# ความไม่แน่นอนของระดับศักยภาพการผลิตกับการดำเนินนโยบายการเงิน

## Uncertainty in the Estimation of the Potential Output and Implications for the Conduct of Monetary Policy


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# กลุ่ม 4: ความไม่แน่นอนของระดับศักยภาพการผลิตกับการดำเนินนโยบายการเงิน

ธนาคารแห่งประเทศไทย

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**สัมมนาวิชาการประจำปี 2551**

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*สายนโยบายการเงิน*

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ข้อคิดเห็นที่ปรากฏในบทความนี้เป็นความเห็นของผู้เขียน
ซึ่งไม่จำเป็นต้องสอดคล้องกับความเห็นของธนาคารแห่งประเทศไทย

**บทคัดย่อ**

จุดประสงค์สำคัญของการดำเนินนโยบายการเงินภายใต้กรอบเป้าหมายเงินเฟ้อคือการรักษาเสถียรภาพด้านราคาเพื่อให้เศรษฐกิจในระยะยาวขยายตัวสอดคล้องกับศักยภาพผลผลิต (Potential Output) นอกจากนี้ ความแตกต่างในระยะสั้นระหว่างผลผลิตที่เกิดขึ้นจริงกับผลผลิตตามศักยภาพ (Output Gap) เป็นเครื่องชี้สำคัญของแรงกดดันต่อระดับราคา กล่าวคือ หากผลผลิตที่เกิดขึ้นจริงสูงกว่าผลผลิตตามศักยภาพ การใช้ทรัพยากรในการผลิตจะเริ่มตึงตัวอันจะส่งผลต่อค่าจ้างแรงงานและอัตราเงินเฟ้อในที่สุด อย่างไรก็ดี ผลผลิตตามศักยภาพเป็นตัวแปรที่ไม่สามารถวัดได้โดยตรง ดังนั้น ความเข้าใจเกี่ยวกับผลผลิตตามศักยภาพและการประเมินระดับศักยภาพของเศรษฐกิจไทยจึงเป็นสิ่งสำคัญในการดำเนินนโยบายการเงินภายใต้กรอบเป้าหมายเงินเฟ้อ

บทความนี้ศึกษาแนวทางในการดำเนินนโยบายการเงินภายใต้ภาวะที่ความไม่แน่นอนของการประเมินศักยภาพการขยายตัวของเศรษฐกิจไทยมีแนวโน้มเพิ่มสูงขึ้นจากความผันผวนของสภาพแวดล้อมทางเศรษฐกิจและการเงินโลกในปัจจุบัน โดยกรอบของการศึกษาจะเน้นที่ปัญหาของความไม่แน่นอนในการวัดศักยภาพผลผลิตของเศรษฐกิจ และแนวทางในการจัดการกับปัญหาดังกล่าวของธนาคารกลางในต่างประเทศทั้งในทางทฤษฎีและปฏิบัติ

* ผู้เขียนขอขอบพระคุณ ดร. อัจนา ไวความดี ดร. ดวงมณี วงศ์ประทีป และผู้ร่วมสัมมนาเชิงปฏิบัติการที่ธนาคารแห่งประเทศไทยทุกท่านที่ให้ข้อคิดเห็น และข้อเสนอแนะที่เป็นประโยชน์อย่างยิ่งต่องานวิจัยฉบับนี้ และขอขอบคุณสำหรับทุกกำลังใจที่ช่วยสนับสนุนให้งานวิจัยนี้สำเร็จลงด้วยดี

Bank of Thailand

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# Uncertainty in the Estimation of Potential Output and Implications for the Conduct of Monetary Policy

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*The views expressed in this paper are those of the authors and do not necessarily represent those of the Bank of Thailand.*

**Abstract**

This paper looks at the implications of uncertainty in potential output estimation for the conduct of monetary policy. Our findings of potential output and the output gap for Thailand are based on commonly used methods such as the Hodrick-Prescott filter and unobserved component models. Estimation problems associated with real-time data, parameter uncertainty, and model uncertainty are investigated. In dealing with such uncertainties, we review various solutions from both theoretical and practical aspects of monetary policy design.

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## บทสรุปสำหรับผู้บริหาร

## ความไม่แน่นอนของระดับศักยภาพการผลิตกับการดำเนินนโยบายการเงิน

จุดประสงค์สำคัญของการดำเนินนโยบายการเงินภายใต้กรอบเป้าหมายเงินเฟ้อคือการรักษาเสถียรภาพด้านราคาเพื่อให้เศรษฐกิจในระยะยาวขยายตัวสอดคล้องกับผลผลิตตามศักยภาพ (Potential Output)

เมื่อกล่าวถึงโดยทั่วไป ผลผลิตตามศักยภาพหมายถึงระดับผลผลิตสูงสุดที่ระบบเศรษฐกิจสามารถผลิตได้อย่างยั่งยืนโดยใช้ทรัพยากรที่มีอยู่ทั้งหมดอย่างเต็มที่ ดังนั้น ผลผลิตตามศักยภาพในที่นี้จะถูกกำหนดโดยปัจจัยการผลิต (แรงงานและทุน) และเทคโนโลยี (ประสิทธิภาพในการนำแรงงานและทุนที่มีอยู่มาใช้ในกระบวนการผลิต)

สำหรับในแง่ของการดำเนินนโยบายการเงิน ผลผลิตตามศักยภาพหมายถึงระดับผลผลิตที่ระบบเศรษฐกิจสามารถผลิตได้โดยไม่สร้างแรงกดดันต่อภาวะเงินเฟ้อ นิยามนี้สอดคล้องกับนิยามเบื้องต้นหากแต่กล่าวในบริบทของนโยบายการเงินที่มุ่งเน้นที่การรักษาเสียรภาพด้านราคาผ่านการดูแลอัตราเงินเฟ้อให้อยู่ในระดับต่ำและไม่ผันแปรจนเกินไป กล่าวคือ หากผลผลิตที่เกิดขึ้นจริงสอดคล้องกับผลผลิตตามศักยภาพ การใช้ทรัพยากรในการผลิตก็จะเป็นไปอย่างพอดีโดยไม่สร้างแรงกดดันต่อระดับราคา หากผลผลิตที่เกิดขึ้นจริงสูงกว่าผลผลิตตามศักยภาพ การใช้ทรัพยากรในกระบวนการผลิตจะเริ่มตึงตัว (เช่น ลูกจ้างต้องทำงานล่วงเวลา เครื่องจักรต้องทำงานเกินกำลังการผลิต) ทำให้ต้นทุนการผลิตปรับสูงขึ้นและสร้างแรงกดดันต่อภาวะเงินเฟ้อในที่สุด

ความแตกต่างในระยะสั้นระหว่างผลผลิตที่เกิดขึ้นจริงกับผลผลิตตามศักยภาพ (หรือที่รู้จักในชื่อของ Output Gap) จึงเป็นเครื่องชี้สำคัญของแรงกดดันต่อระดับราคา โดยสรุปแล้ว หาก Output Gap เป็นบวกในขณะที่ปัจจัยอื่นๆ คงที่ นั่นก็หมายความว่าอัตราเงินเฟ้อมีแนวโน้มที่จะเร่งสูงขึ้น ดังนั้น ความเข้าใจเกี่ยวกับผลผลิตตามศักยภาพและการประเมินระดับศักยภาพของเศรษฐกิจไทยจึงเป็นสิ่งสำคัญในการดำเนินนโยบายการเงินภายใต้กรอบเป้าหมายเงินเฟ้อ

อย่างไรก็ดี ผลผลิตตามศักยภาพเป็นตัวแปรที่ไม่สามารถวัดได้โดยตรง หากแต่ต้องประยุกต์ทฤษฎีเศรษฐศาสตร์ต่างๆ อาศัยแบบจำลองที่ตั้งอยู่บนสมมติฐาน อิงข้อมูลที่อาจมีความคลาดเคลื่อนในการจัดเก็บ ประกอบกับการใช้ดุลยพินิจในการประเมินภาวะเศรษฐกิจ ดังนั้น ความไม่แน่นอนของการประเมินศักยภาพการขยายตัวของเศรษฐกิจจึงเป็นสิ่งที่หลีกเลี่ยงไม่ได้ ซึ่งจะมีนัยต่อการกำหนดนโยบายการเงินที่เหมาะสมต่อไป

บทความนี้ศึกษาแนวทางในการดำเนินนโยบายการเงินภายใต้ภาวะที่ความไม่แน่นอนของการประเมินศักยภาพการขยายตัวของเศรษฐกิจไทยมีแนวโน้มเพิ่มสูงขึ้นจากความผันผวนของสภาพแวดล้อมทางเศรษฐกิจและการเงินโลกในปัจจุบัน โดยกรอบของการศึกษาจะเน้นที่การสร้างความเข้าใจเกี่ยวกับผลผลิตตามศักยภาพของเศรษฐกิจ วิธีต่างๆ ที่ใช้ในการประมาณการ ปัญหาและที่มาของความไม่แน่นอนในการวัดศักยภาพผลผลิตของเศรษฐกิจ และแนวทางในการจัดการกับปัญหาดังกล่าวทั้งในทางทฤษฎีและปฏิบัติ รวมถึงนัยต่อการดำเนินนโยบายการเงินภายใต้ความไม่แน่นอนดังกล่าว เพื่อให้การรักษาเสถียรภาพด้านราคาเป็นไปอย่างมีประสิทธิภาพมากที่สุด

# Executive Summary
# Uncertainty in the Estimation of Potential Output and Implications for the Conduct of Monetary Policy

Serious discussions of monetary policy often involve the notion of potential output or potential GDP. Conceptually, potential output is the level of output that can be sustained for an extended period without exerting upward or downward pressure on inflation. When the actual level of output is above (below) potential output, inflation tends to rise (fall). Estimates of the future path of potential output are therefore central to monetary policy strategy.

Unfortunately, potential output estimation is plagued with uncertainty, be noisy information, model misspecification, or inefficient forecasting. History has shown vividly how the use of an incorrect estimate of potential output resulted in an undesirable policy outcome for the world's most advanced central bank. Overoptimistic assessments of the U.S. output gap during the oil shocks of the 1970's led the Federal Reserve to use accommodating monetary policy when potential output was deteriorating which in turn resulted in runaway inflation after the oil prices had subsided. The U.S. subsequent disinflation experience took about four years at a cost of the severe 1981-2 recession.

Looking at the current situation in Thailand where oil prices and political uncertainty may have affected the economy's potential output, inflation expectations remain high, and there are pressures on the Bank of Thailand to pursue accommodative monetary policy to shore up the slowing economy, an important policy question is where the economy is relative to its potential. In this paper, we employ two most common potential output estimation methods to answer this question. Our results show the Thai economy in the middle of 2008 operating at its estimated potential with estimated medium-term potential GDP growth of about 5.2-5.3%.

Overall, our findings point against an excessively loose monetary policy stance in the current environment. A prolonged period of a negative real policy rate is generally bad for inflation expectations. Furthermore, we cannot disregard the possibility that the economy's potential output may be lower than our estimates, for ex ante potential output overestimation often does not manifest itself until a few years have passed after the initial supply shock. It would be unfortunate if we repeat the policy mistake of the past and fall prey to a vicious cycle of rising inflation and expected inflation.

# Uncertainty in the Estimation of Potential Output and Implications for the Conduct of Monetary Policy

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**Abstract**

This paper looks at the implications of uncertainty in potential output estimation for the conduct of monetary policy. Our findings of potential output and the output gap for Thailand are based on commonly used methods such as the Hodrick–Prescott filter and unobserved component models. Estimation problems associated with real-time data, parameter uncertainty, and model uncertainty are investigated. In dealing with such uncertainties, we review various solutions from both theoretical and practical aspects of monetary policy design.

## 1 Introduction

Serious discussions of monetary policy often involve the notion of potential output or potential GDP, an abstract concept that plays an important role in modern monetary policy conduct. This is because knowledge of where the economy's actual output is relative to its potential output, the so-called output gap, can provide policymakers with valuable information about the underlying inflation pressure and hence an appropriate monetary policy stance.

Unfortunately, potential output is not observable and has to be estimated. Today, there are more than a dozen methods to estimate the economy's potential output. In general, the existence of a variety of methods would pose no problem if these methods were to give similar values of potential output estimates. But occasionally different methods yield different results and therefore different implications for policy. Since no consensus exists yet as to which method yields the correct measure of potential output, deciding on which estimate to believe and to act upon is a challenge for central banks in advanced and developing economies alike. Moreover, all of the existing methods to potential GDP estimation appear to be susceptible to the problem of real time data. That is, this quarter's estimates of the economy's potential GDP using today's data are often different from this quarter's estimates of the economy's potential GDP using data two years from now.

The unreliability of real-time potential output estimates is most dangerous in periods with large changes in potential output that are only gradually detected. Expanding on a point made by Kuttner (1992, 1994), Orphanides (2001, 2003a, b) argues forcefully that the Federal Reserve's overoptimistic estimation of the U.S. potential GDP during the oil shocks of the 1970's had led to policy that was, in retrospect, too expansionary, which in turn aggravated the inflation situation at the time. The subsequent disinflation effort, known memorably as the Volcker disinflation for the newly-appointed Federal Reserve Chairman at the time, took about four years at a cost of the 1981–82 recession which was the most severe in the post-World War II period.

More recently, Phelps (2008) warns that four structural changes have contributed to an increase the U.S. economy's natural rate of unemployment (equivalent to a reduction in the U.S. economy's potential output) and that the FOMC's decision to keep the federal funds rate low in the face of rising inflation is a major policy mistake. In particular, Phelps argues that the current downturn in U.S. employment is not a result of insufficient aggregate demand but a natural consequence of the economy's shifting structure. Because the weakening employment is not a demand problem, keeping the policy rate low will merely postpone the rise in unemployment. On the other hand, it will fuel inflation expectations, causing inflation to further accelerate. As Phelps sees it, the Federal Reserve is once again underestimating the U.S. economy's natural rate of unemployment (that is, overestimating the U.S. economy's potential output in the context of this paper).

Looking at the current situation in Thailand, where inflation expectations remain high and there are pressures on the Bank of Thailand to pursue accommodative monetary policy to shore up the slowing economy, an important policy question is where the economy is relative to its potential. Supply-side indicators, particularly the labor market ones, seem to indicate that the economy may already be operating above its potential. Measurement issues aside, it is difficult to imagine the unemployment rate to stay at a little above one percent over the long run. Moreover, one cannot disregard the possibility of a decline in the economy's potential output. During the past few years, the energy-inefficient economy has experienced persistent increases in energy prices and political uncertainties that deterred both private and public investment. All of these represent adverse shocks to the economy's potential output. Thus, an economic slowdown expected by many people for the second half of this year might simply reflect the economy's adjustment to a lower potential path rather than a sign of insufficient aggregate demand. If this is the case, a continuation of the negative real policy rate may lead to the repeat of the U.S. experience in the late 1970s where the subsequent disinflation effort was extremely costly.

