, \tag{17}$$

<u>NKPC for the U.S.:</u>

$$\pi_{2,t} = \tilde{\pi}_{2,t} + k_2 \sum_{j=0}^{\infty} E_{t-1}(x_{2,t+j}) + z_{2,t}, \tag{18}$$

$$\tilde{\pi}_{2,t} = \tilde{\pi}_{2,t-1} + e_{2,t}, \tag{19}$$

$$z_{2,t} = \varepsilon_{2,t}, \tag{20}$$

$$y_{2,t} = \tau_{2,t} + x_{2,t}, \tag{21}$$

$$\tau_{2,t} = \mu_2 + \tau_{2,t-1} + w_{2,t}, \tag{22}$$

$$x_{2,t} = \phi_{2,1}x_{2,t-1} + \phi_{2,2}x_{2,t-2} + v_{2,t}, \tag{23}$$

Output equation for China:

$$y_{3,t} = \tau_{3,t} + x_{3,t}, \tag{24}$$

$$\tau_{3,t} = \mu_3 + \tau_{3,t-1} + w_{3,t}, \tag{25}$$

$$x_t = \phi_{3,1}x_{3,t-1} + \phi_{3,2}x_{3,t-2} + v_{3,t}, \tag{26}$$

where variables with subscript 1, 2 and 3 belong to Hong Kong, the U.S., and China respectively, except for all γ coefficients in (14) that belong to the domestic country, Hong Kong. In the NKPC representation for Hong Kong, two departures are made from the one-country model. First, since Hong Kong ties its monetary policy to the U.S. via the linked exchange rate system, the three-country model allows Hong Kong trend inflation to be influenced by U.S. trend inflation movements. The importance of U.S. trend inflation is captured through the significance of the coefficient β. Note that in theory, Hong Kong's inflation rate should converge to that of the U.S. in the long-run, in which case the two countries will share a common trend with β equal to one. However, as shown in Fig. 2, it is unclear whether this is empirically the case since the differences between Hong Kong and U.S. price movements are quite substantial.

Next, the cycle component of Hong Kong inflation that follows (14) is allowed to depend on the lagged output gap effects from the U.S. and China through the coefficients γ_1, γ_2, γ_3, and γ_4. In general equilibrium, the terms of trade gap is driven by the difference between the domestic and foreign countries' output gaps, thus the significance of these coefficients may denote the importance of terms of trade fluctuations in explaining Hong Kong inflation dynamics.

Note that the UC model for the U.S. in (18)-(23) is similar to the one-country NKPC model for Hong Kong and is not influenced by any variables that belong to Hong Kong or China[2]. As for China, only an output equation is included as the literature suggests that the fit of Chinese inflation data to standard Phillips curves is problematic (see Genberg and Pauwels, 2005). This is not surprising since there have been large swings and structural changes in Chinese inflation that may stem from events such as changes in the exchange rate regime, trade liberalization, and the impact of price deregulation. Finally, in the three-country model, the shocks to all three output gaps are allowed to be

[2] This is similar to Kim et al. (2012)'s UC model for U.S. inflation except here, z_t is specified as a white-noise process instead of an AR(1) process. However, the empirical findings in Kim et al. (2012) suggest that z_t follows a white noise process for the post mid 1980s which corresponds to the sample studied in this paper.

correlated through correlation coefficients $\rho_{12,v}$, $\rho_{13,v}$, and $\rho_{23,v}$, and likewise, all shocks to trend output are allowed to be correlated through correlation coefficients $\rho_{12,w}$, $\rho_{13,w}$, and $\rho_{23,w}$.

The corresponding state-space model for the three-country model can be written as:

<u>Measurement equation</u>

$$\begin{bmatrix} \pi_{1,t} \\ \pi_{2,t} \\ y_{1,t} \\ y_{2,t} \\ y_{3,t} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} \tilde{\pi}_{1,t} \\ z_{1,t} \\ \tilde{\pi}_{2,t} \\ z_{2,t} \\ \tau_{1,t} \\ x_{1,t} \\ x_{1,t-1} \\ \tau_{2,t} \\ x_{2,t} \\ x_{2,t-1} \\ \tau_{3,t} \\ x_{3,t} \\ x_{3,t-1} \end{bmatrix} + \begin{bmatrix} k_1 \sum_{j=0}^{\infty} E_{t-1}(x_{1,t+j}) \\ k_2 \sum_{j=0}^{\infty} E_{t-1}(x_{2,t+j}) \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{27}$$

$$\left(\Pi_t = H\beta_t + \tilde{Z}_t \right)$$

<u>Transition equation</u>

$$\begin{bmatrix} \tilde{\pi}_{1,t} \\ z_{1,t} \\ \tilde{\pi}_{2,t} \\ z_{2,t} \\ \tau_{1,t} \\ x_{1,t} \\ x_{1,t-1} \\ \tau_{2,t} \\ x_{2,t} \\ x_{2,t-1} \\ \tau_{3,t} \\ x_{3,t} \\ x_{3,t-1} \end{bmatrix} = \begin{bmatrix} (1-\beta) & 0 & \beta & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_1 & \gamma_2 & 0 & \gamma_3 & \gamma_4 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \phi_{1,1} & \phi_{1,2} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \phi_{2,1} & \phi_{2,2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \phi_{3,1} & \phi_{3,2} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \tilde{\pi}_{1,t-1} \\ z_{1,t-1} \\ \tilde{\pi}_{2,t-1} \\ z_{2,t-1} \\ \tau_{1,t-1} \\ x_{1,t-1} \\ x_{1,t-2} \\ \tau_{2,t-1} \\ x_{2,t-1} \\ x_{2,t-2} \\ \tau_{3,t-1} \\ x_{3,t-1} \\ x_{3,t-2} \end{bmatrix}$$

