Model-based Measures of Output Gap: Application to the Thai Economy

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In this paper we compare two model-based measures of the output gap. The first measure, as proposed by Gali (2011), defines output gap as the difference between actual output and the output level that would be if the economy operates under a perfectly competitive market without price or wage stickiness. We used annual data of relevant variables for Thailand and computed the output gap under this approach. The calculated output gap for Thailand shows that the Thai economy performs consistently above the potential level, which is hard to rationalize especially during the period of recession. We then proposed a different model-based measure of the output gap, which is based on the method of "business cycle accounting" (Chari *et al.*, 2007). The approach built on the prototype real business cycle models, which incorporate time-varying wedges that resemble productivity, labor and investment taxes, and government consumption shocks. As a result, the sources of business cycle fluctuation can be classified into efficiency, labor, investment, and government consumption wedges. We carried out a decomposition of real fluctuation in Thailand and then removed those wedges from the real output series to obtain the "potential output", i.e. an output level when all the inefficiencies are removed. The analysis provides the estimated result of potential output and output gap for the Thai economy. Under this approach we found a negative output gap, which is opposite to the finding under Gali's approach.

Keywords: output gap, potential output, business cycle accounting, DSGE

JEL Classification: E01, E27, E32, E47

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Introduction

A dynamic stochastic general equilibrium (DSGE) model has become a mainstream framework for monetary policy analysis. This class of models embodies key Keynesian assumptions, i.e. price and/or wage stickiness, in general equilibrium models that were once used exclusively by the new classical or the real business cycle theory. Such approach breaks down the neutrality of money, a paradigm that nullifies the real effect of monetary policy. With this "New Keynesians" framework, central banks in modern era are equipped with micro-foundation macroeconomic models for setting policy interest rates aimed to stabilize fluctuation in real activities and maintain price stability. A canonical New Keynesian model can be represented by system of equations:

$$\hat{x}_t = E_t \hat{x}_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1})$$

$$\pi_t = \beta E_t \pi_{t+1} + k \hat{x}_t$$

The model above contains two policy goals of stabilizing the economy, i.e. output gap $\hat{x}_t$ and an inflation rate π_t. The monetary authorities choose policy interest rate i_t so as to maintain output and price stability in the economy.

This paper addresses an empirical issue surrounding the output gap measure for Thailand from the viewpoint of theoretical models, as opposed to the traditional practices that are based on filtering techniques or ad hoc model (see Chuenchoksan *et al.*, 2008). In this paper we compare two model-based measures of the output gap. The first measure is more cogent, and was proposed by Gali (2011). Under this approach, the output gap is defined as the difference between actual output and the output level when the economy operates under a perfectly competitive market without price or wage stickiness. We used annual data of relevant variables for Thailand and computed the output gap. However, the calculated output gap for Thailand shows that the Thai economy performs consistently above the potential level.

We therefore propose a different model-based measure of the output gap. This approach is based on the method of "business cycle accounting", which is a pioneering work of Chari *et al.* (2007). Chari *et al.* first introduced the method of business cycle accounting as a quantitative method for decomposing real output fluctuations. Their approach built on the prototype real business cycles models which incorporate time-varying wedges that

resemble productivity, labor and investment taxes, and government consumption shocks. As a result, the sources of business cycle fluctuation can be classified into efficiency, labor, investment, and government consumption wedges. We carried out a decomposition of real fluctuation in Thailand and then removed those wedges from the real output series to obtain the "potential output", an output level when all the inefficiencies are removed. However, some of the wedges may not be removable, for example, those that represent technology shocks or external demand. Therefore, we present three different scenarios in which some or all wedges are allowed to be part of the potential output of Thailand.

The organization of the paper is as follows. The next section provides a brief description of Gali (2011) model, and a calculation of Thailand's output gap under this approach. Then an alternative method based on the framework of business cycle accounting is purposed. The potential output under three different scenarios are computed and compared with the actual output. The last section concludes the paper.

Concept and Method

In this section, the Gali (2011) approach and the "business cycle accounting" purposed by Chari *et al.* (2007) are described as follows.

