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Output Gaps and Inflation in Mainland China

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Abstract

We estimate output gaps using three methods for Mainland China on annual data spanning 1982-2003. The estimates are similar and appear to co-move with inflation. Standard Phillips curves, however, do not fit the data well. This may reflect the omission of some important variable(s) such as the effect of price deregulation, trade liberalisation and/or changes in the exchange rate regime. We reestimate the Phillips curves assuming that there is an unobserved variable that follows an AR(2) process. The modified model fits the data much better and accounts for some of the surprising features of the simple Phillips curve estimates.

Keywords: output gap, Phillips curve, China, omitted variab les
JEL classification: C22, E30, E40, E53

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1. Introduction

Since the economic reform programme started in the late 1970s, the economy of Mainland China (the "Mainland" hereafter) has experienced a number of episodes of pronounced economic growth, interrupted by generally sharp but short-lived periods of slowdown. These macroeconomic cycles have been associated with large movements in inflation. Most recently, the deceleration of economic growth in the period 1995-2002 led to a decline of inflation and, indeed, to the development of deflationary pressures. Specifically, the retail price index declined at an average rate of 1.4% per annum in 1997-2002, compared with an average rise of 8.7% in 1982-96, while annual real GDP growth slowed to 7.7% from 9.4% during the same periods.[1] Growth subsequently rebounded, exceeding 9% on a year-on-year rate basis in 2003 and 2004. Inflation also rose to almost 4% year-on-year in 2004.

These developments have led analysts to wonder whether the Mainland economy has entered an overheating phase, and whether and to what extent macroeconomic policies should be tightened to stabilise the economy. The increase in inflation also raises the issues of the nature of the inflation process in the Mainland and, in particular, whether traditional Phillips-curve models, in which inflation is determined by past inflation and the output gap, are useful for analysing inflation in the Mainland. This is the central question we focus on in this paper.

The paper is structured as follows. In Section 2 we briefly review the limited literature on the role of the output gap in the determination of inflation in the Mainland and in Section 3 we turn to the behaviour of inflation, using four different price indices. While the various measures of inflation differ at times sharply, they are dominated by a few cyclical peaks. In Section 4 we construct measures of the output gap using three different statistical approaches. We show that the resulting estimates are similar, which casts some doubt on the proposition that it is difficult to estimate the output gap in the Mainland because of large structural changes in the economy. In Section 5 we discuss a number of Phillips-curve models and provide econometric estimates, using data for the period 1982-2003. We first show that traditional Phillips curves do not fit the data well and that a generalised Phillips curve, which imposes less structure on the dynamic relationship between the output gap and inflation, fits the data better but leads to parameter estimates that are difficult to interpret. To explore whether these results can be explained by omitted variables, we develop a modified Phillips-curve model which includes an unobserved variable that obeys a second-order autoregressive process. We estimate the model using two methods and find that it can explain the parameter estimates of the generalised Phillips curve. Section 6 concludes.

2. Output gaps and inflation in the Mainland

There are a number of studies on the estimation of potential output in the Mainland, including Chow (1993), Borensztein and Ostry (1996), Hu and Khan (1996), Woo (1998), Chow and Li (2002), Heytens and Zebregs (2003), and Scheibe (2003). However, the link between inflation and the output gap remains

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[1]   The consumer price index, which is available only from 1985 onwards, shows a slight rise of 0.2% per year in 1997-2002 with falls in 1998-99 and 2002, compared with much higher rates of inflation in the earlier years.

under-studied.[2] Oppers (1997) employs a Phillips-curve model and finds that inflationary episodes have generally been associated with increases in aggregate demand. He argues that the factors behind the upswings in activity, and the relative importance of the components of aggregate demand, differed across cycles. In particular, the expansion in the first part of the 1990s was supported mainly by a surge in investment spending which raised production capacity and helped achieve a marked disinflation with a relatively moderate slowdown in growth. Imai (1997) studies short-run output-inflation tradeoffs using a small macroeconomic model and finds that large fluctuations in fixed investment were the main force driving the rate of inflation in the reform period. More recently, Woo (2003) examines the experience of the period 1997-2002 and argues that inadequate financial intermediation contributed to slower growth of aggregate demand than aggregate supply, which imparted a deflationary tendency to the economy. However, the paper does not include a formal study of the impact of the output gap on inflation. Chang (2003) estimates an optimal rate of inflation that is consistent with sustainable economic growth in the Mainland. Xie and Lu (2002) study the relationship between output gaps and inflation in a Taylor-rule framework and finds that the conduct of monetary policy in the Mainland could be explained quite well by this approach.

Two factors explain the paucity of studies on the relationship between inflation and the output gap in the Mainland. First, potential output is difficult to estimate, and measures of the output gap are therefore likely to be poor, reducing their information content for future inflation. The source of these difficulties is in part related to the availability and reliability of statistics.[3] It also reflects the tremendous structural changes in the economy in recent decades, as the Mainland has gone through a period associated with a gradual opening of the economy, industrialisation, and transition from a centrally planned to an increasingly market-based economy. Second, the Mainland has experienced a number of economic shocks and disturbances, some of which were related to policy measures to liberalise the economy, which impacted on prices. Thus, deregulation and liberalisation led initially to sharp increases in inflation as prices rose towards market-clearing levels, but to price declines over time as the greater scope for market forces reduced profit margins. The difficulty of finding empirical proxies capturing such influences complicates the study of the inflation process.

While these considerations are certainly important, they apply to varying degrees to most economies, and their significance in the case of the Mainland is thus an important, but unsettled, issue. For example, do they preclude any meaningful econometric study of the relationship between inflation and the output gap in the Mainland? If not, are there ways to specify the Phillips curve that increase its ability to account for movements in inflation?

This paper presents empirical work that bears on these two questions. First, it considers three different estimates of the output gap in the Mainland and shows that these are strikingly similar. This finding

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[2]   Another strand of research focuses on the role of monetary factors in inflation in China. In particular, Chen (1997) estimates a long-run demand function for money and examines its implications for controlling inflation. Hasan (1999) finds a feedback relationship between inflation and money growth.