$$+\begin{bmatrix}0\\0\\0\\0\\\mu_1\\0\\0\\\mu_2\\0\\0\\\mu_3\\0\\0\end{bmatrix}+\begin{bmatrix}1&0&0&0&0&0&0&0&0&0\\0&1&0&0&0&0&0&0&0&0\\0&0&1&0&0&0&0&0&0&0\\0&0&0&1&0&0&0&0&0&0\\0&0&0&0&1&0&0&0&0&0\\0&0&0&0&0&1&0&0&0&0\\0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&1&0&0&0\\0&0&0&0&0&0&0&1&0&0\\0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&1&0\\0&0&0&0&0&0&0&0&0&1\\0&0&0&0&0&0&0&0&0&0\end{bmatrix}\begin{bmatrix}e_{1,t}\\\varepsilon_{1,t}\\e_{2,t}\\\varepsilon_{2,t}\\w_{1,t}\\v_{1,t}\\w_{2,t}\\v_{2,t}\\w_{3,t}\\v_{3,t}\end{bmatrix}, \quad (28)$$

$$\left(\beta_t = F\beta_{t-1} + \tilde{\mu} + RU_t,\quad U_t \sim i.i.d.N(0,Q)\right)$$

$$Q=\begin{bmatrix}\sigma_{1,e}^2&0&0&0&0&0&0&0&0&0\\0&\sigma_{1,\varepsilon}^2&0&0&0&\sigma_{1,\varepsilon v}&0&0&0&0\\0&0&\sigma_{2,e}^2&0&0&0&0&0&0&0\\0&0&0&\sigma_{2,\varepsilon}^2&0&0&0&\sigma_{2,\varepsilon v}&0&0\\0&0&0&0&\sigma_{1,w}^2&0&\sigma_{12,w}&0&\sigma_{13,w}&0\\0&\sigma_{1,\varepsilon v}&0&0&0&\sigma_{1,v}^2&0&\sigma_{12,v}&0&\sigma_{13,v}\\0&0&0&0&\sigma_{12,w}&0&\sigma_{2,w}^2&0&\sigma_{23,w}&0\\0&0&0&\sigma_{2,\varepsilon v}&0&\sigma_{12,v}&0&\sigma_{2,v}^2&0&\sigma_{23,v}\\0&0&0&0&\sigma_{13,w}&0&\sigma_{23,w}&0&\sigma_{3,w}^2&0\\0&0&0&0&0&\sigma_{13,v}&0&\sigma_{23,v}&0&\sigma_{3,v}^2\end{bmatrix}$$

where $\sigma_{i,\varepsilon v} = \rho_{i,\varepsilon v}\sigma_{i,\varepsilon}\sigma_{i,v}$ for $i = 1,2$ and $\sigma_{jk,v} = \rho_{jk,v}\sigma_{j,v}\sigma_{k,v}$, $\sigma_{jk,w} = \rho_{jk,w}\sigma_{j,w}\sigma_{k,w}$ for $j,k = 1,2,3;\ j < k$.

Similar to (11), the infinite sum term $\sum_{j=0}^{\infty} E_{t-1}(x_{1,t+j})$ in the measurement equation can be calculated as:

$$\sum_{j=0}^{\infty} E_{t-1}(x_{1,t+j}) = \tilde{e}_6'(I_{13} - F)^{-1}\beta_{t|t-1}, \quad (29)$$

where $\tilde{e}_6' = \begin{bmatrix}0&0&0&0&0&1&0&0&0&0&0&0&0\end{bmatrix}$. Likewise,

$$\sum_{j=0}^{\infty} E_{t-1}(x_{2,t+j}) = \tilde{e}_9'(I_{13} - F)^{-1}\beta_{t|t-1}, \tag{30}$$

where $\tilde{e}_9' = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$.

4. Empirical Results

The empirical analysis employs quarterly data that spans 1986Q1 - 2010Q4. The Hong Kong inflation series are calculated as the one-quarter log change of: the CPI, the non-rental component of the CPI, and underlying CPI. In practice, underlying CPI inflation is our preferred measure for Hong Kong inflation as it strips out the impact of one-off government relief measures. These measures are designed to reduce the final cost of various goods and services to people burdened by inflation. Headline inflation does not adjust for this, which may have caused distortions and increased volatility in the data. Inflation data for Hong Kong is obtained from the CEIC database and from the database at the Hong Kong Monetary Authority (HKMA).

For the U.S., the inflation rate is calculated as the one-quarter log change of the CPI obtained from the Federal Reserve Economic Database (FRED). As for data on output, the Purchasing Power Parity (PPP)-adjusted Gross Domestic Product (GDP) is used, with 2005 PPP data obtained from the Penn World Table. GDP data for Hong Kong, U.S., and China are obtained from the Hong Kong Census and Statistics Department, the U.S. Bureau of Economic Analysis and the China National Bureau of Statistics, respectively. For some series quarterly data are not available, so monthly data are converted to quarterly data by averaging monthly data within the quarter.