Gali (2011) Approach

We describe a stripped-down version of Gali (2011) model in this section. The model describes an economy consisting of numerous identical households and firms. These economic agents carry out transactions under monopolistically competitive product and labor markets, where producers and workers have the power to set their own prices and wages respectively. However, commodity prices and wages are not adjustable flexibly due to frictions, as imposed in Calvo (1983) as well as in Erceg *et al.* (2000). Imperfect competition in product and labor market together with price/wage stickiness gives rise to inefficiencies in resource allocation, and therefore sub optimality of market outcome.

A typical household consists of a continuum of members, which is indexed by a pair *(i, j)* representing labor skill type and disutility from work. A representative household maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta^t logC_t - \chi_t \int_0^1 \int_0^{N_t^{(i)}} j^\varphi djdi$$

where choices of C_t represents a composite consumption, constructed from a variety of intermediate consumption goods. $N_t(i) \in [0,1]$ is a fraction of household members with labor skill i who are employed in time t, and B_t a riskless one-period bond holdings at the end of date t, that obey the following budget constraint:

$$P_tC_t + Q_tB_t \le B_{t-1} + \int_0^1 W_t(i)N_t(i) + di + \Pi_t$$

where P_t is price of composite consumption good. Q_t is discount price of a risk less one-period bond at time t. $W_t(i)$ is the nominal wage for labor services of skill i at time t. In addition, χ_t represents exogenous preference shock to household.

An individual with labor skill i and disutility of work j will be willing to work if and only if:

$$\frac{W_t(i)}{P_t} \ge \chi_t C_t j^\varphi$$

That is, the household will be willing to work at date t if and only if the real wage for his labor type exceeds the utility cost of supplying labor, which is expressed in terms of consumption unit.

The marginal supplier of labor type i (denoted by $L_t(i)$) which can be employed or unemployed is given by:

$$\frac{W_t(i)}{P_t} = X_t C_t L_t(i)^\varphi$$

Let L_t be the aggregate labor force, i.e. $L_t = \int_0^1 L_t(i)di$. The above condition can be aggregate and expressed in log form as:

$$w_t - p_t = c_t + \varphi l_t + \xi_t$$

where $\xi_t = log\chi_t$ and approximately, $w_t \simeq \int_0^1 w_t(i)di$, and $l_t \simeq \int_0^1 l_t(i)di$.

Gali (2011) introduced unemployment into the model by defining u_t, an unemployment rate, as the difference between the labor force and employment, $l_t - n_t$. In addition, with the monopolistic competition in labor market, we can define the average wage mark up as:

$$\mu_t^w = (w_t - p_t) - (c_t - \varphi n_t + \xi_t)$$

Therefore, the above equation can be rewritten as:

$$\mu_t^w = \varphi u_t$$

There is continuum of firms $Z \in [0,1]$ which produces differentiated product. Each firm employs the same production technology which can be represented by the following production function:

$$Y_t(z) = A_t N_t(z)^{1-\alpha}$$

where A_t denotes an economy-wide level of technology, $N_t(z)$ represents firm z 's demand for labor at time t and α is a parameter of decreasing returns to labor.

Under the monopolistic competition in the product market, the average mark up can be expressed as:

$$\mu_t^P = \frac{\dfrac{P_t}{W_t}}{(1-\alpha)(Y_t / N_t)}$$

where the right hand side of the above equation is the ratio between price and marginal cost.

The logarithm of average mark up is thus:

$$\mu_t^P = log(1-\alpha) - s_t$$

where s_t is the log of labor share, $\dfrac{W_t N_t}{P_t Y_t}$.

Gali (2011) defined output gap as the deviation of actual output from efficient output, the level of output that would be if wage/price stickiness and markups are removed. The output gap $\hat{y}_t$ can be expressed simply as:

$$\hat{y}_t = -\left(\frac{1-\alpha}{1+\varphi}\right)(\mu_t^P - \mu_t^W)$$

$$n = -\left(\frac{1-\alpha}{1+\varphi}\right)(log(1-\alpha) - s_t + \varphi u_t)$$

We carried out calibration of the output gap for the Thai economy by combining available data with assigned parameters. Annual data for Thailand's unemployment rate u_t, and labor share   are used in this study. The unemployment data are taken from the National Statistical Office (NSO)'s Labor Force Survey, which are available on quarterly and annual basis. We acquired this data through the Bank of Thailand's website.