[3]   There is considerable debate about the accuracy of official output statistics in the Mainland, and data required for estimating potential output using the production function approach, such as capital accumulation and labour force growth, are subject to significant measurement errors. Chow and Li (2002) discuss data issues that arise in estimating production functions for the Mainland.

casts doubt on the view that it is more difficult to estimate the output gap in the Mainland than elsewhere because of the sharp structural changes in the economy since the process of economic reform started in the late 1970s. Next, it proposes an empirical Phillips-curve model that is appropriate in the case of an omitted, serially correlated variable (or a linear combination of variables). This framework is particularly useful in the present case, since the omitted variable can be thought of as capturing the effects on inflation of price deregulation, import tariff reduction, foreign exchange market reforms and other liberalisation measures that have been introduced in the Mainland. These factors are difficult to quantify but have indisputably impacted on inflation in the past two decades. By treating them as an unobserved variable in the econometric analysis, it becomes possible to incorporate them in the Phillips-curve model despite the lack of data on this variable.

3. Inflation

We start by considering the measurement of inflation. We have data on four price indices: the GDP deflator from 1978; a consumer price index (CPI) from 1985; a retail price index (RPI) from 1978; and a producer price index (PPI) from 1979.[4] Figure 1 shows inflation calculated using these four measures of prices. The graph indicates that while most of the fluctuations in inflation are due to a few, sharp cyclical peaks, inflation rates have occasionally diverged. Table 1 contains estimated correlation coefficients as a more formal measure of the similarities of the different time series. These coefficients are uniformly high, ranging from 0.92 to almost unity.

Much attention has been attached to the decline in inflation between 1995 and 2000. Indeed, this period of sharp disinflation was followed by an episode of declining prices which started in late 1997 and raised concerns about deflation (defined as a period of sustained falls in prices). Subsequently, the rate of price change remained close to zero but started to rise in the later part of 2003. As economic growth accelerated, CPI inflation rose to about 3% by the end of 2003 and peaked at above 5% in the summer of 2004 before slowing. The quick turnaround from price declines to increases, coupled with sharp growth in broad money and bank credit, has put a premium on understanding the determination of inflation. An analysis of the output gap, that is, the difference between actual and potential output, which plays an important role in traditional inflation analysis, is warranted.

4. Output gaps

There are two broad approaches to estimating potential output and thus the output gap. One is the production function approach, which makes use of information regarding the sources of growth, that is, factor accumulation and the state of total factor productivity (see Hu and Khan (1996), Chow and Li (1999) and Heytens and Zebregs (2003)). A main advantage of this approach is that it provides an understanding of the sources of growth. Such information is of independent value as it may help guide policies to raise productivity. The main disadvantage arises from the need for high quality data on the

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[4]   The data are from CEIC.

capital stock and the labour force. In many economies, in particular in the Mainland, such data are subject to considerable measurement errors and lack credibility.[5]

Another approach is to identify the trend in real GDP with potential output and to use time series techniques to estimate it. A frequently used tool is the Hodrick-Prescott (HP) filter, which decomposes actual output into a long-run trend and cyclical components. This statistical method does not use any information regarding the determinants of each of the components, but provides a useful approximation of potential output growth. More refined approaches include the unobservable-components (UC) models proposed by Watson (1986) and Clark (1989) for US data. Gerlach and Yiu (2004) estimate output gaps for eight Asian economies using four different time series methods and conclude that both the HP filter and the UC approach generate plausible estimates of the output gap. However, they do not provide estimates for the Mainland.

While the time series approach is easy to implement, it suffers from the drawback that it provides no economic understanding of the sources of growth. Thus, it is arguably best seen as a complement to the more rigorous production function approach. With this caveat in mind, we employ it below to construct three measures of the output gap. First, we use the HP filter to construct a measure of potential output from the logarithm of real GDP.[6] Second, we regress the logarithm of real GDP on a cubic polynomial in time and use the residuals as a measure of the output gap. Third, we estimate the output gap using the UC model employed by Gerlach and Yiu (2004). One attractive feature of this model is that it provides an explicit estimate of the degree of uncertainty of the resulting measure of the output gap. Since the first two methods are straightforward and familiar to most macroeconomists, we do not discuss them further but instead briefly review the UC approach, which is less well known.

4.1   Unobservable components estimates of output gaps

Letting y_t, y_t^p and g_t denote the logarithms of actual and potential output and the output gap, we have by definition:

$$y_t \equiv y_t^p + g_t, \qquad (1)$$

which says that actual output equals the sum of potential output and the output gap. The task we face is to decompose the single observed time series on real GDP into these two components. To do so, we need to make assumptions about the time-series behaviour of these factors. Potential output is assumed to follow a random walk with drift:

$$y_t^p = \mu_{t-1} + y_{t-1}^p + \varepsilon_t^y. \qquad (2)$$

Equation (2) states that the rate of growth of potential output depends on temporary shocks, which are captured by $\varepsilon_t^y \sim \mathrm{N}(0, \sigma_y^2)$, and more persistent growth factors, μ_t. We allow μ_t to vary over the

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[5]   Chow (1993) and Chow and Li (1999) provide detailed discussions about measurement issues. Most of the other studies such as Heytens and Zebregs (2003) use data on the capital stock constructed by Chow and his co-author.

[6]   In doing so we set the smoothing parameter $\lambda = 100$, which is the default for annual data in EViews.

sample period as suggested by Clark (1989):

$$\mu_t = \mu_{t-1} + \varepsilon_t^{\mu},$$ (3)

where $\varepsilon_t^g \sim \mathrm{N}(0, \sigma_g^2)$ denotes a permanent shock to the rate of growth of potential. Finally, the output gap, g_t, is assumed to obey an AR(2) process:

$$g_t = \phi_1 g_{t-1} + \phi_2 g_{t-2} + \varepsilon_t^g,$$ (4)

where $\varepsilon_t^g \sim \mathrm{N}(0, \sigma_g^2)$. Thus, the output gap depends on its past two values.

