Estimating the output gap in the Philippines: A DSGE approach

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Abstract: The unexpected surge in inflation and how it caused the cost-of-living crises in many countries have dominated policy discussions in the post–COVID era. However, one outcome has largely escaped scrutiny: the output gap. This note provides structural estimates of the output gap and characterizes how it behaved from 2002 to 2023 – a period characterized by sustained growth, controlled inflation, rising real wages, and widespread losses due to the pandemic. We specify a small-scale DSGE model allowing monopolistically competitive intermediate goods firms capable of markup pricing over marginal costs. In this note, we take the side of macroeconomists who model the output gap using the concept of flexible price equilibrium. Since the potential output is unobserved, we used Bayesian methods and smoothers to estimate the output gap. Our output gap estimates showed marked fluctuations during the estimation period. Moreover, negative output gaps appear to be associated with the period 2016-2022. We also find that demand shocks explain between 69% and 91% of the conditional forecast error variance of the output gap for 1 and 8-quarter horizons, respectively. Finally, evidence also shows that the policy rate is more sensitive to the output gap relative to inflation, an indication that the output gap plays a major role in determining the policy rate during the study period.

Key Words: small-scale DSGE model, Philippines, Bayesian estimation, the output gap, forced savings

1. INTRODUCTION

The post–Covid era is replete with policy challenges brought about by a confluence of outcomes such as external shocks, staggered domestic adjustments among households and firms, and inflation. During COVID-19, demand was clearly dampened, and economies experienced widespread slack, compelling monetary authorities to lay down conditions favorable for early onset of recovery.

One macroeconomic outcome that still attracts attention is the output gap, which represents the disparity between actual and potential output. Hirose and Naganuma (2010) showed that the output gap, defined as deviation from flexible price equilibrium, provides useful elements for business cycle analysis or fluctuations.

Understanding the output gap is essential. It is a closely watched statistic as it has business cycle properties. A positive output gap may persuade policymakers to increase interest rates to lower inflation pressures or depress demand. On the other hand, the monetary authority may reduce interest rates if the output gap is negative.

Several studies have made significant inroads in the empirical measurement and evaluation of the output gap in the Philippines. Yap (2003) focused on the techniques used for measuring the gap (atheoretical or time series approach, structural approach, and mixed or multivariate approach). Estimates were obtained from the linear time trend model, HP filter, and unobserved components model. When added, the forecasting ability of the inflation equation improved. McNelis and Bagsic (2007) examined the output gap's role in inflation forecasting for the Philippines. Methods for extracting output gaps were used, and once estimated, they were combined with various monetary and other indicators to constitute a nonlinear method for forecasting. Modelers use the HP filter, the production function approach, and SVAR to estimate the output gap. But to our knowledge, DSGE-based output gap computations remain scant.

This study covers the period from 2002 to 2023. We address three questions: First, how did the output gap behaved during the entire sample period? Second, does the output gap affect the policy rate more than inflation? Finally, which shock determines the mean posterior variance?

The paper follows the usual organizational design. Section 2 details the structure of the New Keynesian DSGE model. Section 3 discusses some preliminaries associated with the Bayesian estimation framework. Section 4 details some robustness strategies and results associated therewith. The final section concludes.

2. THE MODEL[1]

2.1 Preliminaries

We use a model economy constituted by three well–known agents: households, firms, and monetary policymakers. A representative household consumes the final good, works in a perfectly competitive labor market, and invests its savings in domestic bonds. The household also owns firms and derives dividend income from them.

There are two types of firms: intermediate goods firms, which operate with market power, and final goods firms, which remain competitive. The final goods firm bundles together intermediate goods to produce the final

[1] This section borrows extensively from Rubaszek, M. & Skrzypczyński, P. (2008), Dacuycuy (2021), McCandless (2008), Hirose and Naganuma (2010).

good. Monetary policymakers use the Taylor rule, which assigns weights to output and inflation gaps to calibrate the policy rate.

2.1 Households

Following the standard treatment in the DSGE literature (Herbst & Schorfeide, 2016; Rubaszek & Skrzypczyński, 2008), there is a continuum of households indexed by $i \in (0,1)$. Households maximize utility subject to a budget constraint. Households are assumed to form external, not deep, habits, thereby necessitating the inclusion of the habit–adjusted level of consumption in the utility function.