First, the one-country model is fitted to Hong Kong inflation data to see how well the model performs without explicitly allowing for output gap effects from the U.S. and China. Table 1 reports the estimation results for the three Hong Kong inflation series. All parameter estimates have the right sign and are of reasonable magnitudes, and they are statistically significant at the 5% level except the correlation coefficient $\rho_{\varepsilon v}$. The estimation results produced from all three Hong Kong inflation series are reasonably similar. Some minor differences are as expected. The variability of shocks to the cyclical component z_t are slightly smaller for underlying CPI inflation, and shocks to trend inflation are less volatile for the non-rental component of CPI inflation. The slope of the Phillips curve is estimated to be around 0.35 for all inflation measures, which is much larger than the slope of 0.02 that Genberg and Pauwels (2005) obtain from estimating a hybrid NKPC over a similar sample period[3]. Finally, for the underlying CPI inflation measure, the model implies a trend output growth rate of 3.9%,

[3] The authors use a Hodrick-Prescott (HP)-filtered output gap as the real activity variable for the NKPC. In the case of Hong Kong, the majority of studies that estimate Phillip curves also tend to use HP-filtered output gaps. The HP gap is a statistical measure obtained by a simple smoothing procedure. However, the shortcomings of the HP filter has been well documented by Harvey and Jaeger (1993) which includes difficulty in identifying the appropriate smoothing parameter as well as high end-sample biases.

and the unobserved output gap implied by the NKPC is fairly persistent with the sum of AR coefficients being 0.895.

Plots of the unobserved components produced from estimating the model with the three inflation measures are similar, so only the estimates that correspond to underlying CPI inflation are reported due to space considerations. First, smoothed trend inflation estimates obtained from the one-country model are plotted in Fig. 3. As shown, Hong Kong trend inflation tracks the overall movements in realized inflation well. Trend inflation was high in the mid-1980s to early-1990s, experienced a sharp drop in the mid-1990s, was low throughout the late-1990s and early-2000s, and has been picking up since the mid-2000s. In comparison to the literature, the estimates of trend inflation shown here are less volatile than the measures that Leung et al. (2009) report using the exclusion method or principal components analysis.

Figure 4 plots the unobserved output gap as implied by the one-country model for Hong Kong alongside the HP-filtered output gap. It should be emphasized that the two output gap measures are very different since the HP-gap is a purely statistical measure, whereas the unobserved output gap is consistent with the NKPC. Nevertheless, the two series share the same general movements, and dates of peaks and troughs in the business cycle roughly coincide. However, the magnitude of swings in the HP-filtered output gap are more pronounced. This may be due to the fact that the HP-filter imposes a smooth trend thus the variability shows up in the cyclical component, whereas the UC model makes no such assumption. Gerlach and Yiu (2004) and Cheng et al. (2011) also show that a univariate UC model for output that is similar to (6)-(8) produces a less volatile output gap that has smaller peaks and troughs as compared to a HP-filtered output gap. However, fluctuations are still larger than those implied by the one-country model. Thus, it may be the case that information in inflation helps identify a less volatile output gap.

Table 2 reports estimation results for the three-country model for Hong Kong, the U.S., and China. The inflation measure for Hong Kong based on underlying CPI, but estimation results are robust across the three different inflation measures for Hong Kong. As shown, the parameter estimates that describe Hong Kong inflation and output dynamics are similar to those reported in Table 1. For the U.S., they are similar to those that Kim et al. (2012) report, when fitting a one-country model similar to (18)-(20), to U.S. inflation and CBO output gap data. Comparing the NKPC parameter estimates across the two countries, the major difference is in the Phillips curve slope estimates k. Hong Kong has a steeper slope of 0.37 versus the U.S. that has a flat slope of 0.01. This finding provides empirical support to Romer (1993)'s argument that more open economies have steeper Phillips curves.

Comparing the trend components of Hong Kong and U.S. inflation rates, Hong Kong trend inflation is more volatile. Estimates of Hong Kong trend inflation from the three-country model are similar to those shown in Fig. 3, except they track actual inflation more closely during the decline in inflation starting in 1997. Fig. 5 shows estimates of U.S. trend inflation, supporting the view that U.S. trend inflation has been sufficiently well-anchored at around 2% since the mid 1980s. From these observed differences in the long-run properties of the two inflation series, it is not surprising that the estimate of β which denotes the degree in which Hong Kong trend inflation is dependent on U.S. trend inflation is estimated at 0.05 which is low.[4] This result stands in contrast with Ha et al. (2002)'s finding that Hong Kong prices will converge to U.S. prices in the long-run.

Comparing estimates of the output equation parameters, the trend output growth rate is highest for China and lowest for the U.S.. China had an annual trend output growth rate of 9.58%, whereas for the U.S., the growth rate is estimated at 3.19%. All three output gap measures are highly persistent as evidenced by the sum of their AR coefficients ϕ_1 and ϕ_2. Shocks to the three output gap series are highly correlated, especially the ones between Hong Kong and China and U.S. and China, yielding evidence of business cycle synchronization. Estimates of Hong Kong trend output are more volatile than those for the US.. The variability of shocks to China's trend output is also high, in contrast to the shocks to its cyclical component which is lower than for Hong Kong and the U.S. by a factor of about 5. Based on estimates from the three-country model, only shocks to Hong Kong and China trend output are correlated, thus the results reported here are based on the constrained model in which the correlation between the other countries' output trend shocks are restricted to zero.