As is discussed by Gerlach and Yiu (2004) in detail, the model – which consists of the autoregressive parameters for the output gap (ϕ_1 and ϕ_2) and the three variances (σ_μ^2, σ_y^2 and σ_g^2) – can be estimated by sequentially evaluating the likelihood function using Kalman filtering. The estimation results, which are obtained using annual data on real GDP for the full period (1978-2003), are provided in Table 2.[7] Two findings are of interest. First, the autoregressive coefficients for the gap are highly significant and obey $\phi_1 > 1, \phi_2 < 0$, and $0 < \phi_1 + \phi_2 < 1$. This implies that a shock to the output gap leads to "hump-shaped" responses in the sense that the gap first grows over time before returning to zero in an oscillatory manner. Second, σ_y^2 is estimated to equal zero, implying that there are no temporary shocks to the growth rate of potential.

Before discussing our estimates of the output gaps, we plot in Figure 2 the growth rate of potential, μ_t, together with a 95 percent confidence band.[8] The figure shows that μ_t declined over time, from (a point estimate of) 9.6% in 1978 to about 8.8% in 2003. However, the confidence band is quite broad, so the growth rate of potential is not precisely estimated. Note also that the confidence bands are larger at the end and the beginning of the sample, which reflects the fact that more is known about μ_t in the middle of the sample.

4.2 Comparing the output gaps

In Figure 3 we plot the output gap resulting from the UC model (UCGAP) together with a 95 percent confidence band. Since the growth rate of potential is not very precisely estimated, the confidence band is quite broad, which suggests that it is difficult to know exactly the state of the business cycle, even ex post. That does not indicate, however, that this measure is "worse" than other estimates of the gap. All measures of potential output and the output gap should be interpreted as point estimates and ought to be provided with confidence bands. Since these are rarely computed, one may assume that they have been estimated quite precisely when in fact they have not. One major advantage of the UC approach is that it renders this uncertainty explicit.

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[7]　We are grateful to Matthew Yiu for estimating the model.

[8]　More precisely, as follows from equation (2), we plot the estimated lagged growth rate of potential.

For comparison purposes, in Figure 4 we plot both the output gap as measured by the HP filter (HPGAP) and constructed using the residuals from a regression of real output on a polynomial in time (TGAP). It is striking how similar these estimated gaps are. In fact, the HPGAP and the TGAP are typically well within the 95 percent confidence band for the UCGAP. The correlation coefficients for the different measures of the gaps in Table 2 range from 0.89 to 0.98. The finding that different methods give rise to strikingly similar estimates of the output gap suggests that these alternative measures will have roughly the same explanatory power for inflation. The similarity of the estimates moreover calls into question the common view that it is difficult to estimate the output gap in the Mainland. Furthermore, the estimated cycles in the output gap are broadly in line with estimates presented in other studies that use the production function approach, such as Heytens and Zebregs (2003).

As a prelude to the econometric work below, it is interesting to note that the estimated output gaps evolve over time in line with movements of inflation and other indicators of macroeconomic conditions. Specifically, the three downturns in economic activity in 1981-83, 1989-91, and 1998-2003 were accompanied by sharp falls in inflation and the upturns around the mid-1980s and the early 1990s saw a marked acceleration in inflation rates. As noted by Oppers (1997), these findings are compatible with the notion that movements in inflation and real activity in the Mainland are largely due movements in aggregate demand.

5. The output gap and inflation

5.1 Preliminary econometric work

Next we explore the information content of the different measures of the output gap. Since applied econometric work on the determination of inflation is frequently based on backward-looking Phillips curves, as a preliminary we estimate a traditional Phillips curve of the form:

$$\pi_t = \alpha + \beta_1 \pi_{t-1} + \delta_0 g_t + \varepsilon_t \tag{5}$$

where π_t denotes inflation, g_t the output gap and ε_t a regression residual. Equation (5) should be interpreted as saying that inflation evolves gradually over time in response to aggregate demand factors, which are captured by the output gap, and aggregate supply shocks which are captured by the residuals. While standard Phillips-curve analysis highlights the importance of bottlenecks in labour markets, in the case of the Mainland these constraints are more naturally thought of as arising in the economy more broadly, including in the transport and energy sectors.

The parameter of interest in equation (5) is δ_0, which captures the impact of the output gap on inflation. Since we have data on four price indices and three measures of the output gap, we could estimate twelve versions of this equation. To reduce the dimensions of the empirical work, we only estimate equations for inflation as measured by the RPI and the GDP deflator since these are available from 1978 onwards, when the GDP data starts. Furthermore, we focus on the UCGAP, which has the advantage that it is possible to estimate a confidence band for it, and the HPGAP, since this is the approach to constructing output gaps adopted in much applied econometric work. This reduces the number of combinations of price indices and output gaps to four.

In Table 4 we present the results. Before discussing these, it should be noted that estimates of Phillips curves in which the contemporaneous output gap enters among the regressors may be subject to simultaneity bias. Since the purpose of the empirical work here is merely to motivate our inflation model presented in the next subsection, we do not discuss this issue further here. We do, however, test for simultaneity bias in our preferred model, as is discussed below.

The results in the first column of Table 4 indicate that, depending on the exact choice of price index and measure of the output gap, the parameter on lagged inflation is about 0.6-0.7 and highly significant. The parameter on the output gap, by contrast, is about 0.2 and insignificant when the deflator is used, but about 0.5-0.6 and significant at the 10% level when the RPI is used. The DW statistics are low, about 1.2, and unreported Q-tests show that there is statistically significant correlation of the residuals, implying that this simple model fails to capture the dynamics of the data.

These estimates do not suggest that a standard Phillips-curve model is helpful for understanding the determination of inflation in the Mainland. We therefore re-estimate a more general model that allows for a second lag of inflation and the output gap:

$$\pi_t = \alpha + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \delta_0 g_t + \delta_1 g_{t-1} + \varepsilon_t \tag{6}$$

As can be seen in column 2 of Table 4, this specification fits the data much better. The estimates β_1 and δ_1 both rise in numerical value and are highly significant, as are the additional lags. Furthermore, the adjusted R-squared rises quite sharply and the DW statistics approach 2, indicating a reduction in the degree of serial correlation in the residuals.