Following An and Schorfeide (2007), Hirose and Naganuma (2010) and Cardani et al. (2022), the household derives utility from consumption relative to a habit stock. The utility function of the i^{th} household follows the constant relative risk aversion (CRRA) specification:

$$U_{i,t} = E_t \sum_{s=0}^{\infty} \beta^{t+s}\, \epsilon_{t+s}^{D} \left\{ \frac{\left(\frac{\left(C_{i,t+s} - \epsilon_{t+s}^{X}\right)}{\left(C_{i,t+s-1}^{h} - \epsilon_{t+s-1}^{X}\right)}\right)^{1-\sigma}}{1-\sigma} - \upsilon_L \frac{N_{i,t+s}^{1+\varphi}}{1+\varphi} \right\} \qquad (1)$$

where $N_{i,t}$ is the household's labor supply; φ is the inverse of the Frisch labor supply elasticity; and σ is the inverse of the intertemporal elasticity of substitution (IES). The parameter h denotes habits. ϵ_{t+s}^{X} represents a type of shock known as `force savings' transitory shock that became active during a crisis. It is an independent and identically distributed random variable. Because of the relevance of persistent processes durin the pandemic, the demand shock is specified as an autoregressive linear process:

$$\epsilon_{t+s}^{D} = (1-\rho_k)\bar{\epsilon}^{D} + \rho_D \epsilon_{t-1}^{D} + \sigma_D \eta_t^{D} \qquad (2)$$

which has the following log–linearized form:

$$\hat{\epsilon}_t^{k} = \rho_k \hat{\epsilon}_{t-1}^{k} + \sigma_k \eta_t^{k}$$

Where $E[\eta_t^k] = 0$. We assume that $E[\epsilon_t^k] = 1$ and that $\hat{\epsilon}_t^k = \frac{\epsilon_t^k - 1}{1}$.

The household receives labor payments and dividends. They consume and pay $P_t C_t$ or invest in securities $B_{i,t}$ that pay R_{t-1} . We discount the role of the government; hence no taxes are charged to households and firms. The constraint is specified as

$$C_{i,t} + \frac{B_{i,t}}{P_t} = R_{t-1}\frac{B_{i,t-1}}{P_t} + \frac{W_t}{P_t}N_{i,t} + Div_{i,t} \quad (3)$$

Maximizing (1) with respect to consumption and bonds, subject to the constraint (6) , leads to the specification of the dynamic IS curve. The first order condition associated with $B_{i,t}$ is

$$\frac{\mu_t^*}{C_t} = \beta R_t E_t\left[\frac{\mu_{t+1}^*}{C_{t+1}}\frac{P_t}{P_{t+1}}\right] \quad (4)$$

Where μ_t^*

$$\epsilon_t^D \left(C_{t+s}/C_{t+s-1}^h\right)^{1-\sigma} - \beta h E_t \epsilon_{t+1}^D \left[\left(C_{t+1} / C_t^h\right)^{1-\sigma}\right] \quad (5)$$

The intra-temporal condition for labor is given by

$$\frac{\epsilon_t^D \upsilon_L N_t^\varphi}{(\mu_t^*/C_t)} = \frac{W_t}{P_t} \quad (6)$$

2.2 Firms

This section heavily borrows from Rubaszek & Skrzypczyński (2008), Herbst & Schorfeide (2016), Hirose and Naganuma (2010) and McCandless (2008). The goods market is characterized by nominal rigidities in price adjustments. There are two types of firms, namely: final goods and intermediate goods firms. According to Herbst & Schorfeide (2016), the set–up allows the introduction of price– setting. Indexed by $j \in [0,1]$, intermediate goods firms produced differentiated goods which are sold to the competitive final goods firm. However, there are two types of intermediate goods firms. Firms belonging to the first type can set prices optimally per period. The second type of firms follows a certain rule of thumb in setting prices, implying that pricing histories are used. The non–zero probability that a firm is unable to set prices optimally is ζ. The constant returns to scale (CRS) production technology of the perfectly competitive final goods firm is specified as:

$$Y_t = \left[\int_0^1 \left(Y_{j,t}\right)^{1-\frac{1}{\lambda_t}} dj\right]^{\frac{1}{1-\frac{1}{\lambda_t}}} \quad (7)$$

where $\lambda_t \in (0, \infty)$ represents the elasticity of demand for intermediate inputs. Given the intermediate goods inputs, the final goods firm maximizes profits, taking as given the prices of intermediate goods. The price at which the final good is sold is

$$P_t = \left[\int_0^1 \left(P_{j,t}\right)^{1-\lambda_t} dj\right]^{\frac{1}{1-\lambda_t}} \quad (8)$$