Against this backdrop, this paper employs several of the most common methods to estimate Thailand's potential output and, in some cases, also the economy's medium-term potential growth. Several issues surrounding estimation uncertainty are explored. Our goal is to raise awareness of their implications to monetary policy conduct and to provide an additional basis for informed policy decision.

The rest of the paper is organized as follows. Section 2 discusses in detail the concept of potential output and its use in modern monetary policy conduct along with an overview of the different methods to estimate the economy's potential output and problems in estimation. Section 3 then presents estimates of Thailand's potential GDP and/or potential GDP growth using the Hodrick–Prescott filter method, the unobserved component model method, and the production function method, as well as the use of real unit labor cost as an alternative measure to the output gap. The problem of real-time information is illustrated using the HP filter method; the use of unobserved components models also allows us to investigate the issues of parameter uncertainty and model uncertainty. Section 4 reviews both the theoretical and practical solutions to uncertainty in potential output estimation. Section 5 provides an assessment of the recent development of the output gap given the latest data available. Finally, Section 6 concludes. Appendix A evaluates some of the theoretical proposals in Section 4 in the context of a small open economy.

## 2 Potential Output and Monetary policy

A central bank's responsibility is often stated explicitly as to preserve price stability and output stabilization. In order to fulfill these objectives, any economic data which help to predict or contain information on inflation are essential.

Potential output is one key variable which can be used, together with the actual level of output, to predict inflation. Given the fact that potential output reflects the potential supply of an economy, any level of output beyond the potential level creates upward pressures on prices while an output level below the potential induces downward pressures on prices. Potential output is therefore a conceptual level of output in the absence of upward or downward inflationary pressures.[1] Viewed in this way, the output gap (measured as the percentage deviation of actual output from the potential level) can be regarded as excess demand. Intuitively, when output is above the potential level (positive output gap), spare capacity and resources such as labor and raw materials become scarcer. Consequently, wages and prices of raw materials tend to rise which in turn cause a further rise in prices, holding things like inflation expectations and supply factors constant. On the contrary, when output is below the potential level (negative output gap), spare capacity can be used up without creating much inflationary pressures.

The concept of potential output is often referred to as the "speed limit" of the economy. As one may be fined for driving too fast, the speeding economy is fined by inflation.[2] Since the speed limit is there for a reason; to prevent accident, driving the economy above the potential limit for a long period is bounded to end up with a large dislocation.

Regarding the positive (negative) output gap as excess (insufficient) demand has a significant implication for the conduct of monetary policy. Since monetary policy is primarily a demand management tool, it should aim at eliminating excess demand (filling up demand when lacking it). Monetary policy should therefore be tightened (eased) when the output gap is positive (negative) to preserve price stability. Depending on the central bank's preferences, how aggressively should monetary policy respond to the output gap determines the fashion in which output will stabilize.

### 2.1 Potential output: level and growth

It is important to distinguish between the level of potential output and the growth rate of potential output. Unless the economy is already at its potential level, closing the output gap to preserve stable inflation implies that the economy would have to grow either faster than potential growth in some periods or slower than potential growth rate in others. In the simplest scenario, if the economy is operating below its potential such that inflation tends to fall, to close

[1] A more theoretical definition of potential output is defined as the level of output when all prices and wages are fully flexible. Therefore, the gap between actual output and potential output reflects the extent of price and wage rigidities that prevents the economy from adjusting to the efficient (potential) level of output.

[2] Other undesirable conditions such as a budget deficit, asset price booms, and a deterioration of the balance of payment can also occur simultaneously.

the gap, output must grow at a rate higher than the growth rate of potential output for some time. In contrast, for an economy operating above its potential, causing inflation to rise, it will have to grow at a rate lower than its potential growth rate to restore constant inflation.

Holding other factors such as inflation expectations constant and assuming for the time being that temporary supply shocks are absent, the implication for monetary policy under different circumstances are shown in Table 1.

Table 1: Output gap and its implication on monetary policy

| **Scenario** | **Inflationary pressures** | **Monetary policy** | **Implication for GDP growth** |
|---|---|---|---|
| GDP > potential output | Rising | Tightening | Below potential rate temporarily |
| GDP < potential output | Falling | Accommodating | Above potential rate temporarily |
| GDP = potential output | Constant | Neutral | Kept constant at potential rate |

## 2.2 Output gap is not the whole story on inflation

The output gap is not the only determinant of inflation. Recent literature since Clarida, Galí, and Gertler (1999) has geared towards the New Keynesian Phillips curve which expresses the determinants of inflation in three components: (1) expected inflation; (2) the output gap; and (3) the cost-push shock which sometimes referred as a "markup shock" as follows:

$$\pi_t = \alpha\pi_t^e + \beta\left(y_t - y_t^*\right) + \mu_t. \tag{1}$$

Inflation, expected inflation, actual output, potential output, and the cost-push shock at time $t$ are denoted as $\pi_t$,$\pi_t^e$, $y_t$, $y_t^*$, and $\mu_t$ respectively. The Phillips curve implies that when the output gap is zero and no cost-push shock is present, inflation is constant and equal to the expected inflation times some parameter, $\alpha$.

Inflation expectations play an important role in determining actual inflation. Intuitively, despite having output at its potential level, if workers expect higher wages while firms can increase their prices then inflation can be a self-fulfilling phenomenon. In practice, the form of inflation expectations is uncertain but it has a crucial implication on monetary policy. If economic agents expect future inflation to be the same as last period (i.e., backward-looking expectation), then inflation tends to be more persistent. In this case, disinflation to reduce expected inflation is costly in terms of output loss. On the other hand, if economic agents have a forward-looking expectation and believe that the central bank will ensure price stability, then high inflation will be less likely to persist as expected inflation become lower in the next period. In this case, the central bank's credibility has an important role in shaping the expectations and can make disinflation less costly.

The parameter $\beta$, or the slope of the Phillips curve, measures the sensitivity of inflation to the output gap. A larger value of $\beta$ implies that disinflation is easier since it requires a small contraction in output to reduce inflation. However, it also means that inflation would rise more proportionately for a given (positive) output gap. Knowing the slope of the Phillips curve is therefore essential for the conduct of monetary policy.

The cost-push shock, $\mu_t$, reflects determinants of marginal cost that do not move proportionately with the output gap. To see this, note that the Phillips curve as originally derived from a stylized fully-optimizing New Keynesian model has inflation related to real marginal cost as:

$$\pi_t = \alpha \pi_t^e + \delta rmc_t$$

where $rmc_t$ denotes the deviation of real marginal cost from its steady-state value. Thus, there is a positive relationship between real marginal cost and the output gap as can be expressed by $rmc_t = \kappa (y_t - y_t^*) + \mu_t$. When the output gap is positive, resources are scarcer and costly, hence real marginal cost tends to rise. In contrast, when the output gap is negative, real marginal cost tends to fall. When $rmc_t$ is defined as product wage over marginal product of labor—see for example Clarida, Galí, and Gertler (2001)—$\mu_t$ is often specified as the wage markup. A cost-push or a markup shock breaks down the positive relationship between output gap and inflation. For example, an increase in the markup would cause prices to rise with less output being produced. This type of shocks hinders economists to identify the source of inflation and as a result an estimated coefficient on the output gap could be misleading.

### 2.3 Factors affecting the output gap

Since the output gap is jointly determined by actual output and potential output, any factor affecting these two variables will affect the output gap. Demand shocks, such as a shift in confidence or a change in external demand, affect actual output. Supply shocks such as an oil price shock are somewhat more controversial, as it affects both the demand for output and the potential supply of the economy. Aggregate demand would be dampened from a less spending power. At the same time, uncertainty about the future outlook induced by the oil shock may reduce investment, and a lower growth rate of capital stock implies a reduction in the potential growth rate of the economy. Total factor productivity (TFP) may be lowered as a result of resource reallocation which becomes less efficient compared with the pre-shock period. Furthermore, if real wage rigidity exists—workers tend to refuse to accept a lower real consumption wage—firms will hire less, leading to a lower level of full employment and a lower potential output. Because actual and potential are both reduced, the net affect on the output gap is unclear.

Another important issue deals with whether economic shocks are temporary or permanent. For example, a temporary supply shock such as an undesirable weather condition would be captured in the cost-push shock since its temporal nature does not imply a loss in potential output. As mentioned earlier, cost-push shocks in this case would create a negative relationship between the output gap and inflation in the short run.

### 2.4 Problems and challenges in potential output estimation

The fact that potential output is unobservable poses much challenge for policy markers. A wrong estimation could lead to a bad policy response that amplifies the business cycle. Orphanides (1999) shows that high inflation in the U.S. during 1970s was the result of overestimating productivity growth, hence depicting a more negative output gap. The policy respond would have been different if estimates were more precise at the time. Below is the list on why getting a correct estimate of potential output is a challenge.

**Model inadequacy.** Estimated models do not capture or distinguish between demand shock and supply shocks. Isolating demand shocks from supply shocks can be difficult when demand and supply shocks are not independent from each other. Many estimates are based upon a few variables which may not be adequate. Availability of long series data is a big constraint in selecting a model specification.

**Different methods give different results.** Each method has its own advantages and disadvantages. They can often give opposite results and difficult to assess Edge et al. (2007) find

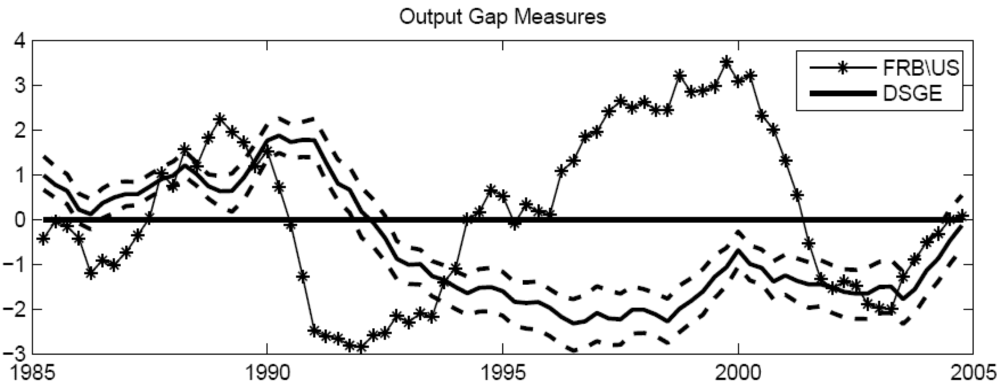


Figure 1: Estimate of the U.S. output gap (Edge et al., 2007)

that output gap using a dynamic stochastic general equilibrium model depicts a very different picture for the U.S. economy compared with that from the production function approach used by the Federal Reserve Board (see figure 1). For a similar point in the case of Thailand's potential output estimates, see Chantanahom et al. (2002). A brief summary of different approaches is discussed in the next section.

**Cost push shocks undermine the usual relationship between output gap and inflation.** Cost push shocks usually originate from a temporary supply shock that does not affect potential output. However, if these shocks persist, potential output could be affected. Whether a shock is temporary or permanent may not be certain.

**Revision of real time data.** Real-time data are often revised when all information is available later in time. Estimates of potential output can be different when revised data is used. This problem is more severe for methods that is sensitive to the end-sample of the data such as the Hodrick–Prescott filter. Pointing that policy decisions are made with real-time data, not the revised data, Orphanides (1999, 2001) argues that monetary policy response would look different when revised data are used. Figure 2 shows the extent of real-time revision of the U.S. output gap estimate.

## 2.5 A brief review of different methodologies

A good overview of different estimates on potential output is discussed at length in Chagny and Döpke (2001). This section briefly discusses, in a nontechnical context, the five common approaches: (1) the Hodrick–Prescott filter; (2) unobserved component models; (3) structural vector autoregressions; (4) production function models; and (5) dynamic stochastic general equilibrium models.

**The Hodrick–Prescott filter.** This is a smoothing method such that trend values are chosen to minimize (1) the distance between the actual value and the trend value; and (2) the change

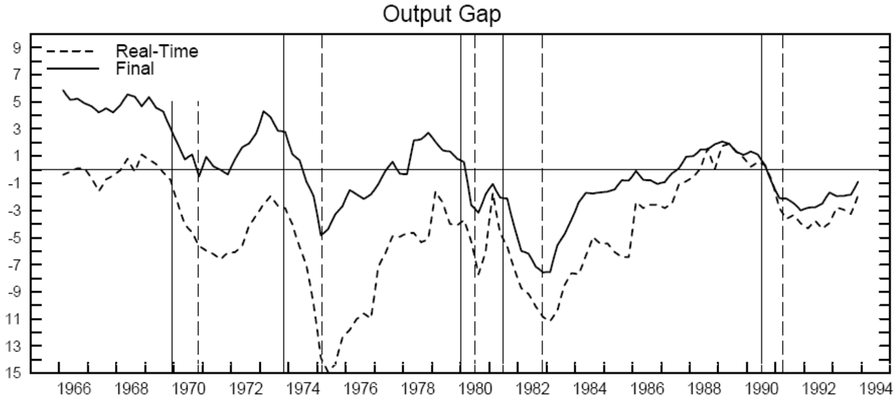


Figure 2: Real-time revision of the output gap estimate (Orphanides, 1999)

in the trend values of the time series data. The obtained trend value of GDP can be regarded as potential output.

This method is widely used because of its simplicity. Only a time series of GDP data is required and estimates can be obtained quickly using a computer software. However, two main disadvantages are as follows. First, potential output depends on the smoothing parameter which can be manipulated. Second, estimates towards the end of the series are sensitive to the end point value. The latter is known as the end-sample problem. Because of these drawbacks, the HP filter is cost-effective to investigate historical potential output but may fail to project recent trend values correctly. This is somewhat unfortunate since a central bank's interest falls upon most recent values of potential output—not its historical values.

**Unobserved component models.** Unobserved component models make use of the state–space model and the Kalman algorithm to derive the trend values of GDP and the output gap. The idea of a state–space model is that an observable time series can be broken into various unobservable components. These unobservable components are linked to transition equations which consist of observable variables. Using the Kalman filter, the unobserved components can then be estimated subject to all specified equations.

This method can be highly complex depending on the specification of the measurement equation and the transition equation. The smoothness of the trend GDP also depends on some parameters that need to be specified.

**Structural vector autoregressions.** The use of structural vector autoregressions (SVARs) to estimate potential output was pioneered by Blanchard and Quah (1989). In general, SVARs impose structural relations into a system of economic equations by restricting the dynamic response of economic variables to economic shocks. These restrictions can also be applied to the "shock" term. To estimate potential output, a long-run restriction is imposed such that demand shocks are transitory while the supply shocks are permanent. Potential output can be constructed as the cumulative sum of past supply shocks while the output gap is captured by the transitory shocks.

This method blends economic theory with statistical techniques, but has one main disadvantage from the implication of long-run restriction. In particular, the use of demand shocks to construct output gap implies that supply shocks have identical effects on potential output and actual output even in the short run.