One striking aspect of these results is that the estimates β_2 and δ_1 are both negative. Indeed, the data appear to imply that it is the change in the output gap, $\Delta g_t = g_t - g_{t-1}$, that drives inflation.[9] This observation warrants two comments. First, the fact that it is the change rather than the level of the output gap that enters the equation implies that a hypothetical permanent increase of the output gap has at most a temporary impact on inflation.[10] It does not mean that the output gap does not impact on inflation. Second, while it may be that it is the change (rather than the level) of the output gap that truly determines inflation, the question arises if this finding could be spurious. We show below that it could result from economically important variables having incorrectly been omitted from the analysis.

Before exploring this hypothesis in detail, we add an additional lag of both inflation and the output gap and estimate:

$$\pi_t = \alpha + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \beta_3 \pi_{t-3} + \delta_0 g_t + \delta_1 g_{t-1} + \delta_2 g_{t-2} + \varepsilon_t \tag{7}$$

The results in column 3 of Table 4 are clearly worse in the sense that the adjusted R-squareds are lower.[11]

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[9] This is sometimes referred to as a "speed limit version" of the Phillips curve.

[10] Of course, the output gap is by construction stationary.

[11] As noted by a referee, while the data set contains 22 observations, the model in equation (7) comprises seven parameters, raising the issue of whether the number of degrees-of-freedom is too low. One advantage of the model presented in the next section, which is restricted version of equation (7), is that it involves fewer parameters and thus conserves degrees-of-freedom.

In particular, with the exception of β_1, the parameters are all insignificant, which probably reflects multicollinearity arising from the fact that the regressors display considerable serial correlation and the fact that we estimate a relatively large number of parameters given the sample size. The parameters have the same sign patterns as in the case of equation (6).

Overall, this analysis leads us to conclude that equation (7) overfits the data and that equation (6), which fits the data much better, leads to parameter estimates that are difficult to interpret.

5.2 A model of inflation in the Mainland

In this section, we explore whether omitted variables may explain the fact that β_2 and δ_1 are significant but have negative signs in equation (6). Such omitted variables could capture one or a number of factors, for instance, the effects of external shocks, price deregulation or expected inflation. To include them into the analysis, consider the following version of equation (5):

$$\pi_t = \alpha + \beta\pi_{t-1} + \delta g_t + \gamma z_t + \varepsilon_t \tag{8}$$

where z_t denotes an omitted variable (or a linear combination of omitted variables) and where we have deleted the subscripts on β and δ since there is only one of each. Of course, equation (8) could be estimated directly if we had data on z_t or if we could construct a plausible proxy for it. However, here we assume that this is not feasible. Suppose, however, that we are willing to assume the following time series representation for the omitted variable:

$$z_t = \theta_1 z_{t-1} + \theta_2 z_{t-2} + v_t \tag{9}$$

Thus, we assume that z_t follows an AR(2) process. Next the issue arises whether we can use equation (9) to obviate the need for data on z_t to estimate equation (8). Combining equations (8) and (9) and multiplying both sides by $(1 - \theta_1 L - \theta_2 L^2)$, where L denotes the lag operator, we have that:

$$\begin{aligned}
\pi_t - \theta_1\pi_{t-1} - \theta_2\pi_{t-2} &= \alpha(1 - \theta_1 - \theta_2) + \beta(\pi_{t-1} - \theta_1\pi_{t-2} - \theta_2\pi_{t-3}) \\
&\quad + \delta(g_t - \theta_1 g_{t-1} - \theta_2 g_{t-2}) + \gamma(z_t - \theta_1 z_{t-1} - \theta_2 z_{t-2}) \\
&\quad + \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2}
\end{aligned} \tag{10}$$

Defining $\tilde{\alpha} = \alpha(1 - \theta_1 - \theta_2)$ and $\phi_t = \gamma v_t + \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2}$, we can then write that:

$$\pi_t = \tilde{\alpha} + (\beta + \theta_1)\pi_{t-1} + (\theta_2 - \beta\theta_1)\pi_{t-2} - \beta\theta_2\pi_{t-3} + \delta(g_t - \theta_1 g_{t-1} - \theta_2 g_{t-2}) + \phi_t \tag{11}$$

or more compactly

$$\pi_t = \alpha^* + \beta_1^*\pi_{t-1} + \beta_2^*\pi_{t-2} + \beta_3^*\pi_{t-3} + \delta_0^* g_t + \delta_1^* g_{t-1} + \delta_2^* g_{t-2} + \phi_t \tag{11'}$$

where $\alpha^* = \tilde{\alpha}$, $\beta_1^* = \beta + \theta_1$, $\beta_2^* = \theta_2 - \beta\theta_1$, $\beta_3^* = -\beta\theta_2$, $\delta_0^* = \delta$, $\delta_1^* = -\delta\theta_1$ and $\delta_2^* = -\delta\theta_2$.

Three aspects of equation (11) are of interest. First, suppose θ_1 is close to unity and that θ_2 is close to zero, so that the unobserved variable is highly autocorrelated. If so, the omission of z_t will spuriously lead to the impression that it is the change in the output gap that impacts on inflation. Moreover, the specification error could also lead the rate of inflation at t -2 spuriously to have a negative coefficient. These results suggest that the omission of a relevant, autocorrelated variable might be able to explain the surprising features of the estimates of equation (6) discussed above. Second, letting σ_ε^2 denote the variance of ε_t (and, for future reference, σ_v^2, the variance of v_t), note that $E(\phi_t, \phi_{t-1}) = \theta_1(\theta_2 - 1)\sigma_\varepsilon^2$ and that $E(\phi_t, \phi_{t-2}) = -\theta_2\sigma_\varepsilon^2$, that is, the residuals should obey negative second-order serial correlation. Of course, whether they do so in practice depends on the relative variances of the structural shocks (v_t and ε_t) and the parameters γ, θ_1 and θ_2. In particular, if σ_ε^2 (or $|\theta_1|$) is sufficiently small, the residuals may appear serially uncorrelated. The importance of any serial correlation is thus an empirical question, which we return to below. Third, the model implies that inflation is driven by three factors: (a) aggregate demand, as captured by the output gap; (b) supply shocks, as captured by ε_t; and (c) shocks to the unobserved variable, as captured by v_t. Past output gaps and supply shocks enter because of the dynamics of the omitted variable.