Accordingly, the final goods firm's demand for the intermediate good is given by

$$Y_{j,t} = \left[\frac{P_{j,t}}{P_t}\right]^{-\lambda_t} Y_t \quad (9)$$

For each intermediate goods firm, the production function is assumed to depend only on labor and is subject to constant returns to scale technology.

$$Y_{j,t} = A_t \epsilon_t^S N_{j,t} - FC_t \quad (10)$$

where A_t represents a deterministic trend gt, ϵ_t^S is a covariance–stationary shock with the form

$$\epsilon_t^S = (1-\rho_S)\bar{\epsilon}^S + \rho_S \epsilon_{t-1}^S + \sigma_S \eta_t^S \quad ()$$

and $FC_t = \frac{Y_t}{\theta}$ is the fixed costs to ensure that profits are zero in equilibrium.

Each firm's cost minimization problem, is

$$\min_{N_t} \frac{W_t}{P_t} N_t + \Phi\left(Y_{j,t} - A_t \epsilon_t^S N_{j,t} + FC_t\right)$$

Φ is the firm's marginal cost. Technology shocks reduce marginal costs while the input price increases them. The marginal cost of the firm could be derived by minimizing total labor cost subject to the feasibility constraint.

$$MC_{j,t} = \frac{\frac{W_t}{P_t}}{A_t \epsilon_t^S} \quad (11)$$

Following Calvo (1983), only a fraction of firms will receive a signal to change their prices with probability $1-\zeta$. The objective function

$$E_t \sum_{s=0}^{\infty} \zeta^s Q_{t,t+s} \left\{ \left(\frac{P_t(k)}{P_{t+i}}\right)^{1-\sigma} Y_{t+s}(j) - \Phi Y_{t+s}(j) \right\}$$

$$\frac{\tilde{P}_t}{P_t} = \varpi_t \frac{E_t \sum_{s=0}^{\infty} \zeta^s Q_{t,t+s} Y_{t+s} MC_{t+s} \left(\frac{P_{t+s}}{P_t}\right)^{\theta}}{E_t \sum_{s=0}^{\infty} \zeta^s Q_{t,t+s} Y_{t+s} \left(\frac{P_{t+s}}{P_t}\right)^{\theta-1}} \quad (12)$$

$$\varpi_t = \frac{\lambda_t}{\lambda_t - 1}$$

The price level equation is

$$P_t = \left[\zeta P_{t-1}^{1-\lambda_t} + (1-\zeta)\left(\tilde{P}_t\right)^{1-\lambda_t}\right]^{\frac{1}{1-\lambda_t}} \quad (13)$$

Following Hirose and Naganuma (2010), the Phillips curve is specified as in log -linearized form is.

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\beta\zeta)(1-\zeta)}{\zeta} RMC_t + \frac{1-\zeta}{\zeta}(z_t - \beta\zeta E_t z_{t+1}) \quad (14)$$

Where RMC_t is the real marginal costs and z_t is a cost push shock..

2.3 Flexible price equilibrium and the output gap

Hirose and Naganuma define the output gap as the deviation of the actual output from potential output. To operationalize, the output gap is the deviation of output from flexible equilibrium output. This is output that would prevail in an environment without cost shocks. Given no rigidities, firms can adjust their prices every period, making infeasible the emergence of cost-push shocks. In this equilibrium $\zeta = 0$, the equilibrium price is equal to the price P_t and the price mark-up is a constant, that is, $\varpi_t = \varpi$.

In this case, real marginal costs will be equal to

$$\frac{\epsilon_t^D \upsilon_L N_{i,t}^{\varphi}}{(\mu_t / C_t)} = \frac{A_t \epsilon_t^S}{Z} \quad (15)$$

The output gap, which is unobserved, measures the percent deviation of actual output from flexible price equilibrium.

$$Gap_t = y_t - y_t^f$$

2.3 Monetary policy

The monetary policy maker's objective is to maintain price and output stability.