**Production function models.** The production function approach is one of the most widely used since potential output obtained in this way takes account of factors of production. A Cobb–Douglas production comprises total factor productivity, labor input, and capital input. The idea is that potential output depends on the natural level of input quantities (factors of production) and input quality (TFP).

This method requires an estimation of TFP, the natural levels of employment and capital which are usually derived from the Solow residual, the estimated non-accelerating inflation rate of unemployment (NAIRU), and capacity utilization. Therefore, estimated potential output in this case depends on other unobserved variables. This is a major drawback.

**Dynamic stochastic general equilibrium (DSGE) models.** This model, based explicitly on microeconomic foundation, projects potential output by solving firms' and households' optimization problems with various assumptions on economic agents' preferences. Unlike the real business cycle models, a DSGE model allows for nominal rigidities and market imperfections. Potential output can be artificially constructed as the efficient level of output when all prices and wages are fully flexible.

This method is theoretically elegant but highly complex. Potential output estimated from DSGE models is very model dependent, and some features of potential output derived in this way are different from the conventional one. In particular, potential output produced by the DSGE model can be volatile rather than smooth as in other conventional methods.

# 3 Estimating Potential Output and the Output Gap

In this section we discuss estimation of potential output and the output gap for the Thai economy using some of the methodologies outlined above. First, we present findings of the long-term growth rate of potential output using the production function as well as infer the output gap using information from real marginal cost. Then we explore in details the HP filter and the unobserved components model to estimate potential output and the output gap simultaneously.

## 3.1 The production function method

This section summarizes findings on Thailand's long-term potential growth rate by Chuenchoksan and Nakornthab (forthcoming). By projecting future growth rates of working hours and productivity, future potential growth rate can be obtained. The growth rate of hours worked is forecasted based on projected population data, while productivity growth is forecasted subject to different scenarios. Key findings for the balance growth path scenario in which capital and output grow at the same rate are shown in table 2. From 2008 to 2015, Thailand's potential GDP is projected to grow between 5.5–6.1 percent on average. By 2026−2035, the potential GDP growth rate will likely fall below 5.4 percent due to ageing population. Chuenchoksan and Nakornthab (forthcoming) also highlight the importance of investment in obtaining the above projection. In particular, Thailand must raise the rate of real gross investment to real GDP from the current level of 22 percent to 28–30 percent (so things like mega-project investments are conceivably already included in the picture). Without the resuscitation of the investment rate, Thailand's potential growth rate going forward may be lower than projected.

Table 2: Projected potential growth by production function approach

| Average annual growth rate | 2000–07 | 2008–15$^E$ | 2016–25$^E$ | 2026–35$^E$ |
|---|---|---|---|---|
| Total hours worked | 1.4 | 0.5 | 0.1 | –0.2 |
| Labor productivity* | 3.5 | 5.0–5.6 | 5.0–5.6 | 5.0–5.6 |
| Real GDP | 5.0 | 5.5–6.1 | 5.1–5.7 | 4.8–5.4 |

*Balanced growth path scenarios. $^E$Estimates.

### 3.2 The real marginal cost approach

Prior to the use of DSGE models, empirical evidence of output gap, derived from a trend or a filter, were controversial in explaining inflation dynamics. Roberts (1995) finds a statistically significant, positive slope for the Phillips curve using the U.S. annual data while Estrella and Fuhrer (1999) find it insignificant when quarterly data are used. Galí, Gertler, and López-Salido (2001) find a negative slope with quarterly data for the U.S. and euro area. Sbordone (1998, 2001) argues that the New Keynesian Phillips curve performs better if real marginal cost[3] is used instead of the output gap. However, Neiss and Nelson (2002) claim that when the output gap is derived from a DSGE model rather than detrending, it does fit empirically well and therefore the Phillips curve based on the output gap should not be rejected. One implication from this is that real marginal cost is more closely related to the output gap when the latter is derived from a DSGE model. This is the motivation for using real marginal cost to proxy the output gap.

Since firms' costs fall heavily on labor wages, we follow Sbordone (2002) who uses real unit labor cost as a proxy for real marginal cost. Unit labor cost is defined as total nominal compensation over real GDP (i.e., cost of labor per real unit of output). Therefore, real unit labor cost is essentially the labor income share which can be easily estimated as total nominal compensation over nominal GDP. Compensation data are taken from the National Statistical Office.

Figure 3 shows the moving averages of estimates of the output gap when real unit labor cost is used, namely, one with the steady state approximated by the sample average (method 1) and the other with the steady state approximated by the HP trend (method 2). The four-quarter moving averages of both estimates suggest the output gap has been negative since 2007.

Although the four-quarter moving averages of the output gap estimates projected by this method are negative, they must be interpreted cautiously. It is important to realize that using real unit labor cost may not be a good proxy for real marginal cost if increases in oil prices also lead to increases in the wage markup. In general, firms charge a markup over marginal cost. If marginal cost captures only labor input cost which is the case with the unit labor cost, then any price increase while keeping labor cost constant will be captured in the markup term. Thus, increases in oil prices are captured by the markup shock which causes negative output gaps (see the comment above on the effects of the markup shock). If the markup shock does indeed exist, a negative output gap depicted by this method would be misleading.[4] Nevertheless, in 2008Q1, the gap seems to move towards a closing trend.

[3]In what follows, real marginal cost is short for the deviation of real marginal cost from its steady state value.

[4]It is possible that, during 2005–2006, oil price shocks did not have much impact on the markup since certain goods and services were subject to relatively tight price control by the Ministry of Commerce.

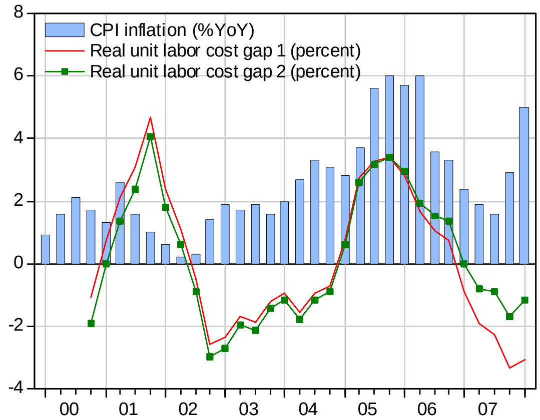


Figure 3: Estimates of the output gap based on real unit labor cost. Solid line: steady state approximated by sample average (method 1). Line with square markers: steady state approximated by HP filtered trend (method 2).

### 3.3 Hodrick–Prescott filtering

The most common techniques used to estimate potential output are based on univariate filters, which use information from the GDP time series only. This methodology assumes that output is independent of dynamics of other macroeconomic variables. The HP filter—perhaps one of the most well-known univariate filters—decomposes a series into a trend and a stationary component by solving the minimization problem:

$$\min_{y_t^*} \sum_{t=1}^{T} (y_t - y_t^*)^2 + \lambda \sum\nolimits_{t=2}^{T-1} \left[(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)\right]^2 \tag{2}$$

where $y_t$ is the observed output (in log) and $y_t^*$ is the unobserved potential output (also in log). The minimization problem is to find $y_t^*$ such that (1) it does not deviate much from $y_t$, as reflected in the first term in the objective function; and (2) its growth rate does not change much over time, as reflected in the second term in the squared brackets. In words, given a time series of actual output, we want potential output to be as close as possible to actual output, and at the same time want potential output growth not to vary much from one period to the next. That is, the solution to this minimization problem is a slowly moving trend that tracks actual output reasonably well. An important parameter in the above minimization problem is $\lambda$, which controls the degree of smoothness of the trend. A higher value of $\lambda$ leads to a smoother trend, as it gives a greater penalty on the variation in the trend growth rate.

The estimates of potential output and the output gap obtained from using the HP filter on the sample covering 1993Q1–2008Q1 are shown in figures 4–5. In the first figure actual output is denoted by the dashed line and the estimated potential output by the solid line. The second figure shows the resulting output gap estimate. The most striking feature of this figure is that, just prior to the 1997 financial crisis, output went beyond its potential by as much as 8 percent in the second and third quarters of 1996, before plunging to about $-9$ percent in 1998Q3. The output gap appeared to exhibit cyclical movements afterwards, with local maxima in early 2000

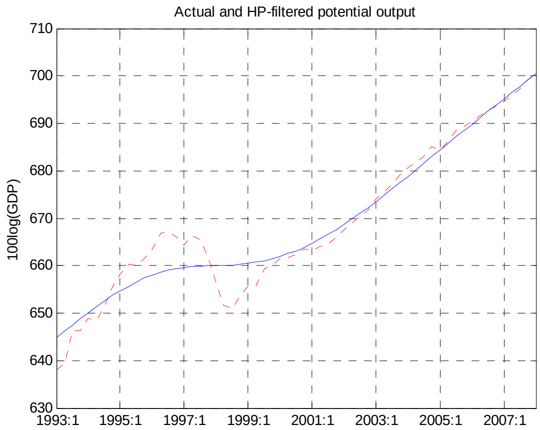


Figure 4: Output: dotted red line. Potential output: blue line.

and early 2004 and local minima in late 2001 and mid 2007. The output gap seemed to be close at the end of the sample period.

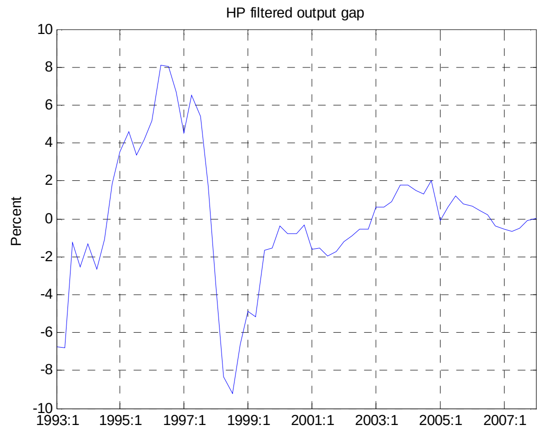


Figure 5: HP-filtered output gap

A caveat is in order. The end-point problem is a typical feature of two-sided filters, which include the HP filter. While one-sided filters use only past information, two-sided filters use both past and future information to compute the current value of the smoothed trend. Consequently, estimates at the end of the sample may be imprecise, as future values have yet to be realized. A corollary to the end-point problem is that the most recent estimates of potential output will almost always change as more data become available.

Figure 6 shows estimates of the output gap using the HP filter, with each line representing the estimate obtained as of the date indicated. The bottommost line is the output gap estimate as of 2006Q1. The next line above is the estimate as of 2006Q2 with the new data on 2006Q2 added; and so on. We see that there is a certain degree of uncertainty in the estimation using the

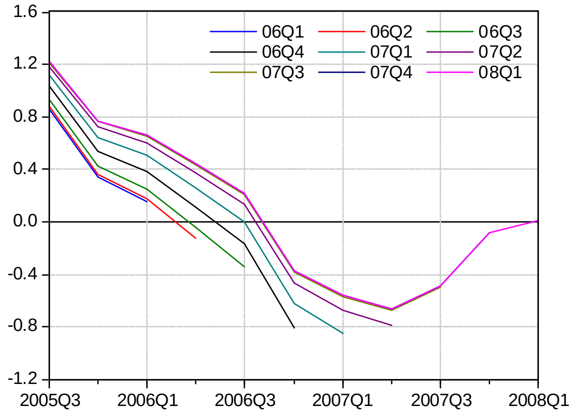


Figure 6: Revisions of output gap estimates using the HP filter. The vertical axis measures the output gap (in percent).

HP filter at the end of the sample. For instance, the 2006Q1 output gap estimated at different times varies as much as 0.5 percentage points, and so are the 2006Q2 and 2006Q3 estimates. Furthermore, the real-time estimate of the 2006Q3 output gap is about $-0.3$ percent, pointing to deflationary pressures in the economy. However, once more data are available, the estimate is revised up, and based on the data as of 2008Q1 the estimate of the 2006Q3 output gap turns out to be about 0.2 percent, which indicates inflationary pressures. With conflicting views on the output gap and the implications on inflationary pressures, an evaluation of monetary policy can be difficult. Although, with hindsight, the general *direction* of the output gap movements in 2006 points to the gap gradually approaching zero and finally becoming negative, such uncertainty in the point estimate arising from poor updating properties needs to be addressed somehow when using the HP filter.

**Conditional Hodrick–Prescott filtering**

One practical way in the policy environment to reduce the uncertainty of the point estimate at the end of the sample is to incorporate judgment in the form of constraints in the filtering problem. Additional information may come from staff economists or policymakers who have detailed knowledge of the economy and current conditions. For example, Butler (1996) imposes a long-run growth restriction on potential output at the end of the sample. Similarly, Conway and Hunt (1997) suggest the estimate of potential output to be tied to some constant growth rate toward the end of the sample period. Benes (2008) develops a Matlab-based toolbox that facilitates incorporating off-model information that is adopted in this section. Such informed judgments can usefully reduce uncertainty at the end point of the sample.

Figure 7 shows estimates of the output gap using the conditional HP filtering algorithm developed by Benes (2008). A judgment is imposed such that potential output grows at a specified rate at the end of each sample corresponding to the policymakers' belief about potential output growth in the next eight quarters starting from 2006Q1—in this case the annualized quarter-on-quarter rate of 5.3 percent, which is the average of the growth rates of the HP trend between 2006Q1 and 2008Q1, is chosen with the benefits of hindsight. The shaded area is enveloped by the lower bound (LB) and upper bound (UB) of the potential

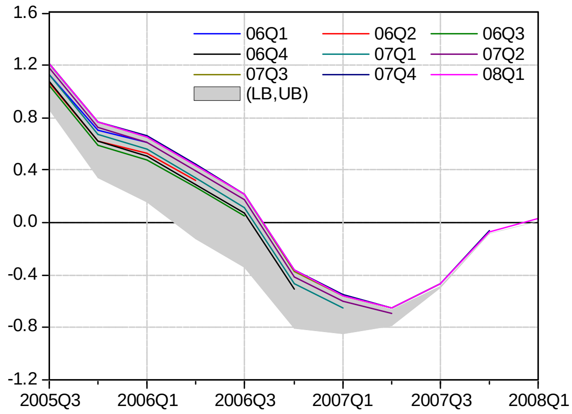


Figure 7: Revisions of output gap estimates using the HP filter with correct judgment The vertical axis measures the output gap (in percent).

output estimates obtained from the simple HP filter as shown in figure 6. Each line depicts the potential output estimate obtained from applying the conditional HP filter to each of the nine data vintages with 2006Q1,...,2008Q1 as end points. We see that, with judgment incorporated in filtering, the end-point problem associated with real time estimation has reduced compared with the case in which the HP filter is mechanically applied.