In Fig. 6, the unobserved output gap for each country is plotted. As shown, the three output gaps move together more closely from the early-2000s onwards. Prior to this period, the output gap of Hong Kong and the U.S. were not synchronized. Given that Hong Kong's monetary policy is tied to the U.S. but their real economies differ, U.S. monetary policy that aims at domestic output gap stabilization may have destabilised Hong Kong's economy, contributing to the high volatility observed in Hong Kong's inflation dynamics. Another observation from the graph is that the current recession is deepest in the U.S., in terms of loss in output, whereas Hong Kong shows the fastest recovery. The Hong Kong output gap looks similar to the series obtained from the one-country model in Fig. 4, except at end-points. For example, examining the lowest point of the most recent recession, the three-country model output gap was lower than the one-country model gap by about 3%. Another interesting observation that follows is that the three-country model output gap at this time is larger than the three-country model output gap during the 1997 Asian financial crisis. As shown in the plot of Hong Kong trend and actual output in Fig. 7, this suggests that, for Hong Kong, the 1997 recession resulted in a large permanent loss in output whereas the loss during the recent recession was mostly temporary.

As for China, China's output gap appears smooth in comparison to that for the U.S. and Hong Kong. The general movement of China's output gap reported here resembles those of Genberg and

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[4] Long-run price movements in Hong Kong should effectively be tied to the U.S. through the Linked Exchange Rate System. Nevertheless, there may be many causes for persistent deviations of Hong Kong price dynamics from that of the U.S.. For example, the high inflation in Hong Kong during the 1990s may be due to favorable export price shocks, which hike up the prices of tradables that ultimately impact the price of non-tradables. The Balassa-Samuelson effect in which the high productivity growth gap between the tradable sector and the non-tradable sector leads to a real exchange rate appreciation that increases prices of non-tradables could also be responsible for Hong Kong's high long-term inflation in the 1990s (see Imai, 2010).

Pauwels (2005), in which the authors estimate a univariate UC model for output similar to (24)-(26). The authors find an output gap that also peaks around the mid-1980s and mid-1990s but their output gap measure is slightly more volatile. By estimating a bivariate UC model for output using U.S. and China data, Jia and Sinclair (2009) also report a more volatile gap. However, note that these output gap estimates for China should be viewed with caution. Output data from the Mainland are known to be subject to considerable measurement errors causing output gap estimates to be imprecise. Moreover, Chinese GDP data is found to be very smooth in comparison with the U.S. and Hong Kong, and this limitation may have contributed to output gap estimates for China that are overly smooth.

As discussed in Section 2, studies in the literature have found Hong Kong price dynamics to be related to macroeconomic factors in the U.S. both at short and long horizons. However, it has been more difficult to establish a link between Hong Kong inflation dynamics and macroeconomic factors in China. In this paper, an encouraging finding is that the coefficients that link the U.S. and China output gaps to Hong Kong inflation in the short-run are all sufficiently large and statistically significant at the 10% level. Examining the estimates of γ_3 and γ_4, China's output gap influence on Hong Kong's cyclical component is approximately twice as large as the impact from the U.S. output gap, as reflected through the coefficients γ_1 and γ_2. In addition, from the signs on these gamma coefficients, it seems to be the case that the U.S. and China output gap have opposite effects on Hong Kong's inflation cycle at the first and second time lags. The finding that China's output gap matters more for Hong Kong inflation is not surprising, since according to the statistics compiled by the Trade and Industry Department, trade between Hong Kong and Mainland China in 2011 is 48.5% of Hong Kong GDP while trade with the U.S. is only 7.6% of GDP.

5. Conclusion

This paper investigates the extent to which domestic and external factors matter for trend and cycle movements in Hong Kong’s inflation rate within the framework of a New Keynesian Phillips curve. The empirical model is an unobserved components model in inflation and output where trend inflation and the output gap in the U.S. and China are allowed to influence Hong Kong price dynamics at long and short time horizons. In contrast to theory, the empirical findings suggest that since the mid-1980s, the degree in which Hong Kong and U.S. inflation rates are related in the long-run is minor. Over the short-run horizon, the domestic output gap turns out to be a very important driving variable in explaining Hong Kong inflation dynamics. However, foreign output gaps from the U.S. and China matter as well, with the coefficient on the China output gap twice as large as that on the U.S.. Comparing the unobserved output gap series that are backed out of the empirical model provides evidence that the output gap of the three countries have become more synchronized since the early-2000s, with the Chinese output gap being the least volatile among the three measures.

The results in this paper are encouraging as they provide evidence of a meaningful relationship between Hong Kong inflation and external macro factors from the U.S. and China. Admittedly, there are other factors not included in the empirical model that matter for Hong Kong inflation. For example, permanent price shocks from China may be important in explaining Hong Kong trend inflation movements. Swings in property prices or global food and energy prices may also matter for Hong Kong's short-run price dynamics. Given the flexibility of the empirical model and the fact that both Hong Kong trend and cycle components are reduced form expressions, it is not difficult to incorporate these features into the model. If the relationship between these factors and the model is found to be important and stable, an interesting avenue for future research would be to evaluate the forecasting performance of the model. Hong Kong is a small open economy influenced heavily by international trade, and its inflation rate is known to be difficult to forecast. Consequently, VAR models are often used to forecast Hong Kong inflation. However, perhaps giving the forecasting model more structure through the New Keynesian Phillips curve framework might yield more fruitful results.