We used two different approaches for estimating the labor share. The first is the conventional method, which employs macro-level data from the National Economic and Social Development Board (NESDB)'s National Income Account. Under this approach, we calculated the ratio of "compensation of employees" to nominal GDP so as to obtain the

labor income share. We did not allocate proprietor's income to labor income since the data on that part of income is not available.

The second approach made use of micro-level data, i.e. various rounds of the NSO's Labor Force Survey, which can be found in Kilenthong (2012). Following a seminal work of Jeong and Townsend (2005), Kilenthong (2012) made use of micro-level data to identify the sources of total productivity growth. In computing the contribution of labor input in growth accounting, Kilenthong (2012) used information about farmer's income, self-employed workers' enumeration, and unpaid family worker in such survey to get a complete coverage of labor contribution. His calculation yielded a higher share of labor income in GDP than what other studies have found using macro-level data (Table 1).

Table 1   Unemployment and labor shares, 1998-2010

Year	Unemployment rate[a]	Labor share[a]	Labor share[b]
1998	4.35	0.298	0.558
1999	4.19	0.304	0.559
2000	3.59	0.304	0.549
2001	3.34	0.309	0.556
2002	2.41	0.304	0.569
2003	2.17	0.301	0.564
2004	2.08	0.302	0.547
2005	1.85	0.305	
2006	1.52	0.296	
2007	1.38	0.298	
2008	1.39	0.298	
2009	1.5	0.307	
2010	1.04	0.288	

Source: [a] National Statistical Office; [b] Kilenthong (2012)

It is obvious that the two methods of calculation yield starkly different ratios of labor share in GDP. We then employ both series to calculate output gap according to the formula outlined in Gali (2011). The value of α , the parameter that captures the diminish returns to marginal product of labor, is assigned to be the average value of the corresponding labor shares. In addition, we followed Gali (2011) by setting φ which is an inverse of Frisch elasticity of labor supply to equal 5, implying an elasticity of 0.2.

The output gap of Thailand during 1998-2010 is shown in Figure 1. The gap between the actual output and the potential one is consistently above zero, implying that the economy performs above its potential, or the market outcome is well beyond the efficient level. This finding is in contrast with what Gali (2010) found in the US and the euro areas, which both performed below their potential levels.
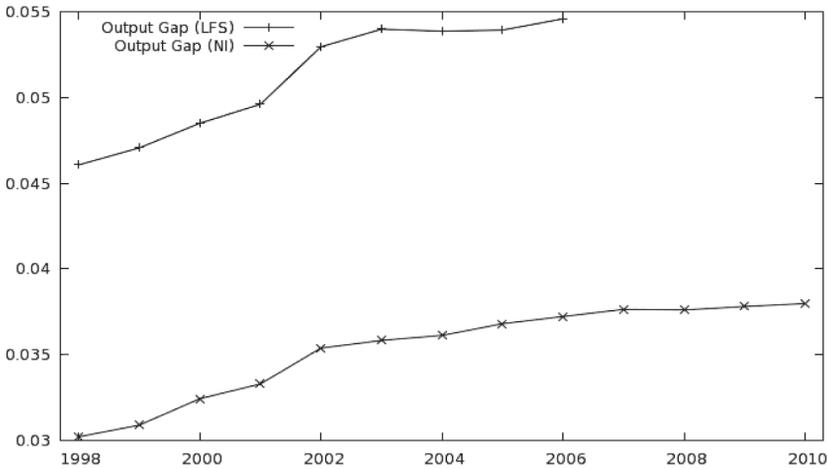

Figure 1 Output gap of Thailand during 1998-2010 under Gali (2010) approach

Inspecting the output gap measure above, we found that this result might be due partly to the low unemployment rate in Thailand. Even during the period of recessions from 2008 to 2009, the unemployment rates were no higher than 1.5 percent, the rate that most experts would consider as reflecting an overheating economy. Due to this dubious measure of unemployment rate, we found that output gap is consistently positive over the sample period.