A sound judgment obviously matters in the conditional HP filtering problems. In the above case a judicious choice of the 5.3 percent growth rate is selected with the benefits of hindsight. Figures 8 and 9 show what happens if we tie down the end-of-sample growth rate of potential output at other rates. In figure 8 our projection of the average growth rate is 5.8 percent. Given that in the base case actual output is below potential output since 2006Q4, and that now the trend growth rate higher than that in the base case, potential output is higher, resulting in a more negative output gap relative to the baseline. In figure 9, with the projection of the growth rate being 4.8 percent per annum, the trend growth rate is lower than the baseline; potential output is lower and the output gap becomes less negative compared with the baseline. In sum, with the wrong judgments as shown in figures 8–9, we are always worse off than the correct judgment as shown in figure 7, and sometime even worse off than mechanically applying the HP filter.

To recap, the real-time estimation problem associated with the end point of the sample when applying the two-sided HP filter can be mitigated. By adding extraneous information in the form of a constraint to the minimization setup of the HP problem, one can reduce the uncertainty associated with the gap measures and as a result use the HP filter to get an estimate of the output gap. Nevertheless, the judgment to be imposed matters, and the important point is that, unless economists or policymakers have a very clear and valid view about the future trend, a more structural model is needed for the estimation of the output gap.

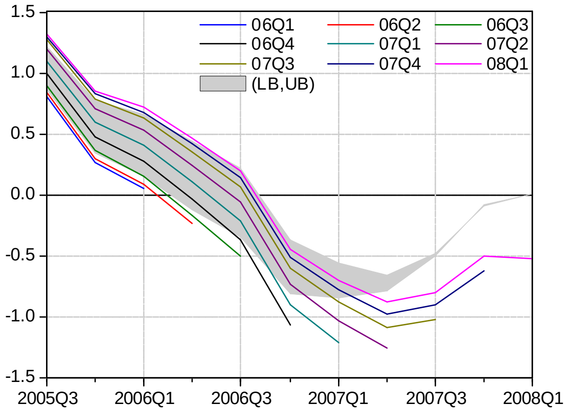


Figure 8: The HP filter with incorrect judgment: overprediction of potential growth. The vertical axis measures the output gap (in percent).

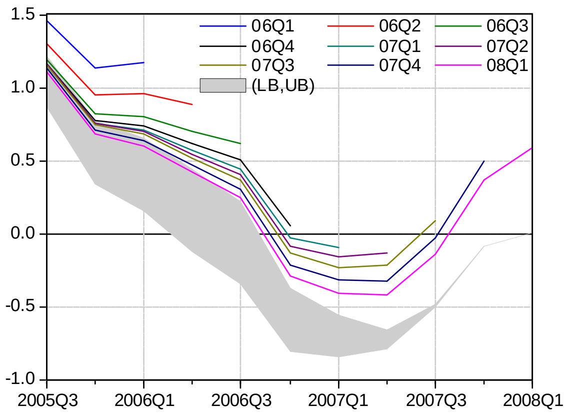


Figure 9: The HP filter with incorrect judgment: underrprediction of potential growth. The vertical axis measures the output gap (in percent).

### 3.4 Unobserved component models

In the estimation of potential output, unobserved component models combine a certain degree of economic theory with data on GDP and other related variables to estimate the most likely values of unobserved variables of the model of interest, namely potential output. For example, if we observe inflation accelerating, it is more likely that there is excess demand in the economy. That is, given this information on inflation, we are more confident that output is more likely to be above potential output. Although there are factors other than the output gap such as an energy price shock that drive inflation up, an observation that inflation is rising should lead us to give more weight to an inference that the output gap is positive.

A simple unobserved component model can be described as follows:

$$\begin{aligned}
y_t &= y_t^* + ygap_t && (3)\\
g_t &\equiv y_t^* - y_{t-1}^* && (4)\\
g_t &= g_{t-1} + \varepsilon_t^{trnd} && (5)\\
ygap_t &= \varepsilon_t^{ygap} && (6)\\
\pi_t &= \pi_t^* + \upsilon_t^{\pi} && (7)\\
\pi_t^* &= \pi_t^e + \gamma ygap_t + \varepsilon_t^{\pi}. && (8)
\end{aligned}$$

Model equations are of two types: measurement equations that link the observables with the unobservables, namely equations (3) and (7), and transition equations (or state equations) that describe the transition dynamics of the unobservables. Equation (3) states that output, $y_t$, which is observed, can be broken down into potential output, $y_t^*$, and the output gap, $ygap_t$ (both $y_t^*$ and $ygap_t$ not observed). According to equations (4)–(5), the growth rate of potential output, $g_t$, is a stochastic growth rate described by a random walk process, with $\varepsilon_t^{trnd}$ is the white noise shock. The output gap is determined by a random shock, $\varepsilon_t^{ygap}$, as shown in equation (6). Equation (7) links observed inflation, $\pi_t$, with unobserved underlying inflation, $\pi_t^*$, the difference between the two variables being the measurement error denoted by $\upsilon_t^{\pi}$. Given that potential output is the level of goods and services that an economy can supply without putting pressure on the rate of inflation, equation (8) is a key relationship from which we use information about the underlying inflation to make an inference about the unobserved variable $ygap_t$.

Three important advantages of using unobserved component models to estimate potential output are as follows.

**Data requirement.** Unobserved component models have a deeper economic foundation than a univariate approach in that it makes use of economic relationships in conjunction with data on output. At the same time using unobserved component models is far less demanding than the production function approach. As in equation (7) above, the additional data required in unobserved component models are usually well defined and well measured such as the inflation rate. This is in contrast with the estimation of potential output using the production function approach that requires data on labor, capital, and the total factor productivity (TFP)—all of which are subject to a considerable degree of measurement errors, especially data on the TFP. Benes and N'Diaye (2004) note that researchers attempting to apply the production function approach often use a univariate method to estimate the trend of productivity; as a consequence, not much is added to the confidence in potential output estimates obtained using the production function, even though this idea is useful in a general sense and indeed motivates the idea that there is some link between conditions in factor markets and potential output.

**Economic framework.** Economic relationships in the unobserved component models enable us to tell a story about potential output from a broader perspective in a more coherent framework relative to the univariate approach. Even in the simple unobserved component model above, not only do we get the estimates of potential output and the output gap, we are able to explain their movements in relation to inflation developments and other related variables—such as cyclical movements in output that is probably attributable to demand shocks, $\varepsilon_t^{ygap}$, or trend movements that are probably attributable to supply or technology shocks, $\varepsilon_t^{trnd}$. Furthermore, we can check whether the history of the inflation shock, $\varepsilon_t^{\pi}$, corresponds to our understanding of the Thai economy over the past.

**Sources of uncertainty in estimation.** In addition to the advantage in terms of data requirement, unobserved component models provide an appropriate framework to learn about the relative importance of several sources of uncertainty in the estimation. One can study the sensitivity of the potential output estimate with respect to different parameterizations in the model. For example, we want to know how much the estimate of the output gap would change if the slope of the Phillips curve turns out to be steeper than what we think (that is, $\gamma$ is higher); or what would happen if a higher proportion of supply shocks relative to demand shocks affect the economy (that is, the variance of $\varepsilon_t^{trnd}$ relative to that of $\varepsilon_t^{ygap}$ increases). Such uncertainty in the underlying structure of the economy affects potential output estimates, which have implications for the conduct of monetary policy. While the HP filter and the structural VAR may not have anything to say about uncertainty in the estimation, unobserved component models provide a consistent framework for studying this issue.

In what follows, we outline the model, present the resulting estimates, and discuss the results in conjunction with the various empirical findings on the Thai economy.

### 3.4.1 The model

The baseline model which builds on the simple unobserved component model is described below:

$$
\begin{aligned}
y_t &= y_t^* + ygap_t && (9)\\
g_t &\equiv y_t^* - y_{t-1}^* && (10)\\
g_t &= g_{t-1} + \varepsilon_t^{trnd} && (11)\\
ygap_t &= \phi^{ygap} ygap_{t-1} + \varepsilon_t^{ygap} && (12)\\
\pi_t &= \pi_t^* + \upsilon_t^{\pi} && (13)\\
\pi_t^* &= \omega^f \pi_{t+1}^* + \left(1-\omega^f\right) \pi_{t-1}^* + \gamma ygap_t + \varepsilon_t^{\pi}. && (14)
\end{aligned}
$$

Here output is defined as $y_t = 100 \times \log(\mathrm{GDP}_t)$ and output growth is the annualized quarter-on-quarter percentage change. Modifications of the simple model are described below.

The output gap in equation (12) is assumed to evolve according to a first-order autoregressive process. In effect we now add persistence to the movements of the output gap. Persistence is the extent to which shocks today have an effect on the future path of variables—in other words, how gradually shocks to macroeconomic variables dissipate over time. A model that correctly portrays the lagged time macro variables take before reverting to the long-term trend after being hit by shocks needs a certain degree of persistence.

Equation (14) is the hybrid New Keynesian Phillips curve. The structural explanation for such inflation dynamics is due to partial indexation in the forward-looking price setting framework. In each period only a certain fraction of firms are able to reset prices. Those that can will choose their prices optimally as a markup over real marginal cost, which is related to excess demand or the output gap. Those that cannot will simply set their prices equal to inflation in the previous period. The net result is a Phillips curve that has forward-looking and backward-looking elements, which explain observed inflation dynamics better than the purely forward-looking Phillips curve and has a deeper theoretical foundation than the model with completely backward-looking behavior.

### 3.4.2 Calibration

Our goal is to solve for the unobserved $y_t^*$ and $ygap_t$ (as well as other unobserved variables $g_t$ and $\pi_t^*$ and the three disturbances) given the data on observed variables ($y_t$ and $\pi_t$), the structure of the model described above, and model parameters. We can estimate the parameters; however, estimation potentially involves a number of complications, especially the possibility of a structural break inherent in the Thai data following the 1997 financial crisis. As a result, we choose to calibrate the model—that is, we select the values of parameters of the model based on empirical findings and our understanding of the Thai economy.

First, for the parameter governing the persistence of the output gap dynamics, we choose $\phi^{ygap} = 0.5$, which is close to the value found in Tanboon (2007) that is obtained from fitting the first-order autoregressive process for the HP-filtered output time series.

Second, in calculating potential output which is the smooth component of observed output, the variance of $\varepsilon_t^{ygap}$ relative to that of $\varepsilon_t^{trnd}$ is critical in determining the degree of smoothness of the potential output trend. If there is a high proportion of aggregate demand shocks, with supply conditions largely unaffected, then potential output does not necessarily move closely with the data on output, and it is appropriate to use a high degree of smoothing in the filter. If the shocks to the economy are primarily shocks to aggregate supply, then potential output is moving with the data, and a low degree of smoothing is appropriate. We view that demand shocks are dominant in driving real business cycles in the Thai economy. As often mentioned in several issues of the *Inflation Report*, potential and materialized risks to economic growth include (1) fluctuations in oil prices that depress economic activity; (2) shocks to domestic demand due to fragile consumer confidence and business sentiment; and (3) shocks to the export sector either due to softening in external demand or exogenous movements in trading partners' currencies vis-à-vis the domestic currency. We thus choose the ratio of the standard deviation of $\varepsilon_t^{ygap}$ relative to that of $\varepsilon_t^{trnd}$ to be 20 to 1. This ratio is in the range of plausible values commonly used in the literature. Benes and N'Diaye (2004) fix this ratio to 5; the corresponding value for the HP filter when recast the minimization problem in the state–space representation sets this ratio to 40.

Third, for the hybrid New Keynesian Phillips curve (14), the slope of the Phillips curve ($\gamma$) is calibrated to 0.2, which is close to the Bayesian estimate obtained by Chai-anant et al. (forthcoming) for a small New Keynesian model of the Thai economy. The value of $\omega^f$ is set to 0.3—expectation of future inflation tends to govern about 30 percent of current inflation—consistent with the average of estimates by Khemangkorn et al. (forthcoming) who use GMM as in Galí and Gertler (1999) to estimate the hybrid New Keynesian Phillips curve for the Thai economy.

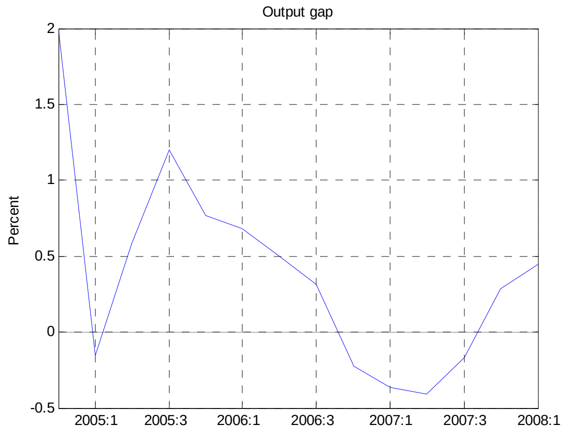


Figure 10: Preliminary estimate of the output gap

### 3.4.3 Results

**Initial (unconditional) results.** Preliminary results according to figure 10 suggest that the estimated output gap turned positive starting in 2007Q4. Moreover, figure 11 shows that the growth rate of potential output toward the end of the sample period tapers off to about 5 percent.

Although the growth of the Thai economy in 2007Q4 improved from previous quarters in line with the improvement in domestic demand—private spending picked up gradually, while public spending met its target given the acceleration in budget disbursement—we believe that the output gap perhaps remained slightly negative in this quarter, given that domestic demand was still in a recovery phase, and that consumer confidence and business sentiment remained fragile, as cautiously noted in the April 2008 *Inflation Report*. The fact that investment was relatively robust should lead to a higher potential output, thus lowering the probability that the output gap was positive this quarter.

Instead of mechanically applying the Kalman filter to the model, in what follows we will internalize the staff's understanding of the recent developments in the economy into the Kalman filtering problem of the unobserved component model. The algorithm we use is due to Benes (2008) and Benes, Binning, and Lees (2008). Instead of adding a sequence of shocks to the path of the variable on which we wish to impose judgment—in this case, the output gap—the algorithm searches the entire set of shocks with the minimum set of variance that returns the conditioned path of the output gap, in effect ensuring that the solution is indeed consistent with the model.

**Main results—conditional Kalman filtering.** In what follows we will incorporate an assessment that the economy was slightly below its potential in 2007Q4, conditioning the Kalman filtering problem subject to a discretionary estimate for the output gap in 2007Q4 of $-0.05$ percent. Key findings are summarized below.