5.3 Estimates

Next we estimate the model. We first do so by fitting equation (11') using non-linear least squares (NLS). This approach is simple and therefore attractive, but disregards the fact that the error term may display serial correlation.[12] We therefore also estimate the model using Kalman filtering by interpreting equation (8) as an observation equation and equation (9) as a state equation. While more computationally burdensome, this approach allows us to estimate the variances of v_t and ε_t, and makes it possible to construct estimates of the realisation of the unobserved variable, z_t.

Before turning to the estimates, note that since it is not possible to identify γ, we set it equal to unity.[13] Furthermore, since the results in Table 4 indicate that the HPGAP fits the data best and the adjusted R-squareds are somewhat higher when inflation is measured by the deflator rather than the RPI, in what follows we use these variables in the interest of brevity.[14]

5.3.1 NLS estimates

Column 1 in Table 5 reports estimates of the parameters in equation (11), using non-linear least squares. The estimate of θ_1 is 1.3 and highly significant. By contrast, θ_2 is estimated to be -0.4, but is not significant at the 10% level.[15] The impact of the output gap on inflation, which is captured by δ, is somewhat greater than unity and thus larger than before, and is significant at the 10% level. The impact of the lagged inflation rate, captured by β, is negative but insignificant. This finding is perhaps somewhat surprising and we discuss it further below.

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[12] This is the main difference between the NLS and Kalman filtering estimates. A smaller difference is that while the NLS estimates minimises the sum of squared errors, the Kalman estimates are obtained by maximizing the value of the likelihood function.

[13] To understand the lack of identification, define a new variable $z^* = \tau z$, where τ is an arbitrary non-zero constant, and denote the associated parameter γ^*. Note that a model in which $\gamma^* z^*$ enters equation (8) will fit the exactly as well as a model in which z enters (since $\gamma^* = \gamma/\tau$). Thus, we can not estimate separately the volatility of z and γ.

[14] The results are quite similar if the other price indices and measures of the output gap are used.

[15] Analogously to the case of the output gap, these parameter estimates imply that the omitted variable follows a humped-shaped pattern in response to v-shocks.

Next we assume that $\beta = 0$ and reestimate the model. The results in column 2 of the same table are much better. In particular, θ_1 and θ_2 are both significant at the 5% level and are estimated to be around 1.2 and -0.5, respectively. The intercept, α, and the parameter on the output gap, δ, are both positive and significant. Furthermore, the equation appears to fit the data quite well, as evidenced by a *Q*-test for second-order autocorrelation of the residuals (p = 85.5%), a Jarque-Bera test for normality (p = 76.7%) and a White test for heteroscedasticity (p = 55.0%). Finally, a likelihood ratio test of the restrictions implicitly imposed by equation (11) on (7) yields p = 43.3%, which implies that they are not rejected by the data. Thus, the hypothesis that the rather surprising sign patterns of the parameters arising from estimates of equation (6) stem from an omitted variable that obeys an AR(2) specification seems compatible with the data. It should be emphasised that the model is quite parsimonious in that it only involves four parameters (α, δ, θ_1 and θ_2).

5.3.2 *Kalman-filter estimates*

Next we re-estimate the model by applying Kalman filtering to the *observation* equation (8) and the *transition* equation (9).[16] The results are provided in Table 6. Not surprisingly, these are very similar to those reported in Table 5 and we therefore do not comment on them in detail. Instead we focus on the estimates of σ_ε^2 and σ_ν^2, which we are able to estimate and which are the main novelties in Table 6, and on β. The results in column 1 show that the variance of ε_t, which determines the degree of serial correlation in the residuals, is (rounded to) zero, which explains the absence of autocorrelation in the errors in the equations estimated in Table 5. Note also that the estimate of β is close to zero and insignificant. This finding is in contrast to the existing literature on Phillips curves, which typically finds a positive and significant β. However, it should be kept in mind that little is known about the omitted variable and that there is no reason why it could not be closely related to inflation. In particular, it might capture inflation expectations, in addition to the effects of liberalisation. Thus, the finding that past inflation is insignificant does not, on its own, invalidate the model. Assuming that $\sigma_\varepsilon^2 = \beta = 0$, we obtain the estimates the in the second column. The fact that the value of the likelihood function is essentially unaffected by these two restrictions indicates that they are valid.

Next we plot the estimate of z_t together with the rate of inflation in Figure 5.[17] Interestingly, the two series evolve in a strikingly similar way from 1992 onwards. In the first part of the sample, however, the unobserved variable only rises from 1989 onwards while actual inflation starts to increase already in 1984. Overall the graph suggests that the reason β is estimated to be insignificantly different from zero is that the unobserved variable and lagged inflation contain much the same information.

One possible reaction to the finding that the omitted variable is more important than lagged inflation in explaining current inflation might be that the model is of little use for analysing inflation. That conclusion, however, is unwarranted. As demonstrated by equation (11) the omitted variable merely imposes a tight relationship between current and past inflation rates and output gaps, which are observed. Thus, the

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[16]   This section was added in response to comments from seminar participants at the BIS. Harvey (1993) contains an introduction to Kalman filtering.

[17]   This estimate is "two-sided" or "smoothed", that is, it is based on the full sample of data. See Harvey (1993) for a discussion.

model can be used in the same way as any standard Phillips curve model. The benefit of the omitted-variables approach is that it provides an explanation for why the lagged output gap and the twice-lagged inflation rate enter with negative signs in the unrestricted Phillips curve in equation (6).