BCA Approach

We thus turned to an alternative method of estimating potential output, the business cycle accounting (BCA) approach. We follow Chari *et al.* (2007) in modeling Thai economy as an economy in a stochastic growth environment hampered with time-varying wedges. Chari *et al.* show that a large class of economic models, including those with various detailed frictions (e.g. input-financing frictions, sticky prices, and credit market

imperfections) is equivalent to a prototype stochastic growth model, "real business cycles" model, with time-varying wedges. These wedges represent distortions either due to policies or structural factors, which prevent the economy from operating at its full potential. The wedges under consideration here include efficiency wedge A_t , labor wedge τ_t^n , and investment wedge τ_t^k .

In this economy, a representative agent chooses a consumption-investment plan and labor-leisure time allocation to solve:

$$max_{\{c_t,n_t,k_{t+1}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t, 1-n_t) \right]$$

subject to

$$c_t + k_{t+1} = (1-\tau_t^n)w_t n_t + (1-\tau_t^k)r_t k_t + (1-\delta)k_t + T_t$$

where c_t denotes the agent's consumption in period t . This variable is supposed to represent per capita non-durable consumption in the data. k_{t+1} denotes the next-period per capita capital stock that will be available for output production in date $t+1$. n_t and $1-n_t$ are fractions of time allocated to work and leisure in date t , respectively.

The representative household earns income from supplying its capital holdings and its time endowment as inputs for competitive firms. Each unit of labor hours in date t earns $(1-\tau_t^n)w_t$, where w_t is the wage rate. Note that the labor wedge τ_t^n enters the household budget in the same way as a labor income tax rate.

r_t denotes the rental rate in date t . In this specification, inefficiency in capital market, as well as financial market friction (e.g. Carlstrom and Fuerst (1997)) are captured in the capital wedge τ_t^k .[1]

The final term on the right hand side of the budget constraint T_t is transfers that the government made to the household.

There are numerous firms doing business in a perfectly competitive market. They hire factors of production, labor and capital, from households, to produce a homogeneous final good that can be used either as consumption or investment good. A representative firm solves:

$$max_{K_t,N_t} \quad A_t F(K_t, N_t) - w_t N_t - r_t K_t$$

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[1] See Chari *et al.* (2007) which provides an equivalent result of the detailed model and the prototype model with investment wedge. According to Chari *et al.*, there is no significant distinction between the specification with investment wedge and the one with capital wedge. We opt to use the latter as our starting point.

Both households and firms behave optimally. They solve their own resource allocation problem, i.e. maximizing discounted sum of life-time utility and maximizing period-by-period profit, respectively.

Equilibrium in this economy is brought about by the price mechanisms in the factor markets. That is, the demand for inputs K_t and N_t, will be equated to the corresponding quantities supplied by households, k_t and n_t. Or $k_t = K_t, n_t = N_t$

The market-clearing condition ensures that the resource constraint is obeyed.

$$c_t + k_{t+1} + g_t = A_t k_t^\alpha n_t^{1-\alpha} + (1-\delta)k_t$$

where g_t can be regarded as an additive shock to aggregate demand. In the context of an open economy, this term is a government spending-cum-net-exports shocks.

The market clearing conditions above, together with the following marginal conditions, constitute the equilibrium path of the prototype economy.

$$\frac{u_{1-n_t}}{u_{c_t}} = (1-\tau_t^n).A_t F_{N_t}$$

$$u_{c_t} = \beta E_t \left[u_{c_{t+1}} ((1-\tau_{t+1}^k)A_{t+1}F_{k_{t+1}} + 1-\delta) \right]$$

where u_c and u_{1-n} represent the marginal utility of consumption and leisure, respectively, while F_n and F_k represent the marginal product of labor and marginal product of capital. The first FOC provides a criterion for an equilibrium allocation of time endowment between leisure and labor. The inter-temporal consumption allocation, in equilibrium, must obey the second FOC.

We assume explicit functional forms of utility and production function so that we are able to quantify the unobserved wedges that drive the business cycles.