*Potential output* and the *growth rate of potential output* can be seen in figures 12 and 13. Figure 12 shows actual output (dashed line, measured in units of $100\times \log(\text{GDP})$), along side

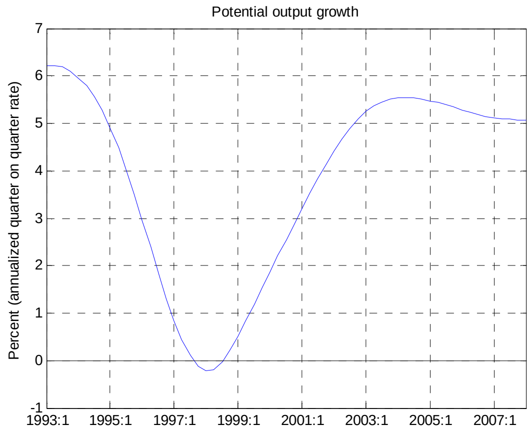


Figure 11: Preliminary estimate of the growth rate of potential output

with the estimated trend (solid line). Figure 13 plots a time series of potential growth, which is the first difference (or slope) of the solid line shown in figure 12. Overall, potential output grows at positive rates with the exception of 1997Q4–1998Q3 during which the growth rate of potential output registered negative and reached the lowest at −0.22 percent in 1998Q1. After that potential growth increases steadily and appears to converge to 5.2 percent toward the end of the sample period.

The *output gap*, which is the difference between actual output and potential output, is shown in figures 14 and 15 (the latter showing the recent development in the past two years). In figure 14 we see that, just prior to the 1997 financial crisis, GDP is above the estimated potential output by about 7.5 percent. At the trough of the crisis output registered approximately 9 percent below potential; after that the output gap gradually approached zero in early 2000 before moving away and remaining in the negative territory until early 2003. Since then until mid 2006 output was above potential except for 2005Q1 due to the tsunami fallout. Recently, as shown in figure 15, the output gap appeared to be negative between late 2006 and late 2007. This is consistent with a softening in private consumption and a postponement of investment decisions in response to higher prices and costs as well as a tightened monetary policy (the policy rate had been raised 12 times since the second half of 2004) to reduce demand-side inflationary pressures. The output gap was slightly negative at −0.05 percent in 2007Q4 according to our judgment and finally became slightly positive at 0.07 percent in 2008Q1. On the whole output fluctuated within 2 percent of potential output since 2000.

*Inflation* and how it helps determine the output gap are illustrated in figures 16–18. Figure 16 shows CPI inflation and the unobserved underlying inflation (emphasized line). We see that underlying inflation moves in line with CPI inflation but with a lower degree of fluctuations. To see whether the underlying inflation moves in line with the output gap, figure 17 compares movements in the underlying inflation (emphasized line) with those of the output gap. Three points are of notice. First, the degree of comovements increases after the 1997 crisis. This finding is consistent with Bhanthumnavin (2002) who uses OLS to estimate the Phillips curve for Thailand and finds no evidence of the Phillips curve relationship prior to 1997. Second, with inflation and the output gap generally moving together after 1998, this relationship seems to break down most evidently in 2005Q1 as a result of the adverse shock to output given the tsunami disaster. Third, although underlying inflation correlates with resource utilization (proxied by the output gap) reasonably well, inflation appears to accelerate more than the output gap implies towards 2008. Such acceleration in inflation with respect to the output gap is due to factors other than excess demand that drive inflation dynamics, namely cost-push shocks and inflation expectations. As shown in figure 18, we see that the contribution from non-excess demand components in the Phillips curve (i.e., the Phillips curve innovations) markedly increases towards the end of the sample period—perhaps attributable to oil price hikes and upward revisions in inflation expectations.

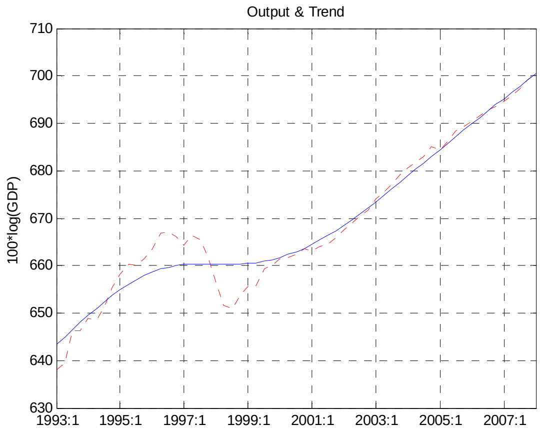


Figure 12: Actual output: dashed line. Potential output: solid line.

### 3.5 Evaluation of the estimated output gap

It is helpful to check the veracity of our estimate of the output gap, as shown in figure 15, with recent economic developments as documented in the *Inflation Report*.

First, figure 15 shows that the output gap suddenly shrank in 2005Q1—consistent with our understanding of the Thai economy in the aftermath of the tsunami. On the demand side, GDP contracted from the previous quarter most since the 1997 financial crisis as a result of an abrupt decline in durable consumption and tourism. Although it is possible that this shock also affects potential output, the estimate suggests that the effect of the shock on the supply side was less severe than on the demand side as witnessed from a sharp contraction in demand. As a result, we observe in our estimate a negative output gap for one quarter, after which the output gap immediately turned positive.

Second, the output gap appeared to be negative between late 2006 and late 2007. According to the October 2007 issue of the *Inflation Report* which explains economic conditions in the first two quarters of the year, domestic demand slowed down by more than expected. The slowdown was particularly apparent in private investment, which contracted year-on-year in both quarters as a result of various sources of uncertainty in the economy, including uncertainty in government economic policies. In addition, growth of private consumption was weaker than expected, given that continued fragile consumer confidence had a negative impact on the purchase of durable

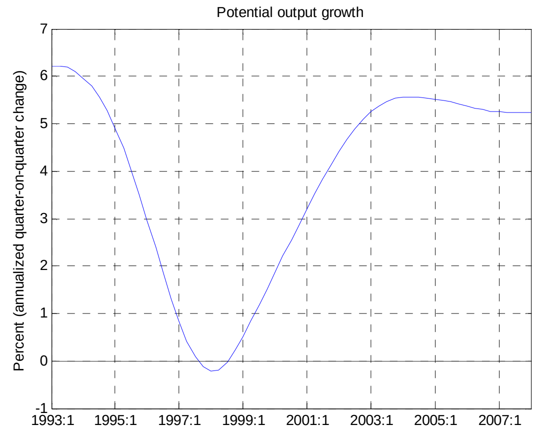


Figure 13: The growth rate of potential output

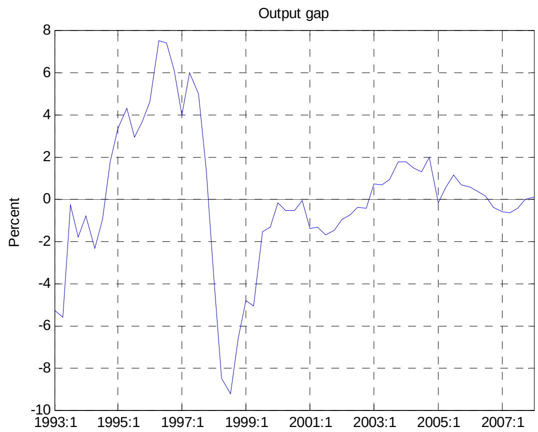


Figure 14: Estimate of the output gap

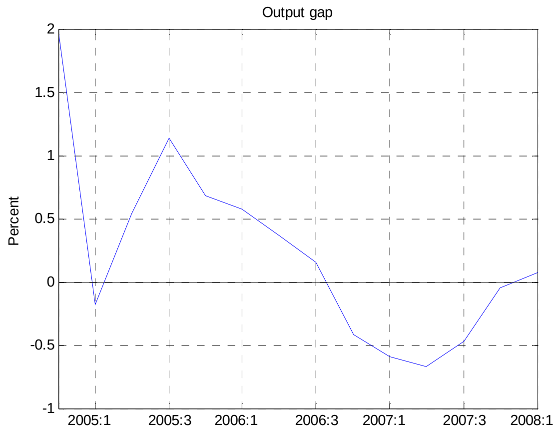


Figure 15: Estimate of the recent output gap

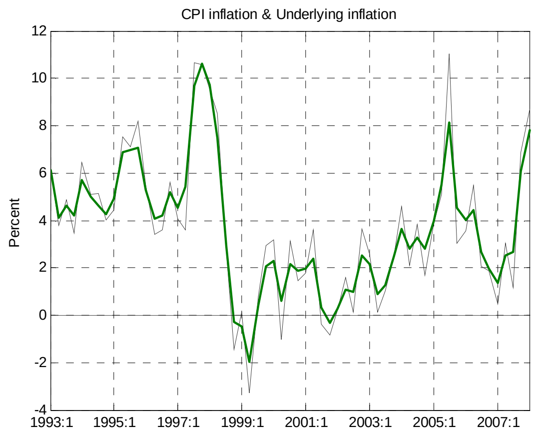


Figure 16: CPI inflation: dotted line. Underlying inflation: emphasized line.

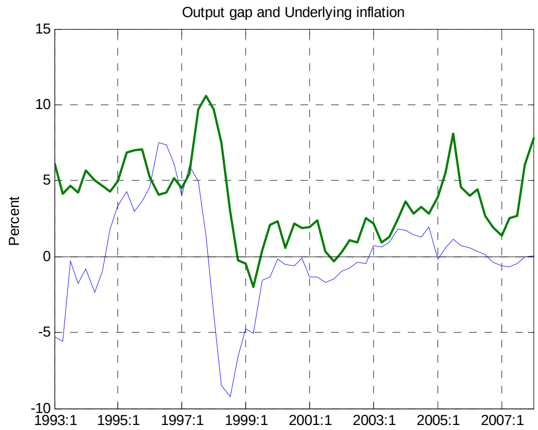


Figure 17: Underlying inflation: emphasized line. Output gap: solid line.

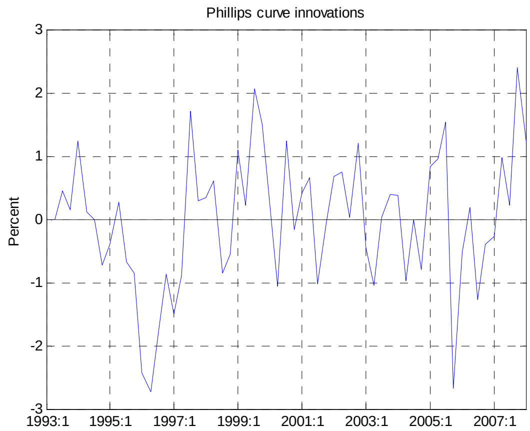


Figure 18: Shock to the Phillips curve

goods. The *Report* also notes that, in spite of the lower-than-expected growth in private spending in the first half of the year, economic indicators in 2007Q3 showed signs of a gradual but continued recovery in both the private consumption and private investment indices. This is consistent with the finding that output started to revert to its potential in 2007Q3, causing the output gap to shrink as illustrated in figure 15.

## 3.6 Uncertainty in the estimation of the output gap

### 3.6.1 Parameter uncertainty

Although uncertainty comes from various sources, namely data uncertainty, model uncertainty, and parameter uncertainty, here we will look at the sensitivity of the output gap estimate with respect to calibrated parameters, namely, the degree of persistence in the movements of the output gap , the variance of the innovations to the output gap relative to innovations to potential output, and the slope of the Phillips curve.[5] The issue of model uncertainty will be discussed below.

**Parameter uncertainty in the model without judgment.** First, we consider the sensitivity of the output gap estimate in the no-judgment model (which gives the "initial results" above). Figures 19–21 show output gap simulations obtained by varying each of the three parameters separately. The number of parameterizations is set to 50. In figure 19 the AR(1) parameter in the output gap process, $\phi^{ygap}$ in equation (12), varies in the range of 0.2–0.8. In figure 20 the standard deviation of the innovations to the output gap process relative to the innovations to the trend process, $var(\varepsilon_t^{ygap})/var(\varepsilon_t^{trnd})$ in equations (11) and (12), takes the value between 10 and 30. In figure 21 the slope of the Phillips curve, $\gamma$ in equation (14), varies in the range of 0.1–0.6. Each of these ranges represents plausible parameter values and includes the calibrated value.

We see that the output gap estimate is most sensitive to $\phi^{ygap}$, given that $\phi^{ygap}$ enters directly in equation (12) which governs dynamics of the output gap. The distribution of the output gap estimates is wide, with the average of the quarterly standard deviations given by 0.27—twice or almost three times as large as 0.13 and 0.10 obtained from the other two cases. As far as the output gap of most recent dates is concerned, its interval estimate is as large as 0.80 percentage points. In short, given the current model setup and calibration, uncertainty in the output gap estimates mainly comes from how we specify the dynamic process of the output gap.

**Parameter uncertainty in the model with judgment.** In this part we consider uncertainty of the output gap estimate in the state–space model with conditional filtering (which corresponds to the main results above). We repeat the same exercises as above but in the model in which we now apply our judgment that the output gap in 2007Q4 is slightly negative.

[5] We try to vary the degree of forward-looking expectations in the Phillips curve. However, numerical accuracy obtains only for a few parameterizations that may not include all plausible values of $\omega^f$. For those parameterizations of $\omega^f$ for which solutions exist, variation in the output gaps and potential growth estimates is minor.

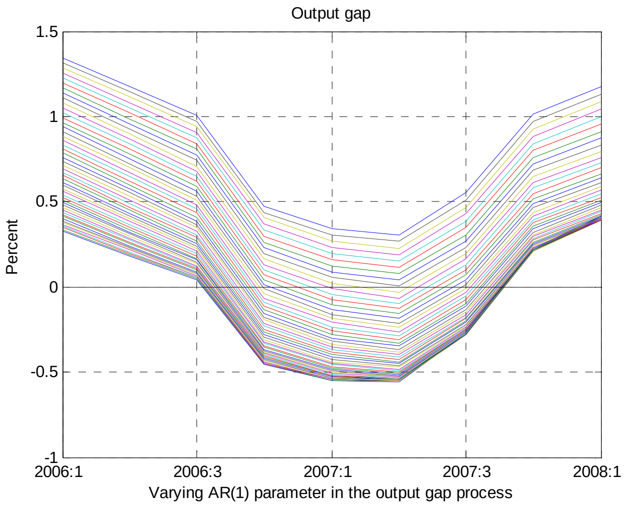


Figure 19: Varying $\phi^{ygap}$ in the no-judgment model.

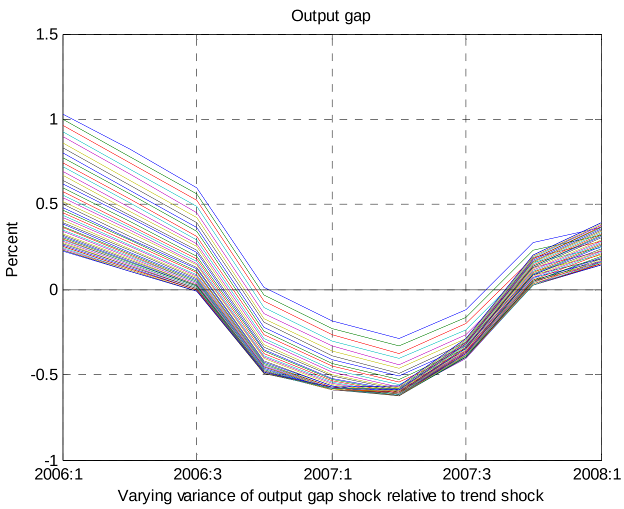


Figure 20: Varying $var(\varepsilon_t^{ygap})/var(\varepsilon_t^{trnd})$ in the no-judgment model.