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Table 1. Estimation Results for the One-Country Model [1986Q1-2010Q4]

Parameters	CPI	Non-rental CPI	Underlying CPI
Phillips curve slope, output trend drift, and AR coefficients of the unobserved gap			
k	0.345 (0.168)	0.364 (0.153)	0.379 (0.185)
μ	0.965 (0.132)	0.966 (0.130)	0.976 (0.137)
ϕ_1	1.588 (0.078)	1.574 (0.077)	1.582 (0.081)
ϕ_2	-0.714 (0.070)	-0.709 (0.065)	-0.687 (0.068)
Standard deviations and correlations			
σ_e	1.088 (0.197)	0.841 (0.158)	1.145 (0.181)
σ_w	1.229 (0.118)	1.218 (0.112)	1.280 (0.108)
σ_v	0.463 (0.110)	0.478 (0.102)	0.397 (0.110)
σ_ε	2.064 (0.210)	1.940 (0.182)	1.692 (0.192)
$\rho_{\varepsilon v}$	-0.548 (0.378)	-0.286 (0.271)	-0.743 (0.419)
Log-likelihood:	*-289.902*	*-280.604*	*-279.526*

Note: Standard error are in parentheses.

Table 2. Estimation Results for the Three-Country Model [1986Q1-2010Q4]

Inflation Equation Parameters			
	Hong Kong	U.S.	China
k	0.366 (0.183)	0.010 (0.005)	-
β	0.052 (0.022)	-	-
γ_1	-2.296 (1.255)	-	-
γ_2	2.279 (1.240)	-	-
γ_3	4.401 (2.287)	-	-
γ_4	-4.004 (2.353)	-	-
Output Equation Parameters			
	Hong Kong	U.S.	China
μ	0.937 (0.135)	0.797 (0.085)	2.395 (0.093)
ϕ_1	1.678 (0.053)	1.714 (0.081)	1.894 (0.036)
ϕ_2	-0.785 (0.048)	-0.719 (0.079)	-0.919 (0.033)
Standard Deviations and Correlations			
	Hong Kong	U.S.	China
σ_e	1.079 (0.208)	0.180 (0.112)	-
σ_ε	1.661 (0.209)	1.834 (0.142)	-
σ_w	1.266 (0.100)	0.307 (0.079)	0.845 (0.063)
σ_v	0.357 (0.085)	0.435 (0.077)	0.084 (0.037)
$\rho_{1,\varepsilon v}$	-0.718 (0.449)		
$\rho_{2,\varepsilon v}$	0.123 (0.147)		
$\rho_{13,w}$	0.254 (0.099)		
$\rho_{12,v}$	0.570 (0.142)		
$\rho_{13,v}$	0.998 (0.002)		
$\rho_{23,v}$	0.998 (0.001)		
Log-likelihood: -397.276			

Note: Standard error are in parentheses.