5.3.3   Discussion

While the empirical results are supportive of the model, several aspects of the equation deserve further attention.[18] First, since there have been several inflation cycles in the Mainland, it is plausible that the structure of the inflation process has evolved over time. We therefore divide the sample into three episodes: a first cycle between 1982 and 1991, a second cycle between 1992 and 1998, and a stable period between 1999 and 2003. Next we perform Chow tests for structural breaks between the different episodes, using the equation presented in column 2 of Table 5. Perhaps surprisingly, we do not reject the hypothesis of no structural breaks.[19] While these results suggest that the equation is stable, it should be noted that there are few observations in each period and that the parameters may therefore be estimated with too much uncertainty for the structural break tests to have much power.

Second, the estimate of the parameter on the current output gap may be subject to simultaneity bias. We therefore reestimate the equation, using lagged inflation rates and lagged output gaps as instruments, and report the results in column 3 of Table 5 to facilitate a comparison with the NLS estimates discussed above. The estimated impact of the output gap on inflation is now larger than before but somewhat less significant (p = 6.3%). Given the estimated standard error, the difference does not, however, appear statistically significant.[20]

Third, it may be that the estimates of the output gap are subject to measurement errors. We therefore reestimate the model using the current and two lagged growth rates of real GDP as instruments for the output gap. The results in column 4 are virtually identical to those in column 2 in Table 5. We therefore conclude that the results do not suggest that any mismeasurement of potential GDP impacts importantly on the results.

6.   Conclusions

This paper studies the relationship between inflation and the output gap in Mainland China by fitting Phillips-curve models for the period 1982-2003. A number of time-series techniques are employed to estimate potential output and to construct measures of the output gap. These are strikingly similar, and movements in them appear associated with swings of inflation. They are also broadly similar to estimates in the literature that make use of a production function approach.

We then turn to the question whether the determination of inflation in the Mainland can be understood using a Phillips-curve framework. The estimates suggest that a simple application of the Phillips curve

[18]   We are grateful to the referees for suggesting the work reported here. All estimates in this section are based on the NLS estimates reported in Table 5.

[19]   The p-value for a test of the hypothesis that the parameters are the same before and after 1992 is 84.1%, and before and after 1999 94.0%. The p-value for a joint test of these hypothesis is 55.8%.

[20]   This is confirmed by a formal Hausman test.

does not fit data well and that this may reflect an omission of some important variables. Given the tremendous structural change and policy shifts in the Mainland in the estimation period, this hypothesis appears plausible. In particular, price deregulation, trade liberalisation and changes in the exchange-rate regime over time have likely impacted on inflation. Since it is difficult to capture or measure the influence of these forces empirically, we model them as an unobserved variable. The results suggest that once a serially correlated omitted variable is allowed for, the model fits the data much better. Thus, movements in inflation are at least partially due to movements in aggregate demand as captured by the output gap. The introduction of the omitted variable also explains what at first glance appear to be surprising features of the simple Phillips-curve estimates.

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Table 1. Correlation of Alternative Measures of Inflation

Annual Data, 1979-2003				
	CPI	**Deflator**	**RPI**	**PPI**
CPI	1			
Deflator	0.928	1		
RPI	0.995	0.923	1	
PPI	0.919	0.924	0.924	1.000

Notes: Inflation is measured using the consumer price index (CPI; from 1985), the GDP deflator (Deflator; from 1979), the retail price index (RPI; from 1979) and the producer price index (PPI; from 1980). The exact sample periods vary depending on data availability. The correlations are computed using all available data.

Table 2. Estimates of the Unobservable-Components Model for the Output Gap

Annual Data, 1978-2003		
$\phi_1 = 1.291$ (5.113)	$\sigma_\mu^2 \times 1000 = 0.008$	
$\phi_2 = -0.749$ (9.311)	$\sigma_y^2 = 0$	$\sigma_g^2 \times 1000 = 0.346$

Table 3. Correlations of Alternative Measures of the Output Gap

Annual Data, 1978-2003			
	HPGAP	**UCGAP**	**TGAP**
HPGAP	1		
UCGAP	0.979	1	
TGAP	0.959	0.891	1

Notes: The output gaps are computed using the Hodrick-Prescott filter (HPGAP), the unobservable-components method of Gerlach and Yiu (2004) (UCGAP) and a cubic time trend (TGAP).

Table 4. Estimates of Alternative Phillips-Curve Models

Annual Data, 1982-2003

Regression	GDP Deflator HPGAP			GDP Deflator UCGAP			RPI HPGAP			RPI UCGAP		
Price index / Output gap	1	2	3	1	2	3	1	2	3	1	2	3
α	0.015	0.017	0.14	0.016	0.019	0.016	0.019	0.017	0.015	0.021	0.021	0.019
	(1.308)	(1.754)	(1.258)	(1.302)	(1.986)	(1.403)	(1.460)	(1.418)	(1.091)	(1.565)	(1.757)	(1.380)
β_1	0.707 ***	1.044 ***	1.137 ***	0.701 ***	1.014 ***	1.086 ***	0.621 ***	1.018 ***	1.004 ***	0.593 ***	0.989 ***	0.960 ***
	(4.405)	(5.802)	(3.963)	(4.180)	(5.706)	(3.855)	(3.898)	(5.327)	(3.38)	(3.583)	(5.279)	(3.222)
β_2		-0.379 *	-0.544		-0.380 **	-0.516		-0.364 *	-0.390		-0.384 **	-0.380
		(2.087)	(1.559)		(2.115)	(1.522)		(1.990)	(1.080)		(2.159)	(1.070)
β_3			0.124			0.120			0.078			0.058
			(0.594)			(0.549)			(0.367)			(0.275)
δ_0	0.177	0.741 **	0.788	0.140	0.735 **	0.722	0.605 *	1.135 ***	0.955	0.532 *	1.075 ***	0.878
	(0.678)	(2.613)	(1.447)	(0.574)	(2.789)	(1.364)	(1.895)	(2.936)	(1.312)	(1.796)	(3.071)	(1.248)
δ_1		-0.805 ***	-0.933		-0.787 ***	-0.827		-0.967 **	-0.672		-0.914 **	-0.590
		(2.884)	(1.143)		(3.006)	(1.030)		(2.415)	(0.576)		(2.464)	(0.512)
δ_2			0.116			0.041			-0.211			-0.238
			(0.118)			(0.068)			(0.252)			(0.288)
Adj. R-sq.	0.510	0.705	0.674	0.507	0.715	0.684	0.509	0.659	0.619	0.500	0.668	0.628
DW	1.245	1.758	1.872	1.255	1.765	1.863	1.183	1.943	1.904	1.176	1.965	1.905

Notes: Absolute value of t-statistics in parentheses; */**/*** denotes significance at 10/5/1% level.