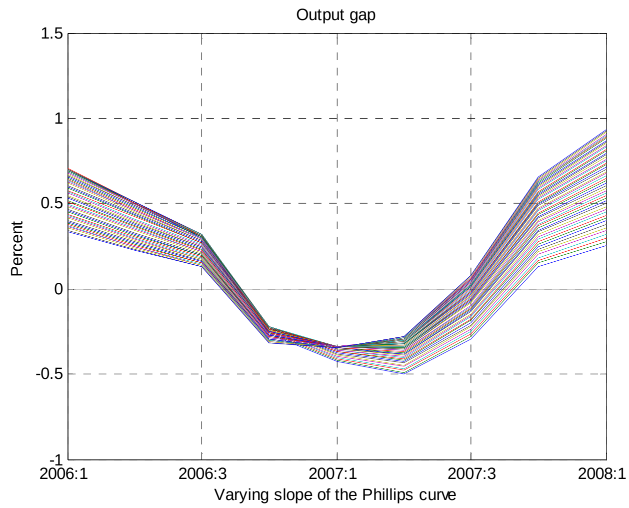


Figure 21: Varying $\gamma$ in the no-judgment model.

Two observations in figures 22–24 that need only brief discussions are as follows. First, we see a reduction in uncertainty, as shown by smaller dispersions of estimates compared with those in figures 19–21. Second, we see that there is virtually no uncertainty in estimation for 2007Q4. These observations are as expected, because we have imposed a restriction on the output gap in this quarter; consequently, output gap estimates in periods before and after this quarter are constrained to move such that the output gap in 2007Q4 precisely corresponds to our judgment.

Two important points are as follows. First, even though we have succeed in reducing uncertainty, especially at the end of the sample period, it should be kept in mind that such a reduction in uncertainty is by construction. This leads to the second point—that is, uncertainty in the estimation is now translated to accuracy of the judgment imposed. Figure 25 shows the results of varying the slope of the Phillips curve given an alternative discretionary estimate of the output gap that was slightly positive in 2007Q4.

In sum, judgment may have an important role to play in the estimation of the output gap (as well as in any other estimation) and well-informed judgment, which comes from modelers, sector specialists, and policymakers, is the key to accuracy of the estimation.

### 3.6.2 Model uncertainty

Another source of uncertainty in the estimation of the output gap is the model itself. While the baseline model as described in equations (9)–(14) is a standard state-space model used to estimate potential output and the output gap, there are a number of variants that have been used, for example, a purely backward-looking Phillips curve in which inflation expectations are informed by past inflation, or a Phillips curve with a one-period lagged output gap instead of the contemporaneous value. We have tried using these two alternative specifications and found that results obtained from these two modifications do not differ much from the baseline estimate. Furthermore, these two specifications can be difficult to justified theoretically given standard dynamic stochastic general equilibrium models such as those introduced by Smets

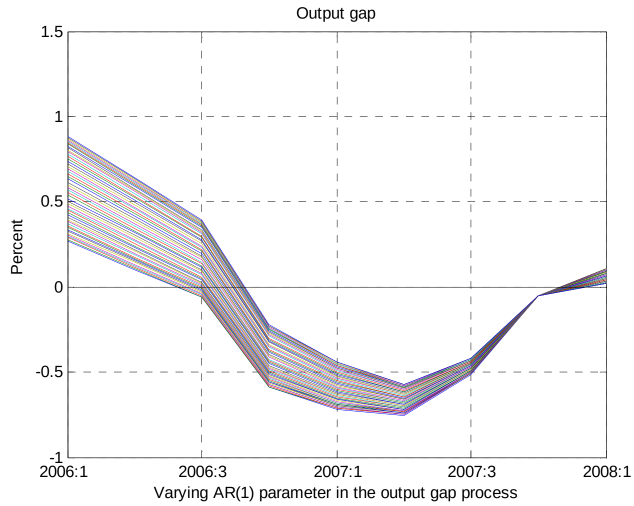


Figure 22: Varying $\phi^{ygap}$ in the model with judgment.

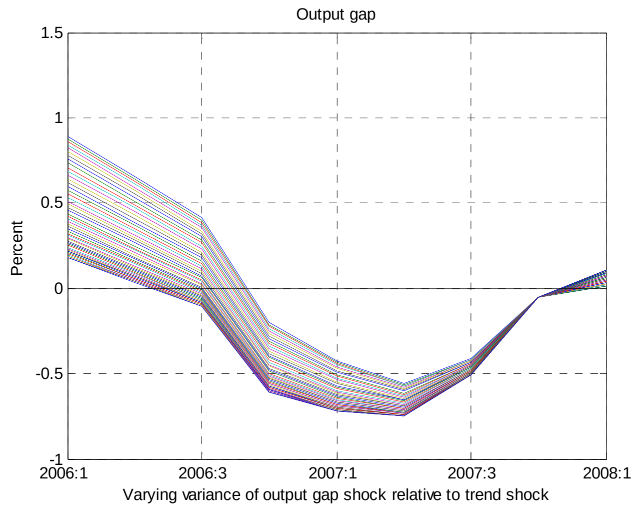


Figure 23: Varying $var(\varepsilon_t^{ygap})/var(\varepsilon_t^{trnd})$ in the model with judgment.

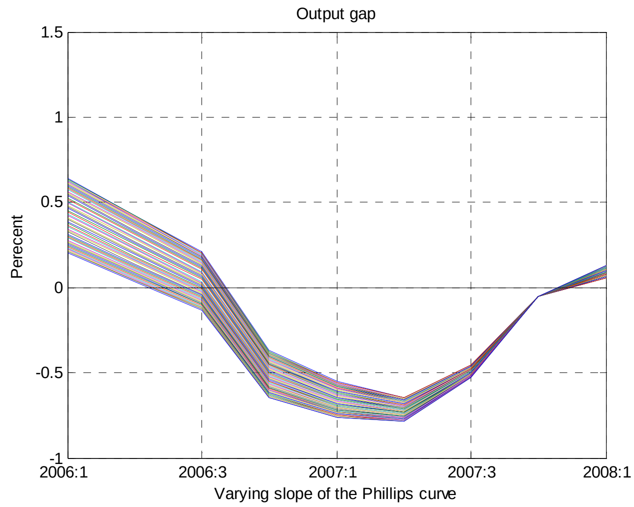


Figure 24: Varying $\gamma$ in the model with judgment.

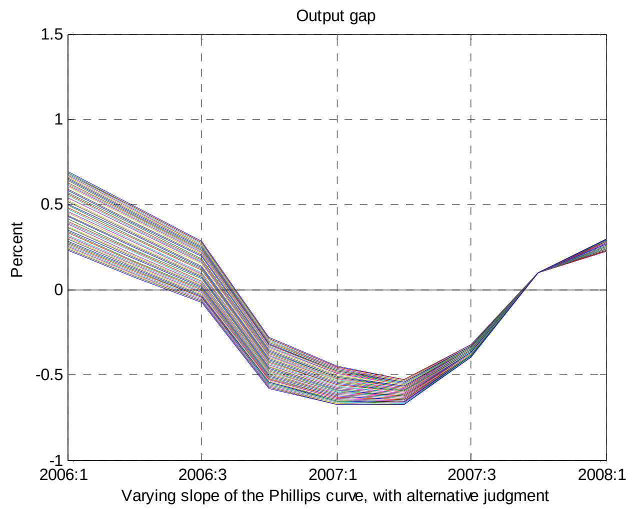


Figure 25: Varying $\gamma$ in the model with alternative judgment.

and Wouters (2003) and Christiano, Eichenbaum, and Evans (2005) in the following senses. First, although lagged inflation may be added to better capture dynamics, the forward-looking element in the form of inflation expectation still plays an important role in those structural models with micro-based foundations. Second, according to the New Keynesian Phillips curve, the price set by firms depends among other things on the *current* real marginal cost, which in turn relates to the current level of resource utilization.

Although not included in the model, we have considered adding deviations of the unemployment rate or the capacity utilization rate from their trends as done in some studies. The rational for including the relationships between these two variables is that information from the labor market or goods-producing industries at plant level may be helpful in determining the degree of resource utilization in the economy. For example, we may add to the model:

$$\begin{aligned} u_t - u_t^* &= \gamma_1 ygap_t + \varepsilon_t^u \\ CAPU_t - CAPU_t^* &= \gamma_2 ygap_t + \varepsilon_t^{CAPU}. \end{aligned}$$

However, there are certain issues that may complicate our estimation. First, with data on the quarterly unemployment rate only available from 1998Q1, incorporating the unemployment rate in our model essentially means throwing about a third of 61 observations away (we are doing relatively better with the capacity utilization data which start from 1995). Second, we do not have a strong prior based on existing empirical findings about Okun's coefficient, $\gamma_1$, which tells us how much GDP is reduced for every one percentage point by which the unemployment rate exceeds the natural rate. Third, to determine $u_t^*$ and $\text{CAPU}_t^*$, some studies simply use the HP filter. We are not sure that the information obtained from adding $u_t$ and $CAPU_t$ will somehow be distorted by potential inaccuracy of the equilibrium values obtained by mechanically applying a univariate filter outside the state-space system. As a result, we have not included the above two equations in the model, although we do use the information from the unemployment rate and the capacity utilization rate to cross check our baseline estimate.

An extension that we hope to pursue in the future is to enrich the Phillips curve with determinants of inflation other than the output gap, for example, deviations of oil price inflation or the real exchange rate from their trends. We leave this issue for future works.

## 4 Dealing with output gap uncertainty

A common wisdom in dealing with output gap estimates from various methodologies is to find one that has the most predictive power on inflation. However, this is subjected to the Lucas critique in which the nature of inflation dynamics today may be different from the past. Therefore, past relationship may not be a good approximation for today's development. In particular, inflation expectations may have changed towards a more forward looking form while the slope of the Phillips curve today could be different from the past. Reforms and structural changes also undermine the predictive power of past relationship. Thus, testing the estimate from each method for a good fit may not be the best solution. As Greenspan (2003) puts it, a central bank's task is not so different from a risk management whereby policymakers must deal with uncertainties and analyze costs and benefits associated with various possible outcomes. The important fact is that all central banks know the limitation of estimated output gaps. This section discuss various strategies, both theoretically and practically, in dealing with such problems.

### 4.1 Dealing with the uncertainty: Theory

On a theoretical basis, we summarize four ways for dealing with output gap uncertainties.

**Model averaging.** This strategy incorporates the use of all available methods such that policy responses can perform well on average. Different probabilities could be assigned to different methods and expected outcome could then be extracted. Loosely speaking, this method minimizes the *average loss* across models. As a result, the averaging method makes policy responses more cautious and behave like a gradualist.

**Robust control.** Unlike the averaging method, when probabilities are difficult to assign and uncertainty seems high, policymakers may prefer to minimize the maximum loss across models. In this case monetary policy can be aggressive. For instance, given that hyperinflation can inflict massive welfare loss, if some estimates point towards such direction, policymakers may take action aggressively to avoid the worse scenario.

**Nominal income targeting.** Some economists suggest nominal income as a target to obviate the need to estimate unobservable variables (including the output gap). See, for example, McCallum (1999), McCallum and Nelson (1999a, b), and Jensen (2002). With nominal income targeting, policymakers do not need information from the output gap to predict inflation since nominal income already takes care of both prices and real output. Nominal income targeting is in fact almost akin to money growth targeting, except that where the latter lost its popularity from changes in velocity, the former does not face with such a problem. Nevertheless, Rudebusch (2002) points that nominal income targeting is inferior to other policy rules. This is because monetary policy will respond to nominal income fluctuations in the same identical fashion regardless of the sources of shocks—nominal prices or real output. If monetary policy has a different lag impact on prices and real output, which they seem to be, then monetary policy response in this way will not be efficient.

**Speed limit policy.** Walsh (2003a, b) recommends an alternative approach for the conduct of monetary policy by using information from the change in the output gap instead of the level. Using the change instead of the level of the output gap is equivalent to focusing on the growth rate of actual GDP relative to the growth rate of potential GDP:

$$\Delta gap_t = (y_t - y_t^*) - \left(y_{t-1} - y_{t-1}^*\right) = (y_t - y_{t-1}) - \left(y_t^* - y_{t-1}^*\right).$$

A positive change in the output gap implies actual growth rate being above the potential growth rate and vice versa. Due to uncertainty in the estimation of the output gap, monetary policy should respond to changes in the output gap to lessen the severity of the problem. Intuitively, errors in the estimated level are often more severe than errors in the estimated change.[6] If level estimates are flawed with uncertainties, its direction of changes in the output gap may prove useful. For instance, when the output gap becomes negative initially, monetary policy should be accommodative. In the next period, a further rate cut should be called for only if the gap has become more negative. If there is no change in the output gap—that is, if the gap remains at the same negative level—monetary policy should remained unchanged. If the level data is used instead, the negative output gap would imply a further rate cut which can be damaging given wrong estimates. This strategy also implies that monetary policy should be tightened when the output gap is negative but continuously moves towards a zero gap. According to Walsh, the speed limit policy makes monetary policy more credible (reduces time

[6] This is true when errors in the estimated level are highly persistent, that is, errors from past periods carry over to the next period.

inconsistency and policy bias problems), which is most beneficial if expected inflation takes a forward-looking form. Along a similar line, Orphanides and Williams (2002) suggest that *changes* in the unemployment rate be used in monetary policy rules when natural rate data such as the natural rate of unemployment are clouded with noisy real-time estimates. Their findings are similar to Walsh's suggestion but their model relates monetary policy with the unemployment gap rather than the output gap.

It should be noted that most of these theoretical solutions have been developed in the context of a closed economy. In Appendix A below, we investigate the performance of both nominal income growth and speed limit instrument rules when potential output is not observable in an empirically motivated small open economy model. There we find that a simple Taylor rule performs relatively well in our setting, with the nominal income growth rule an attractive alternative.

## 4.2 Dealing with the uncertainty: Practices

In addition to above strategies, practical solutions which follow closely with theoretical grounds employed by many central banks are as follows.

**Gradualism.** This practice dated back to Brainard (1967) who suggests that policymakers act cautiously when faced with uncertainties about the state of the economy and their policy impacts. In a gradualist view, a rate increase of 25 basis points followed by another increase of the same amount in the near future is preferable to a one-time increase of 50 basis point. Bernanke (2004) states that the Federal Open Market Committee (FOMC) takes a gradualist approach for three reasons. First, there is uncertainty about the economy. Second, patterns of small but multiple steps can influence long-term market rates better via expectation. Third, gradualism reduces risks to financial stability. Taking action cautiously also allows policymakers to wait for a revised data or new additional information which reduces the uncertainty of recent economic development.