First, we assume that the utility function to is logarithmic, as follows: $u(c, 1-n)$ is $ln(c_t) + \phi ln(1-n_t)$. As a result, the corresponding first-order conditions in the household problem can be shown in the following set of equations:

$$\phi \frac{c_t}{1-n_t} = (1-\tau_t^n)w_t$$

$$\frac{1}{c_t} = \beta E_t \left[\frac{1}{c_{t+1}} ((1-\tau_{t+1}^k)r_{t+1} + 1-\delta) \right]$$

We assume that the production function $F(K,N)$ is constant returns to scale in K and N. Specifically, its functional form is assumed to be Cobb-Douglas. That is,

$$F(K_t, N_t) = K_t^\alpha N_t^{1-\alpha}$$

As a result, the firm's profit maximization yields:

$$r_t = \alpha A_t K_t^{\alpha-1} N_t^{1-\alpha}$$

$$w_t = (1-\alpha)A_t K_t^{\alpha} N_t^{-\alpha}$$

The relevant equations are collected as a system of equations as follows:

$$\phi.\frac{c_t}{1-n_t} = (1-\tau_t^n)(1-\alpha)A_t k_t^{\alpha} n_t^{-\alpha}$$

$$\frac{1}{c_t} = \beta E_t\left[\frac{1}{c_{t+1}}.((1-\tau_{t+1}^k)\alpha A_{t+1} k_{t+1}^{\alpha-1} n_{t+1}^{1-\alpha}+1-\delta)\right]$$

$$c_t + k_{t+1} + g_t = A_t k_t^{\alpha} n_t^{1-\alpha}+(1-\delta)k_t$$

To carry out a business cycle accounting analysis, one can extract the unobservable series of wedges from the actual data of macroeconomic variables through the relationships shown in this system of equations above. The methodology for implementing numerical analysis can be found in Chari *et al.* (2006).

To estimate potential output and the corresponding output gap, we assigned numerical values to the parameters in the log-linearized version of the model above, and then solved for the state space representation of the state variables of the model, taking as given the unobservable wedges. Once the matrices in the state-space system are computed, we calibrated the potential output while turning off (partially) the paths of the wedges.

Data

The quarterly data from NESDB were used in this study. The data includes GDP, private consumption expenditure, gross capital formation, net exports, and government expenditures. All data are seasonally adjusted and valued at 1988 prices. In addition, all variables are transformed into a per-capita counterpart by dividing them with the population in the corresponding quarters.

We used survey data on average hours worked during an interview week from the Labor Force Survey from 1993 to 2009. The computation was carried out through the SDA archive, on the University of Chicago-UTCC Research Center web. The observations revealed that the hours worked data have gone through some kind of structural change. The average level during 2001-2009 is significantly lower than the average level in the earlier period. Since we cannot offer any concrete explanation about this structural change, we decided to work with the quarterly data within the sample period of 2001 to 2009 instead.

Our model specifies per capita consumption as a non-durable consumption and regards a durable component of the private consumption expenditure as a part of household investment. NESDB provided a decomposition of private consumption expenditure only in the annual series of NIPA. We therefore have to use our judgment in removing durable consumption components from the private consumption expenditure series. We regard the expenditures in the classification "expenditures on metal products, machinery and equipment", as well as "transportable goods" (e.g. product of woods, rubber and plastic products, etc.) as durable consumption and therefore remove them from the quarterly private consumption series. The removed part was lumped into investment series and becomes a consolidated investment expenditures which now contain private, public and household investment.

In our model, capital stocks include household durables and gross fixed capital formation. We do not have data on the consolidated capital stock at the initial period, 1993 quarter 1 (though the data of capital stock that excludes the household's component is available on an annual basis). But since our sample period starts on 2001 q1, we use the investment data together with the law of motion of capital to construct the capital stocks series.

Let i_t be the investment of household durables, gross fixed capital formation and private and public investment:

$$K_{t+1} = i_t + (1 - \delta)K_t$$

Then *n* period later the capital stock will be:

$$K_{t+n} = \sum_{j=1}^{n-1} (1 - \delta)^j i_{t-j} + (1 - \delta)^n K_t$$

If the initial capital stock is depreciated in *n* periods then the capital stock at $t + n$ will be:

$$K_{t+n} = \sum_{j=1}^{n-1} (1 - \delta)^j i_{t-j}$$

Given that $\delta = 0.1$ per year, by 2001 the capital stock ten years earlier will completely depreciated and the existing stock at the beginning of 2001 is the sum of an undepreciated investment prior to year 2001, $\sum_{j=1}^{n-1} (1 - \delta)^j i_{t-j}$.