Figure 1. Hong Kong Inflation

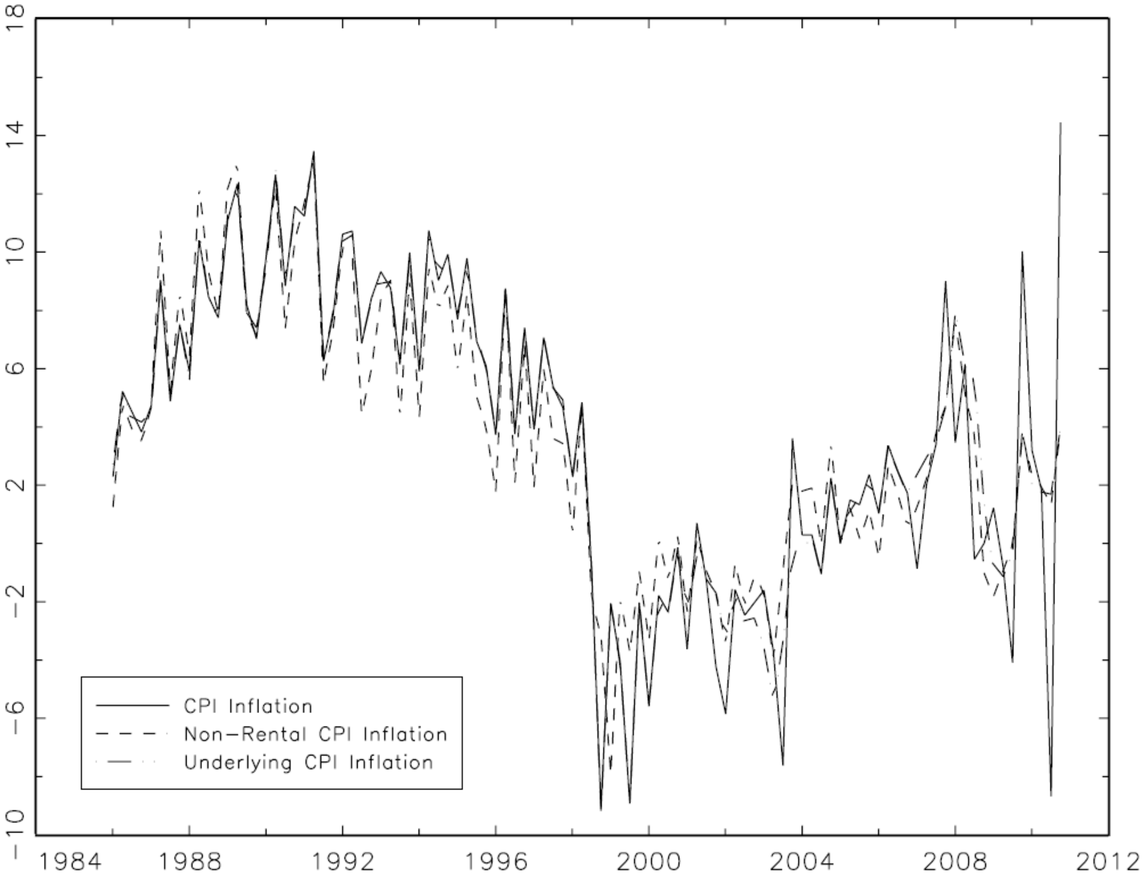

Figure 2. Hong Kong and U.S. Inflation

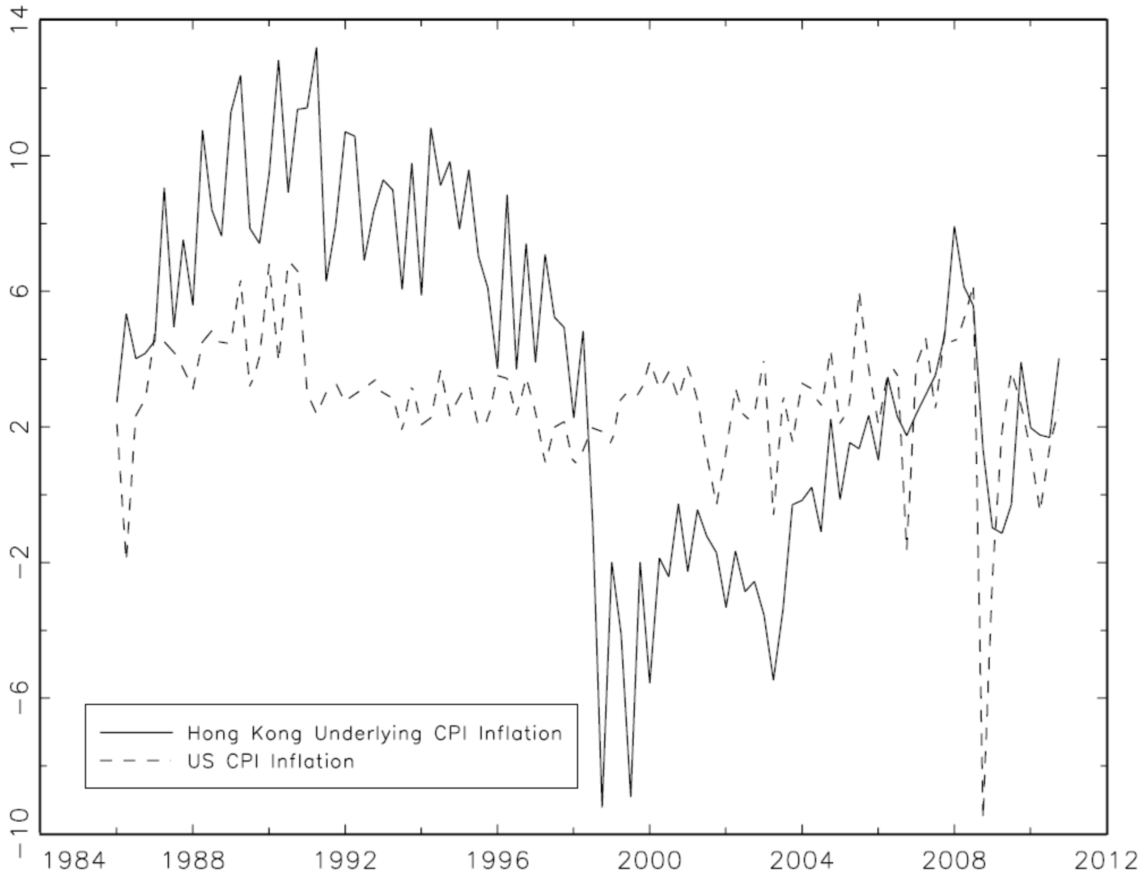

Figure 3. Hong Kong Actual Inflation and Smoothed Estimates of Trend Inflation from the One-Country Model