**Structure of the monetary policy committee.** Kohn (2006) mentions that the structure of the FOMC provides Bayesian-like benefits. He cites Blinder and Morgan (2005), who suggest that decisions reached by a committee consisting of many experts are usually superior to those produced by individuals.

**Communication to anchor expected inflation.** Nowadays, central banks throughout the world attempt to make themselves more transparent with various forms of communication to the public. This is done through reports, press releases, and speeches which aim to ease public understanding, justifying policy decision, and anchors inflation expectations. The output gap can lose its information on inflation if it is clouded by expected inflations. Indeed central banks usually give a forecast or a range of inflation prospect to help shape inflation expectations. Some central banks explicitly use inflation targeting to enhance their credibility and commitment. As long as expected inflation remains unchanged, rising inflation and falling inflation implies positive and negative output gaps, respectively, given no cost push shock.

**Less attention on output gap, more on inflation.** McCallum (2001) stresses that output gap is measured so poorly that policymakers should not give much importance in the conduct of monetary policy. Mishkin (2007) also shares this view: "The bottom line is that we must never take our eye off of the inflation ball." Freedman (1999) cites during the ECB conference that the Bank of Canada puts less emphasis on measured output gap and gives more emphasis on other leading indicators of inflation. The argument behind these views is that whether

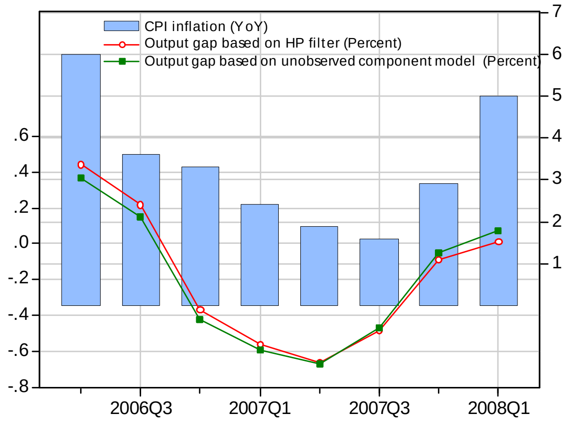


Figure 26: CPI inflation (right scale, YoY) and measures of the output gap (left scale, percent)

inflation comes from expected inflation or a positive output gap, both are needed to be taken care of in any case.

**Look at other indicators.** Other economic variables can provide useful information on the state of the economy. Examples of these measures are the ratio of unfilled orders to shipments in manufacturing, vacancy rates for offices, and industrial buildings, and measures of labor shortages. Rising inflation with high capacity utilization and tight labor market is a symptom of producing beyond the potential level. According to Jenkins and Longworth (2002), the Bank of Canada evaluates production capacity and tightness in the labor market along with the output gap estimate. Remsperger (2005) points out that the Deutsche Bundesbank avoided the potential output uncertainty problem by focusing instead on deviations of money growth from target, deviations of the inflation rate from the price norm, and deviations of the growth rate of real output from the growth rate of potential output. The emphasis on deviation of money growth carries on to today's European Central Bank which uses the deviation of Euro-area M3 growth from a reference rate to gauge "risks to price stability."

In sum, as viewed by Mishkin (2007), a central bank cannot escape the need for information on output gap but to realize that such estimates are uncertain. If inflation moves in a different direction than suggested by the output gap, one can doubt the reliability of the gap estimates. Indeed, these are challenges for central banks, especially when cost-push shocks come to play.

# 5 An Assessment of Recent Development in the Output Gap

## 5.1 Relative performance of different estimates of the output gap

Figure 26 plots CPI inflation (year-on-year percentage change, bars) against two measures of the output gap based on the HP filter (marked with circle symbols) and the unobserved component model (marked with square symbols). We see that CPI inflation does move in line with the two measures of the output gap, albeit with some lag. This is because the year-on-year measure tends to capture backward dynamics as far back as four quarters ago.

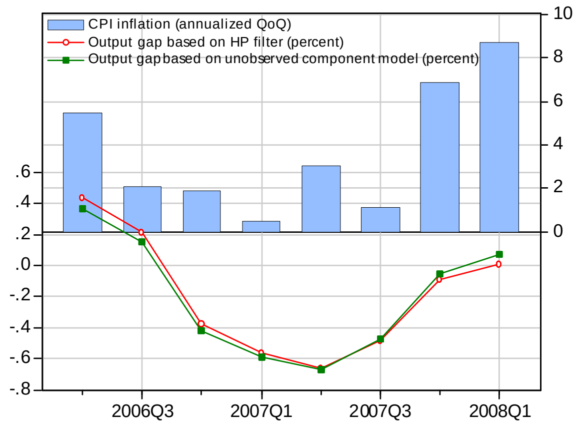


Figure 27: CPI inflation (right scale, annualized QoQ) and measures of the output gap (left scale, percent)

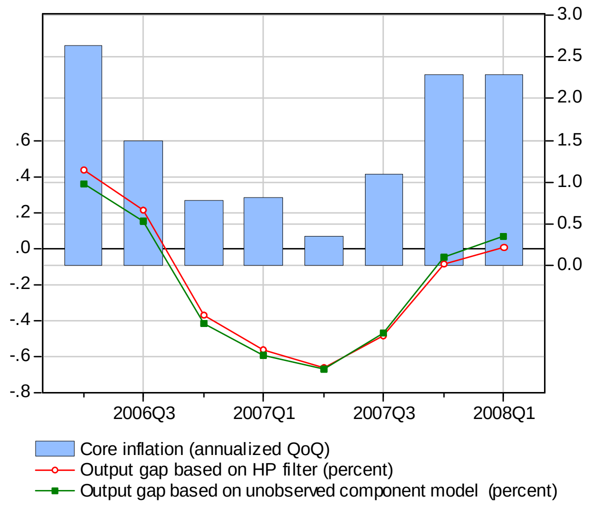


Figure 28: Core inflation (right scale, annualized QoQ) and measures of the output gap (left scale, percent)

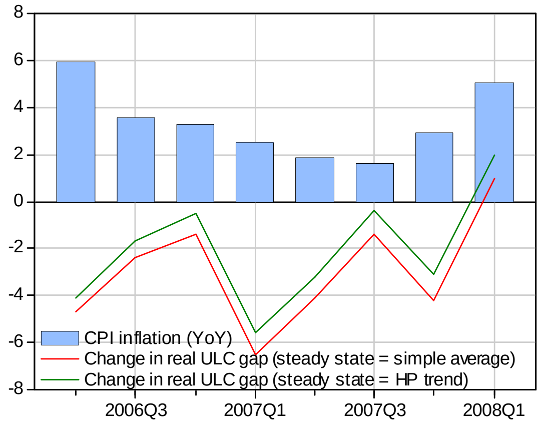


Figure 29: Changes in real unit labor cost gaps

When CPI inflation measured on a basis of annualized quarter-on-quarter percentage change is used as shown in figure 27, we see that the output gap estimates mostly move in tandem with this measure of inflation, given that the backward dynamics of the year-on-year measures have been eliminated. The exception is at 2007Q2; that is because of the surge in oil prices owing importantly to temporary factors, namely maintenance shutdowns of a number of U.S. oil refineries and production uncertainty following strikes undertaken by labor unions in Nigeria. Thus, we use another measure of inflation that excludes the inflation coming from energy prices—that is, core inflation. We see in figure 28 that overall the output gap estimates do move in tandem with this measure of inflation.

Relative to the measures of the output gap based on the real marginal cost approach, as shown in figure 3, we see that overall the HP and unobserved component model based output gap estimates track movements in core inflation reasonably well during 2006Q2–2008Q1.

### 5.2 A current assessment of the output gap in the Thai economy

Based on the latest data available up to the first quarter of 2008, although the size of the output gap differs from one estimate to another, all point towards an elimination of slack in the economy in 2008Q1. In particular, we view that the output gap was slightly positive and very close to zero in this quarter. A persistent increase in oil prices since 2004 is likely to have adversely affected potential output through a reallocation of resources, a delay in investment, a reduction in the growth of the capital stock, and thus the growth of potential output. Despite the negative impact of oil shocks, demand appeared to have regained some traction in this quarter as private consumption and private investment continued to improve significantly. With demand strongly picking up on the back of a softened growth potential of the economy, our assessment is that slack in resource utilization was likely to have reduced to the extent that the output gap was in the neighborhood of zero in 2008Q1.

Although the real marginal cost method gives a negative estimate of the output gap recently, we have pointed out that real unit labor cost may not be a good proxy for real marginal cost. In particular, recent oil price shocks are likely to be captured by the cost-push term which

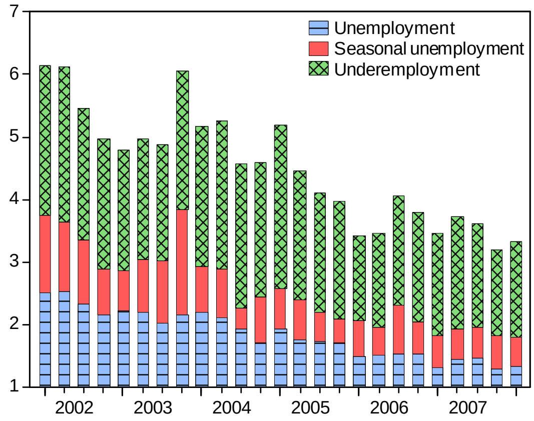


Figure 30: Unemployment indicators (seasonally adjusted). Source: National Statistical Office of Thailand.

undermines the positive relationship between the output gap and inflation. Therefore, the output gap estimate obtained from this method is likely to exhibit a downward bias. Thus, less weigh must be given to this method. One strategy to lessen the problem of uncertainty in level is to use its change instead—i.e., speed limit strategy. Figure 29 shows a positive value of changes in real unit labour cost gap in 2008 Q1. They imply a policy response that is consistent with other approaches.

Another piece of corroborative evidence of the economy operating close to its potential can be seen in a tight labor market and high capacity utilization. Chuenchoksan and Thanadhidhasuwanna (2008) examine recent developments in the labor market and find that various indicators point towards a tightening trend. As shown in figure 30, on a seasonally adjusted basis, the unemployment rate, seasonal unemployment rate, and underemployment rate all show a declining trend. Moreover, indicators of unemployment duration reveal that most unemployed workers are being unemployed for only a short time, i.e., less than three months. At the same time, figure 31 shows high capacity utilization in the manufacturing sector. All of these indicators lend support for a closing output gap in 2008Q1.

With the output gap in 2008Q1 likely to be very close to zero, it is also expected to remain close in 2008Q2. Although the GDP growth of 5.3 percent in 2008Q2 is lower than the estimated average potential growth rate over 2008–15 that lies in the range of 5.5–6.1 percent projected by the production function method, this estimated range is based on the assumption of a balanced growth path such that investment is projected to pick up. However, current investment may not be characterized by balanced growth, and it is likely that this range for the potential growth rate is too high for the economy at present. If one takes the potential growth rate of 5.2–5.3 percent as suggested by the HP filter and unobserved component model methods, the current growth rate of 5.3 percent implies that the output gap for 2008Q2 continues to be close to zero as in 2008Q1; since the actual and potential growth rates are equal, the size of the gap must remain unchanged. If this is the case, rising inflation from 5.0 percent in 2008Q1 to 7.5 per cent in 2008Q2 must come from the other determinants—inflation expectations and cost-push shocks.

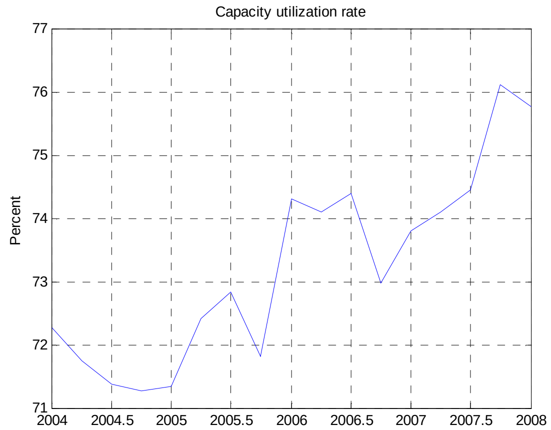


Figure 31: Capacity utilization rate

# 6 Concluding remarks

Monetary policy is always conducted in the presence of uncertainty. Among the key sources of uncertainty facing any central bank is uncertainty associated with the economy's potential output estimation. History has shown vividly how the use of an incorrect estimate of potential output resulted in an undesirable policy outcome for the world's most advanced central bank. In the current situation where persistent supply shocks may have adversely affected the economy's potential output, inflation expectations remains elevated, and there are pressures on the Bank of Thailand to pursue activist monetary policy to shore up the slowing economy, the possibility of an overoptimistic assessment of the economy's potential output is thus of practical importance to Thailand's monetary policy strategy.

This paper employs two of the most popular potential output estimation methods—the HP filter and the unobserved component model—to study estimation problems associated with real-time data, parameter uncertainty, and model uncertainty. While acknowledging that these estimation problems cannot be entirely avoided, our results highlight how an incorporation of sound judgment can greatly increase the accuracy of the underlying estimates.

Our baseline results show that Thailand's potential GDP growth has come down slightly since the energy-inefficient economy was hit by the surge in oil prices in 2004. Thailand's medium-term potential GDP growth estimates using the two aforementioned methods are currently about 5.2–5.3 percent. At the same time, we find the Thai economy in the middle of 2008 operating close to its estimated potential.

An important implication of these findings is that any growth rate above those levels will exert an upward pressure on prices. Potentially adding to this price pressure is the possibility that actual potential output growth is even lower than our estimates, for ex ante overestimation of trend growth often does not manifest itself until a few years have passed following the initial negative shock to potential output. Overall, our findings point against an excessively loose monetary policy stance in the current environment.

# Appendix A: Performance of simple rules in a small open economy setting when potential output is unobserved

Much of the theoretical literature on potential output uncertainty has been in the context of a closed economy. In this section, we provide an assessment of selected simple instrument rules in an empirically-motivated hybrid New Keynesian model of a small-open economy. Our model is essentially an extension of the closed economy model developed by Ehrmann and Smets (2003). Its structure is similar to those found in Batini and Haldane (1999), Svensson (2000), Lam (2003), and Leitemo and Söderström (2005).

The model economy can be represented by four structural equations. The first one is the hybrid IS curve:

$$y_t = \delta y_{t-1} + (1-\delta)\,\mathsf{E}_t y_{t+1} - \sigma\left(i_t - \mathsf{E}_t \pi_{t+1}\right) + \chi q_t + \phi y_t^f + \varepsilon_t, \qquad (15)$$

where $y_t$ is (log) real output, $i_t$ is a one-period nominal interest rate (the central bank's monetary policy instrument), $\pi_t$ is domestic inflation (the rate of change in the index of domestic goods prices)[7] , $q_t$ is the (log) real exchange rate defined in terms of domestic currency (i.e., an increase in $q_t$ corresponds to real depreciation), $y_t^f$ is the (log) foreign output, $\mathsf{E}_t(\cdot)$ is an expectation operator, and $\varepsilon_t$ is a demand disturbance. The structural parameter $0 \leq \delta \leq 1$ captures the degree of output persistence.