We used the average growth rate of per capita (consolidated) capital stock over the period 2001-2009 to represent γ_A. It is arguable that the long-run rate of growth could be computed from the GDP per capita series as well, since in theory both variables share the same rate of growth along the balanced growth path. However, our data shows that the

output and capital stock series have different average growth rate over the sample period. We thus chose the rate of growth of capital stock to represent γ_A for this study.

Result

The numerical values of parameter values in this system of equations are assigned. The labor share α is assumed to be 0.4, a number that lies between the share computed from NESDB's NIPA and the one found in Kilenthong (2012). The discount factor β equals 0.98, which is consistent with the long-run real interest rate of 0.02. Finally we assumed that physical capital depreciates at a constant rate δ which equals 0.025 per quarter or 0.1 per year.

Along the balanced growth path, all real per-capita variables, c_t, k_t, g_t and y_t grows at the same constant rate, which is identified as the rate of technological progress in the neoclassical growth model. Let γ_A be the rate of technological progress. Then,

$$A_t = (1 + \gamma_A)^t e_t^\varepsilon$$

where ϵ_t is a stochastic process representing the efficiency wedge.

We scaled all real per capita variables (except hours worked) as follows:

$$\hat{x}_t = \frac{x_t}{(1 + \gamma_A)^t}$$

We then construct alternative series of potential output under the scenarios that some or all of these wedges are removed. To be specific, we consider three hypothetical scenarios. First, all the wedges are removed. Second, we allow only the accounting wedge and the efficiency wedge. Finally, all but the capital wedge are included.

We work with the log-linearized version of the first-order conditions above. That is,

$$\ln \hat{c}_t - \frac{n}{1-n} n_t = \varepsilon_t + a(\ln \hat{k}_t - n_t) - \tau_t^n$$

$$E_t \ln \hat{c}_{t+1} - \ln \hat{c}_t = \beta r E_t [\varepsilon_{t+1} + (\alpha - 1)(\ln \hat{k}_{t+1} - n_{t+1}) - \tau_{t+1}^k]$$

$$\frac{c}{y} \ln \hat{c}_t + \frac{k}{y} \ln \hat{k}_{t+1} + \frac{g}{y} \ln \hat{g}_t = \varepsilon_t + \alpha(\ln \hat{k}_t - n_t) + (1-\delta) \frac{k}{y} \ln \hat{k}_t$$

From the system of equations above, we classify variables into two groups. The first group is a group of state variables, which consists of $\hat{k}_t, \varepsilon_t, \hat{g}_t, \tau_t^n$ and τ_t^k. The second group of variables is the collection of control variables. This group consists solely of observable variables, which are $\hat{c}_t, \hat{k}_{t+1}, \hat{y}_t$, and n_t.

We can rearrange variables in the system of equations above to form a linear equations relating state to control.

$$Y = A \cdot X$$

where $Y = [\hat{c}_t, \hat{k}_{t+1}, \hat{y}_t, n_t]'$ and $X = [\hat{k}_t, \varepsilon_t, \hat{g}_t, \tau_t^n, \tau_t^k]'$

Based on the parameter values that we assigned in the previous section, all the elements in matrix A can be found. We are able to show that:

$$
\begin{bmatrix} \hat{y}_t \\ \hat{c}_t \\ n_t \\ \hat{k}_{t+1} \end{bmatrix}
=
\begin{bmatrix}
.045 & 1.06 & -.55 & -.612 & .082 \\
.098 & .203 & .6 & -.059 & -.089 \\
-.017 & .18 & -.28 & -.31 & .04 \\
.92 & .85 & -1.15 & -.55 & -.83
\end{bmatrix}
\cdot
\begin{bmatrix} \hat{k}_t \\ \varepsilon_t \\ \tau_t^k \\ \tau_t^n \\ \hat{g}_t \end{bmatrix}
$$