Table 5. NLS Estimates of a Phillips-Curve Model with Omitted Variables

Annual Data, 1982-2003

Regression	1	2	3	4
Method	NLS	NLS	IV	IV
α	0.126 (0.441)	0.050** (2.183)	0.049** (2.156)	0.050** (2.313)
θ_1	1.314*** (5.159)	1.219*** (5.673)	1.288*** (6.352)	1.204*** (5.680)
θ_2	-0.435 (1.721)	-0.495** (2.170)	-0.582** (2.477)	-0.500** (2.101)
β	-0.184 (0.687)			
δ	0.985* (2.094)	1.136** (2.641)	1.624 (1.988)	1.254** (2.545)
Adj. R-sq.	0.697	0.702	0.679	0.700
DW	1.831	1.891	1.888	1.825

Notes: Absolute value of t-statistics in parentheses, */**/*** denotes significance at 10/5/1% level. The instruments used the regression in column 3 are inflation lagged one and two years, and the output gap lagged one, two and three years. In the regression in column 4, the instruments are inflation lagged one and two years, and the current and two lags of real GDP growth.

Table 6. Kalman-Filter Estimates of a Phillips-Curve Model with Omitted Variables

Annual Data, 1982-2003

Model	1	2
α	0.052 (1.420)	0.053** (2.381)
θ_1	1.173*** (3.192)	1.210*** (5.239))
θ_2	-0.456 (1.157)	-0.497** (2.177)
β	0.040 (0.108)	
δ	1.125* (1.895)	1.137** (2.112)
σ_ε^2	0.000	
σ_v^2	0.001	0.001
Log likelihood	48.139	48.121

Notes: Absolute value of t-statistics in parentheses, */**/*** denotes significance at 10/5/1% level.
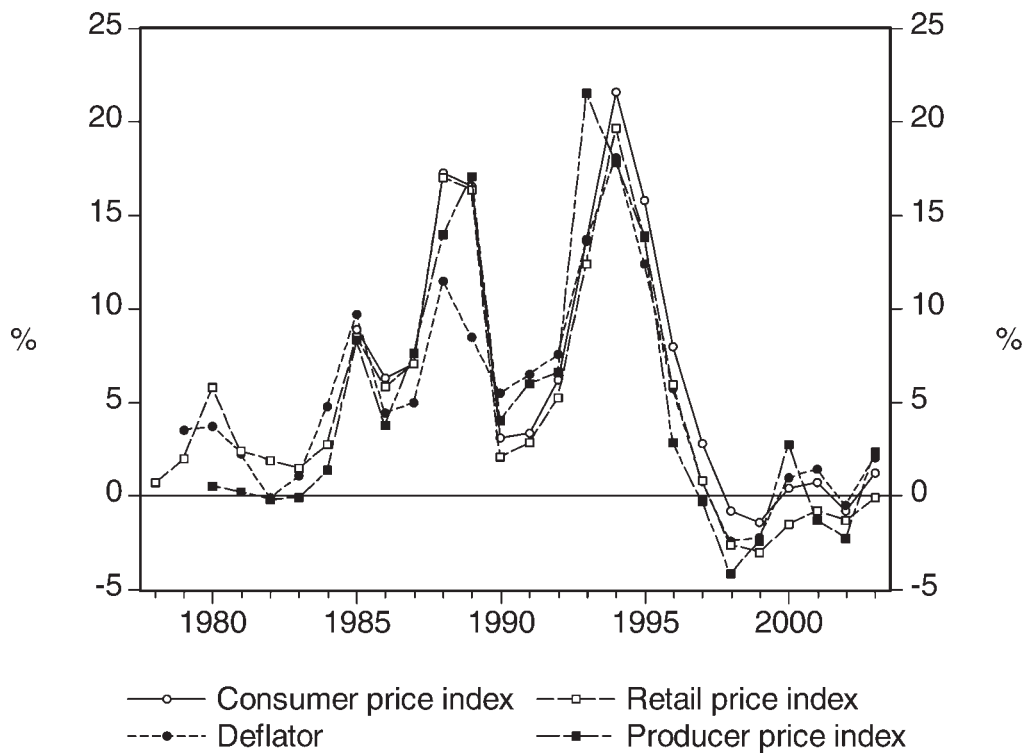
Figure 1
Alternative Measures of Inflation