The interpretation of equation (15) is straightforward. Current output is positively related to the weighted average of lagged output and expected future output. In addition, output depends negatively on the ex ante real interest rate, but positively on the real exchange rate and foreign output. The appearance of lagged output in this otherwise standard expectational IS curve theoretically could come from habit formation of consumer behavior as in Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).

The second equation is the hybrid New Keynesian Phillips curve for a small open economy:

$$\pi_t = \alpha \pi_{t-1} + (1-\alpha)\,\mathsf{E}_t \pi_{t+1} + \kappa\left(y_t - \bar{y}_t\right) + \phi q_t + u_t,$$

where $\bar{y}_t$ is (log) potential output and $u_t$ is a cost-push shock. The structural parameter $0 \leq \alpha \leq 1$ captures the degree of backward-looking behavior in price setting. The equation is essentially an open-economy analogue of the Fuhrer–Moore (1995) closed-economy Phillips curve specification. Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003) provide a theoretical justification for the lagged inflation term as resulting from partial or full indexation to the most recent inflation measure by producers that cannot optimally adjust their prices. In an open-economy setting, however, real marginal cost is determined by both the output gap and the real exchange rate through costs of imported intermediate inputs.

The third equation is the real uncovered interest parity:

$$i_t - \mathsf{E}_t \pi_{t+1} = \mathsf{E}_t q_{t+1} - q_t + \left(i_t^f - \mathsf{E}_t \pi_{t+1}^f\right) + \eta_t,$$

where the disturbance term $\eta_t$ represents a foreign-exchange risk premium which incorporates any exogenous residual disturbances to the nominal exchange rate. This equation can be derived from combining the uncovered interest parity (UIP) and purchasing power parity (PPP) conditions. See, for example, Svensson (2000) and Galí and Monacelli (2005).

[7]Absent non-traded goods, domestic inflation and CPI inflation are linked as $\pi_t^{CPI} = \pi_t + \omega\left(q_t - q_{t-1}\right)$ where $\omega$ is the share of imported goods in the CPI. See, for example, Svensson (2000).

The final equation is the equation governing the evolution of the economy's potential output, which we assume to follow an autoregressive process:

$$\bar{y}_t = \rho\bar{y}_{t-1} + \nu_t.$$

This specification abstracts from the possibility that a period of persistent inflation may affect the level of potential output. We assume that the parameter $\rho$ is close to one to account for the fact that changes in potential output are generally highly persistent.

Along the line of Ehrmann and Smets (2003), we assume that agents observe output, inflation, and the real exchange rate, but not potential output. Given this information structure, only demand shocks and risk premium disturbances are identified. As a consequence, agents will face a signal extraction problems in trying to distinguish cost-push shocks from potential output shocks. For example, a fall in output accompanying an increase in inflation could conceivably come from either a positive cost-push shock or a negative potential output shock or a combination of the two. It is this signal extraction problem that gives rise to output gap uncertainty in this model.

As discussed by Svensson and Woodford (2003), the presence of forward-looking variables complicates the estimation of signal extraction problem significantly. Forward-looking variables by definition depend on private-sector expectations of future endogenous variables and current and future policy actions, which depend on the estimate of the current state of the economy. There is however a circularity problem as the estimate of the current state of the economy in turn depends, to some extent, on observations of the current forward-looking variables. Fortunately, Svensson and Woodford (2003) also show that a standard Kalman filter can be modified to circumvent this circularity problem.

To complete the description of the model economy, we need to specify the processes for the exogenous disturbances and foreign variables. Without loss of generality, we set all foreign variables to zero. All four exogenous disturbances (the demand shock, the cost-push shock, the foreign-exchange risk premium shock, and potential output shock) are assumed to be serially uncorrelated and independent from one another.

In order to analyze optimal monetary policy and performance of simple instrument rules, we assume that the central bank's loss function is given by

$$L_t = \mathsf{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\pi_{t+\tau}^2 + \lambda\left(y_{t+\tau} - \bar{y}_{t+\tau}\right)^2 + \lambda_i\left(i_{t+\tau} - i_{t+\tau-1}\right)^2\right]. \tag{16}$$

This specification reflects the widespread agreement over the objectives of monetary policy in the literature. The parameters $\lambda$ and $\lambda_i$ represent respectively the weights on output stabilization and interest rate smoothing relative to inflation stabilization. Note that because our model implicitly assumes perfect exchange rate pass-through, the relevant inflation in the central bank's loss function is domestic inflation rather than CPI inflation. See Benigno and Benigno (2003), Clarida, Galí, and Gertler (2001), and Galí and Monacelli (2005). The rationale behind this is that in such case the former is where the price rigidity lies.[8]

Table A.1 gives calibrated values of the model parameters. Since our model resembles most to that of Lam (2003), we simply take most of the baseline parameters from his model. We note

[8]Corsetti and Pesenti (2005) argue that when exports are priced in the currency of destination market, a practice known as local currency pricing, in which case there is no exchange rate pass-through, it can be welfare enhancing for the central bank to stabilize CPI inflation rather than domestic inflation.

however that these values are broadly consistent with those used elsewhere in the small-open economy literature.

Table A.1: Baseline model parameters

| | |
|---|---|
| IS curve | $\delta = 0.5, \sigma = 0.15, \chi = 0.05$ |
| Phillips curve | $\alpha = 0.5, \kappa = 0.05, \phi = 0.025$ |
| Potential output | $\rho = 0.97$ |
| Stochastic shocks | $\sigma_\varepsilon = 0.015, \sigma_u = 0.015, \sigma_\eta = 0.005, \sigma_\nu = 0.015$ |
| Others | $\omega = 0.3, \beta = 0.99, \lambda = 0.25, \lambda_i = 0.1$ |

Six types of simple rules are considered.

1. Taylor rule, domestic inflation:

$$i_t = \theta_i i_{t-1} + \theta_\pi \pi_t + \theta_y \left(y_t - \bar{y}_{t|t}\right)$$

2. Taylor rule, CPI inflation:

$$i_t = \theta_i i_{t-1} + \theta_\pi \pi_t^{CPI} + \theta_y \left(y_t - \bar{y}_{t|t}\right)$$

3. Forecast-based Taylor rule:

$$i_t = \theta_i i_{t-1} + \theta_\pi \mathsf{E}_t \pi_t + \theta_y \left(y_t - \bar{y}_{t|t}\right)$$

4. Speed limit rule:

$$i_t = \theta_i i_{t-1} + \theta_\pi \pi_t + \theta_{\Delta y} \left[\left(y_t - \bar{y}_{t|t}\right) - \left(y_{t-1} - \bar{y}_{t-1|t}\right)\right]$$

5. Nominal income growth rule:

$$i_t = \theta_i i_{t-1} + \theta_\pi \pi_t + \theta_{\Delta x} \left(\pi_t + y_t - y_{t-1}\right) = \theta_i i_{t-1} + \left(\theta_\pi + \theta_{\Delta x}\right) \pi_t + \theta_{\Delta x} \left(y_t - y_{t-1}\right).$$

6. Proxy rule:

$$i_t = \theta_i i_{t-1} + \theta_\pi \pi_t + \theta_{\Delta\pi} \left(\pi_t - \pi_{t-1}\right).$$

We pick these rules for the following reasons. First, the Taylor rule with domestic inflation serves as a benchmark for the other rules. A number of papers, including Ehrmann and Smets (2003) on which our model is based, have shown that Taylor rules yield similar macroeconomic stability to equilibrium under optimal commitment. The use of domestic inflation as an argument here reflects the underlying loss function.

The second simple rule is motivated by the fact that it is CPI inflation and not domestic inflation that the private sector focuses on. Note that because in this model, CPI inflation and domestic inflation are linked through the change in the real exchange rate, the rule amounts to adding a constrained response of the policy rate to the rate of real depreciation over the previous period.

The third rule has expected inflation in place of current inflation in the policy rule. This corresponds to inflation-forecast-based instrument rule promoted by the like of Batini and Haldane (2003). Variants of this rule are used in the Quarterly Projection Model (QPM) of the Bank of Canada and the Forecasting and Policy System (FPS) of the Reserve Bank of New Zealand.

The last three simple rules are three theoretical proposals to tackle the problem of potential output uncertainty. Two of them are also advocated as the recommended conduct for monetary policy in general. The fifth rule is the speed limit rule advocated by Walsh (2003a). The sixth rule has the policy rate responds to the inflation rate and the growth rate of nominal income along the line of Jensen (2002). Written as above, the rule is also isomorphic to a rule that responds to inflation and real income growth. Thus, it is not subject to the Rudebusch (2002) objection mentioned in the text. Finally, the seventh rule corresponds to what Leitemo and Lonning (2005) labels a proxy rule whereby the central bank uses the change in the inflation rate as a proxy for the output gap. Note that both the sixth and the seventh rule do not have the estimated output gap in their reaction function at all.

In each case of the six cases, we assume that the central bank commits to the respective simple rule and solve for the rational expectations solution of the resulting system of linear equations. As there are no closed-form solutions to our model, we use the optimal linear regulator problem (OLRP) algorithm provided by Gerali and Lippi (2008) to compute the associated numerical solutions. The same intertemporal loss function (16) is used to find the optimal reaction coefficients for all rules.

Table A2: Values of losses under different policies
as percent of losses under complete information commitment

| | Complete information | Imperfect information | | | | | |
|---|---|---|---|---|---|---|---|
| | I | I* | II | III | IV | V | VI |
| Commitment | 100.0 | 109.3 | 106.3 | 111.1 | 101.8 | 104.5 | 109.1 |
| Discretion | 143.7 | 152.0 | 143.5 | 136.1 | 180.3 | 162.7 | 152.7 |
| 1. DI–Taylor rule | 107.1 | 116.1 | 115.2 | 115.8 | 104.6 | 123.4 | 115.8 |
| 2. CI–Taylor rule | 111.0 | 120.0 | 123.2 | 128.1 | 105.8 | 138.2 | 119.9 |
| 3. Forecast-based Taylor rule | 110.7 | 119.6 | 125.6 | 139.4 | 104.6 | 110.0 | 121.6 |
| 4. Speed limit rule | 112.3 | 120.6 | 115.2 | 121.7 | 108.6 | 110.0 | 120.5 |
| 5. Income growth rule | 113.7 | 120.9 | 115.2 | 121.7 | 108.6 | 110.1 | 120.7 |
| 6. Proxy rule | 124.2 | 132.2 | 111.6 | 124.8 | 108.2 | 162.1 | 131.7 |

I = Baseline parameters; II = Less inflation inertia; III = Steeper Phillips curve; IV = Persistent cost-push shock; V = Persistent demand shock; VI = Persistent foreign risk premium shock

Table A.2 gives the values of losses under the (timeless perspective) commitment policy, the optimal discretion policy, and the optimized simple rules as percent of losses under complete–information commitment for several different scenarios. Here, complete information is defined as the case where potential output is perfectly observed. The scenario "less inflation inertia" corresponds to the case where we set the backwardness parameter ($\alpha$) in the Phillips curve equation to 0.1. In the "steeper Phillips curve scenario," we increase the slope of the Phillips curve ($\kappa$) to 0.2, a value calibrated for the Thai economy. In the three persistent shock scenarios, we assume that the respective shocks follow the first-order autoregressive process and set their autoregressive coefficients to 0.5.

Several important observations emerge from Table A.2.

First, imperfect information worsens the performance of all policies. This can be seen by comparing the second and the third (starred) columns across respective row. Nevertheless, the increases in the relative percent loss do not appear to be very large. This result is consistent with most other research that imperfect information alone has only modest implications for optimal simple rules as long as the central bank uses the available information as efficiently as possible.

Second, all simple rules deliver better outcomes than optimal policy under discretion where the central bank reoptimizes period by period. The relative performance of these rules however differs according to the assumed scenario.

Third, at a broad level, the Taylor rule with domestic inflation (DI–Taylor rule) outperforms the other rules. Furthermore, in many scenarios, its outcome comes very close to those under optimal commitment. The finding shows that the results reported for the closed-economy model of Ehrmann and Smets (2003) carries over to a small-open economy setting.

Fourth, the two alternative specifications of the Taylor rule in general do not fare well. That the CI–Taylor rule underperforms the DI–Taylor rule in our model is expected since it is domestic inflation that enters the central bank's loss function. In this setting, the addition of the constrained response to real exchange rate movement worsens the performance of the Taylor rule. As for the forecast-based Taylor rule, although it delivers the best outcome in the presence of persistent demand shocks, its performance is among the bottom of the pack in most of the other circumstances. The poor showing of the forecast-based Taylor rule is consistent with what have been found in the literature, for example, Levin, Wieland, and Willaims (2001) and Svensson (2003).

Fifth, the speed limit rule and the income growth rule deliver similar outcome in our model, with the former dominating the latter slightly. The two rules outperform the DI–Taylor rules in the presence of persistent demand shocks and with less inflation inertia. The latter finding is consistent with the conventional wisdom in the literature that the welfare gain from the adoption of speed limit and income growth policies increases as the economy becomes more forward looking.

Finally, our results suggest a reservation for the adoption of the proxy rule. Although the rule performs best when inflation is highly forward looking, its relative performance deteriorates sharply in the several of the other scenarios. Most importantly, in the presence of persistent demand shocks, the outcome of the proxy rule is nearly indistinguishable from the discretion outcome, a whopping sixty percent over optimal commitment under complete information.

Altogether, these observations suggest that adherence to a simple Taylor rule does reasonably well in the face of potential output uncertainty. Nevertheless, a case can be made for speed limit and nominal income growth rule which come ahead in two circumstances and not too far behind the Taylor rule in the others.

Three important caveats are in order. The first is that what we consider here is instrument rules as opposed to targeting rules. The latter was the subject of Lam (2003). Nevertheless, we note that our results are consistent with Lam (2003), for his baseline scenario corresponds to our persistent demand shock scenario.

Second, our analysis abstracts from the issues of parameter uncertainty. In each scenario, the reaction coefficients of simple rules are the optimized ones. One way to study the effect of parameter uncertainty on these rules is to fix their coefficients at the values under the baseline scenario and assess their performance across varying scenarios.

Third but most important is that our results rest on the assumption that estimated potential output that appears in these rules has been optimally estimated. As shown by McCallum and Nelson (2004), using the wrong measure of potential output deteriorates the performance of the optimal instrument rule significantly. Optimal estimation means that the central bank uses available information efficiently. In this respect, it is doubtful that the popular HP filter method would deliver an optimal estimate of potential output given that the method only relies on data on actual output. On the other hand, the unobserved component method which utilizes a larger information set is subject to model risk. One can easily argue that the models of Section 3 are too simple to capture the real economy. In light of all these, the income growth rule which delivers slightly higher losses than the speed limit rule but does not have estimate potential output in it may be worth considering.

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