The potential output is constructed from the system above by using just the part of the system that is relevant to $\hat{y}_t$. In the first scenario, we construct $\hat{y}_t$ that would have been if τ_t^n, τ_t^k and $\hat{g}_t$ are all set to zero. The potential output in this scenario is shown in Figure 2 as the solid line that lies well below the actual output. The implied output gap from this scenario is similar to the ones we found in the previous section, i.e. Gali (2010) approach. The output gap is consistently above zero.
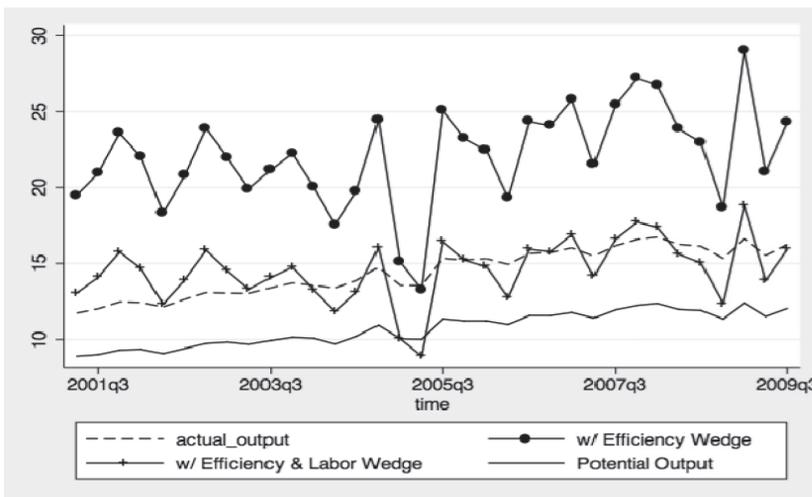

Figure 2 Various estimates of potential output

Our explanation for this first scenario result is that our specification here treats net exports as part of the accounting wedge, and by completely removing this wedge from our state-space system, the resulting potential output series stayed below the actual output in all periods. Our result concurs the common wisdom that exports sector is an essential growth engine for Thai economy.

In the second scenario, we feed the accounting wedge and the efficiency wedge obtained from the previous section into the equation above. This measure of potential output is almost everywhere greater than the actual output. This scenario fits well with the notion that potential output represents the efficient resource allocation for the economy. As a result, the implied output gap would be negative. If we use this measure of potential output to compute an output gap, we would find that the gap narrows during the economic downturn and widens during the upturn.

In the last scenario, in which the labor wedge is incorporated into the model, we can see that the output series moves around the actual output. This measure may not be at odds with the definition of potential output in the New Keynesian framework, see Gali (2008). However, the implication for monetary policy is contrary to conventional wisdom and admittedly bizarre because our measure of potential output drops below the actual output in recession. The corresponding output gap is negative, a situation which the New Keynesians interpret as an overheating economy. Thus, a monetary authority is supposed to cool down the economy by raising the policy rate. This outcome only exacerbates the situation.

Conclusion

Gali (2011) relates inefficiencies due to imperfect competition and due to wage/ price stickiness to the measure of model-based output gap. His calculation of output gap for the US and the euro areas revealed the distance between the actual and the potential level. However, when we applied such methodology to the Thai data, we found the opposite result: the Thai economy performs better than its potential level. We did not detect any flaws in Gali's model but instead placed some doubts on the measurement of Thai economic variables, especially the unemployment rate.

We then propose an alternative model-based measure of output gap, which is based on Chari *et al.* (2006; 2007)'s business cycle accounting. Under this approach, we place various "inefficiencies" or "wedges" into the prototype closed economy real business cycle model. This is a different class of models from the New Keynesians type that Gali (2011) use. We constructed a dynamic system for the Thai economy in the form of state-space representation, and computed the series of potential output by turning off some or all of the wedges. This approach yields various measures of the output gap depending on what kinds of wedges we completely eliminate. We are able to find some measures that deliver positive output gap during the recent recession, which is Gali failed to deliver.

Our calculation indicates some prospect for using this framework for further study; one can include or remove inefficiencies that may be regarded as obstacles to attaining full potential output level in the short-run. We encourage readers to extend this model by incorporating the external sector explicitly in the model, which would include external shocks or wedges.

Acknowledgement

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