Figure 2
Estimates of the the Growth Rate of Potential Output
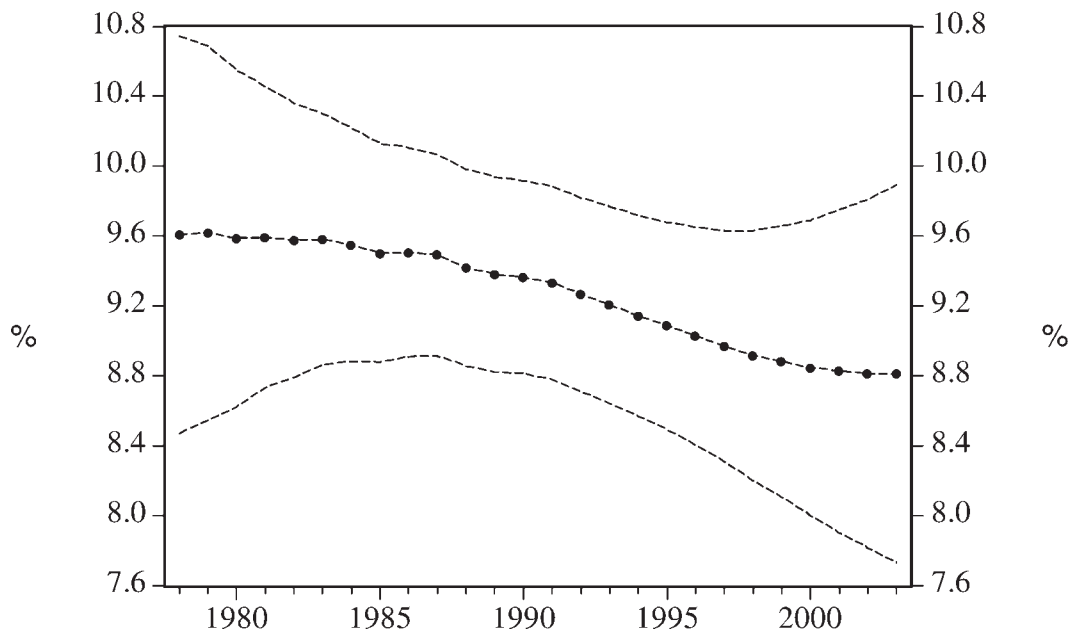(together with 95 percent confidence band)

Figure 3
Estimates of UCGAP
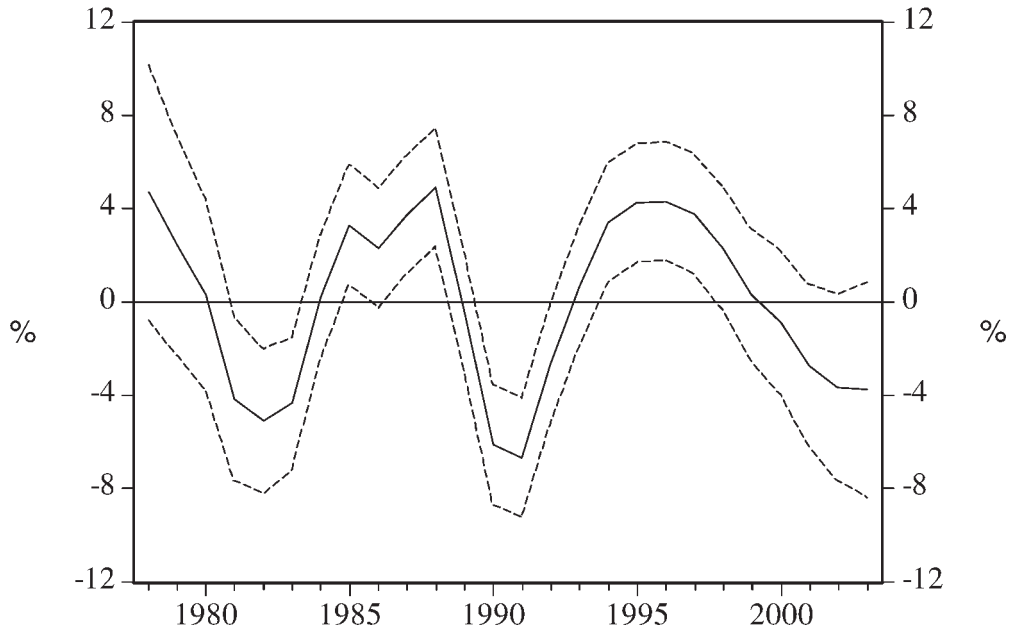(together with 95 percent confidence band)

Figure 4
HPGAP and TGAP
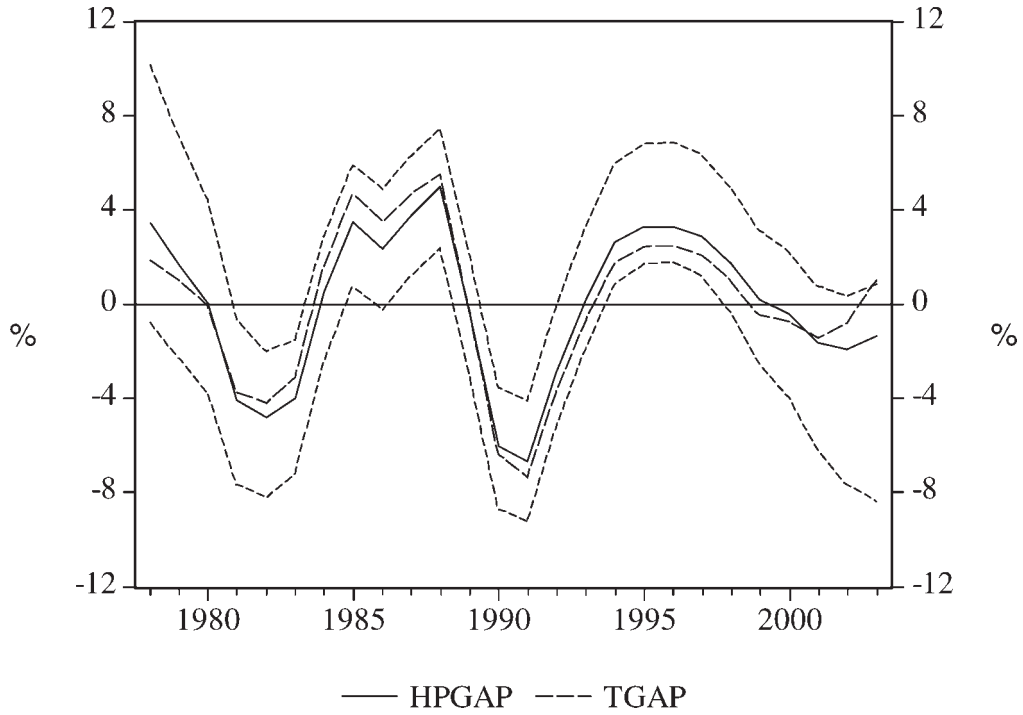(together with 95 percent confidence band from UCGAP)

—— HPGAP --- TGAP

Figure 5
Inflation and Unobserved Variable
(Using deflator)