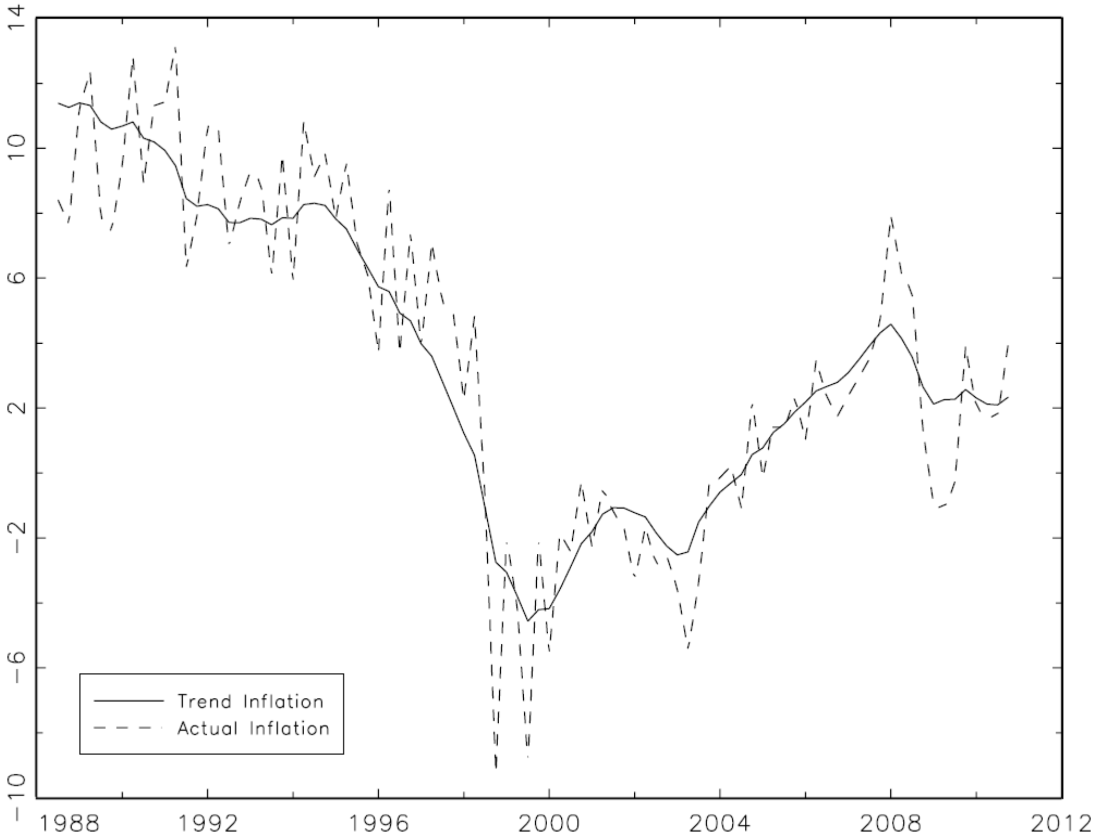

Figure 4. Hong Kong Unobserved Output Gap from the One-Country Model and the HP-filtered Output Gap

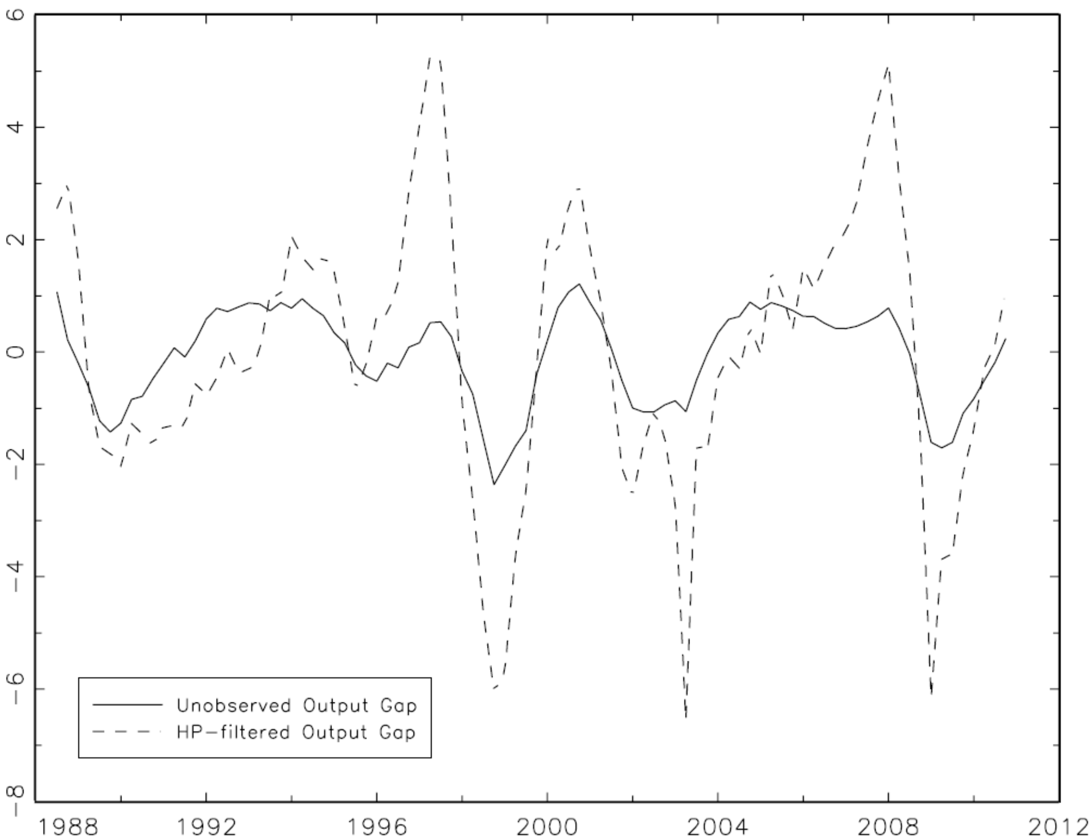

Figure 5. U.S. Actual Inflation and Smoothed Estimates of Trend Inflation from the Three-Country Model