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{\bar{r}}\right)^{\gamma} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\gamma_\pi} (Gap_t)^{\gamma_{\mathrm{AY}}}\right]^{1-\gamma} exp(\sigma_M \epsilon_t^M) \quad (16)$$

where $\bar{r}$ is the steady state interest rate and $\bar{\pi}$ is the inflation target. ϵ_t^M is a monetary policy shock. Note that specification (16) follows the output growth rule version of the Taylor rule as discussed in Schorfeide and An (2007).

2.4 Shocks

We assumed that forced-savings shocks are not realized in the model. Thus, the model consists of productivity, demand, cost, and monetary policy shocks. All, except monetary shocks are represented by autoregressive error processes.

3. RESULTS AND DISCUSSION

3.1 Data

Data were obtained from the Philippine Statistics Authority's (PSA) OpenStats and Bangko Sentral ng Pilipinas (BSP) websites. To establish robustness and align our methodology to BSP's inflation targeting framework, we use GDP per capital price deflator data to compute for the quarterly inflation rates, and the overnight reverse repurchase rate (ORRP). Dynare was used to construct the Bayesian log posterior and estimate the parameters.[2]

For our robustness strategy, we compare models with or without the forced savings shocks.

3.2 Posterior distribution of parameters

For estimating the parameters of our model, the number of replications (or iterations) for the Metropolis-Hastings Markov Chain Monte Carlo algorithm is 300000 with 25% of the data used during the burn-in phase. The number of parallel chains for Metropolis-Hastings algorithm was set to 2.

Table 1. Posterior distribution of selected structural parameters

Parameter	Prior Mean	Posterior Mean	95% HPD Interval	
ζ	0.6	0.6161	0.5964	0.6356
γ_π	0.5	0.4315	0.1572	0.7415
γ_{AY}	0.8	0.7268	0.5263	0.9288

Source: Author's.

Based on Table 1, evidence points to the output gap being more informative than inflation in explaining how the policy rate was determined.

3.3 Estimated output gap

Figure 1 shows the smoothed output gap series. Expectedly, actual output was significantly lower than potential output during the pandemic. However, positive realizations of the output gap appear to be associated period prior to the global economic crisis. The estimated potential output series during the Aquino and Duterte administrations were higher than than output, leading to negative output gaps.

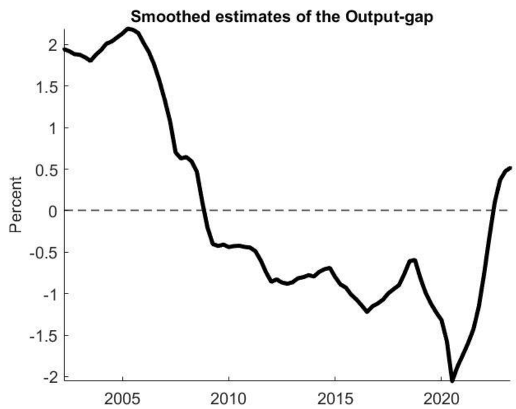

Fig. 1. Output Gap: 2002Q2 – 2023Q1

3.4 Variance decomposition

Table 2 shows the respective contributions of shocks to the conditional variance of the output gap for various periods.

Based on the posterior variance decomposition, the variance of the output gap is primarily explained by demand shocks, which is similar to Naganuma and Hirose's study. Output growth, on the other hand, is explained by both demand and productivity shocks.

Table 2. Posterior mean conditional variance decomposition of output gap (in percent)

	Monetary policy shock	Demand shock	Cost push shock	Productivity shock
Period 1	27.86	69.08	0.06	3
Period 4	12.97	85.53	0.38	1.13
Period 8	7.57	90.93	0.92	0.58

Source: Author's.

4. CONCLUSIONS

In this simple note, we use Bayesian approaches to estimate the structural parameters of a simple closed-economy DSGE model. This allowed us to measure the output gap, which is defined as the deviation of actual output from its flexible price equilibrium.

We have several takeaways. First, we find that the output gap can convey meaningful business cycle properties. Second, the conditional variance decompositions reveal that the output gap can be explained significantly by demand shocks. Third, evidence also shows that the output gap plays a major role in determining the policy rate.

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