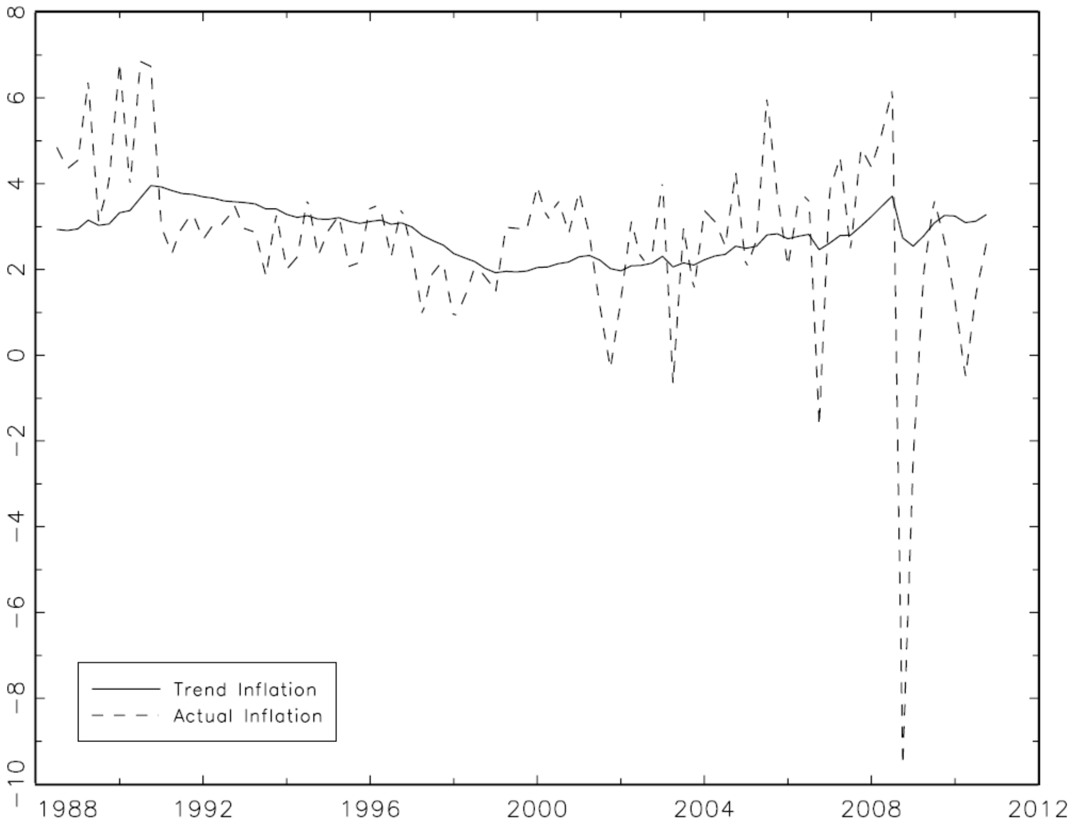

Figure 6. Output Gaps from the Three-Country Model

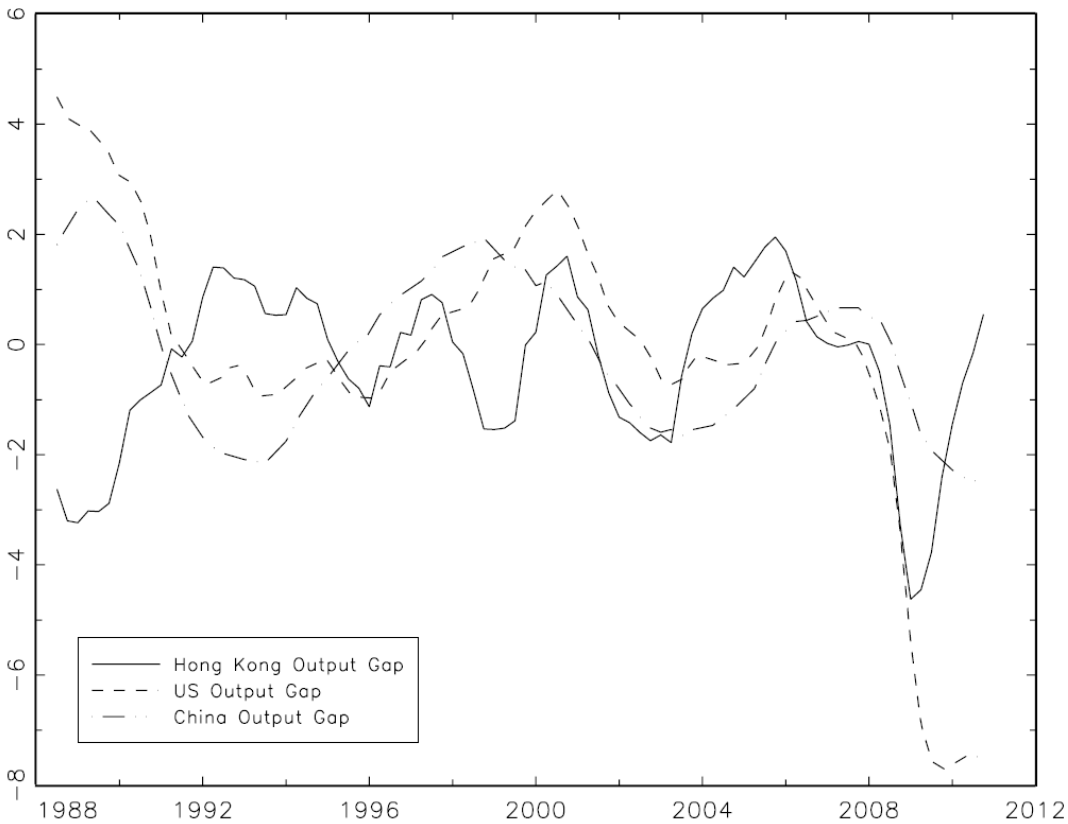

Figure 7. Hong Kong Actual and Trend Output