# LARGE-SCALE ASSET PURCHASE AND SOVEREIGN DEBT MARKET DURING THE PANDEMIC


## ABSTRACT

I built a New Keynesian model calibrated to the recent large-scale asset purchase program by many emerging market central banks during the pandemic. The paper examines the effectiveness of asset purchase policies in improving liquidity conditions in the financial market. The findings suggest that asset purchase policies can effectively ease liquidity conditions in the sovereign debt market. Additionally, the study shows that large-scale asset purchases can complement conventional monetary policy by generating higher output and inflation with smaller reductions in nominal interest rates, particularly in the presence of market imperfections during negative demand shocks. The simulations also indicate that the central bank's asset purchase could serve as an alternative tool even when conventional monetary policy is limited or unavailable.



*Keywords: LSAP, Sovereign Debt, Long Term Yield, Portfolio Balance Effect*

**JEL Classification: E52; E58; E12.**

# I. INTRODUCTION

During the pandemic, emerging market (EM) central banks employed quantitative easing by engaging in large-scale asset purchases (LSAP) of sovereign bonds. The primary objective of LSAP was to complement prevailing monetary policy measures, thereby mitigating the adverse impacts of the pandemic on financial markets. But how much policy space does LSAP produce for the EM central bank during the pandemic? The extent to which LSAP contributes to the policy space of EM central banks amidst the pandemic remains uncertain. The greater the confidence that EM central banks on the efficacy of LSAP, the more they can communicate the use of this unconventional tool, and its effects and risks. With that, I examine the effectiveness of LSAP in improving liquidity conditions in the Philippine sovereign debt market. The analysis involves the construction of a New Keynesian (NK) model calibrated to reflect the recent experiences of the Bangko Sentral ng Pilipinas (BSP) during the pandemic.

In their influential work, Bernanke et. al (2004) propose LSAP as an alternative monetary policy tool during the zero lower bound episodes. They suggest that LSAP works within financial markets by influencing the supply of assets in the economy, prompting a rebalancing of asset portfolios towards riskier assets. The central bank's intervention through asset purchases serves to diminish the supply of government securities in financial markets. This reduction in the supply of government securities, in turn, drives up their prices, leading to a subsequent reduction in their yields.

The global occurrence of the COVID-19 shock has introduced refreshed uncertainties to financial markets, prompting many advanced economies (AE) central banks to implement LSAP during the pandemic. This event has given rise to a substantial body of literature exploring the utilization of LSAP by advanced economies during the pandemic, with notable contributions from researchers such as Chen et al. (2012), Christensen and Rudebusch (2012), Fratzscher et al. (2018), Gambacorta et al. (2014), Hattori et al. (2016), and Rebucci et al. (2020).

More recently, there has been a growing body of literature focused on the EM central bank's LSAP during the pandemic. One theme in this literature explores the impact of EM LSAP on government bond yields. Arslan et al. (2020) demonstrate in their study that LSAP significantly reduces local currency bond yields, with a marginal effect on exchange rates. Similarly, Prabheesh et al. (2024) conclude that LSAP has the potential to lower bond yields and increase equity returns. Fratto et al. (2021) further reveal that not only does EM LSAP reduce long-term bond yields, but their effect is even more pronounced than that of conventional interest rate cuts. On the same note, Beirne and Sugandi (2023) argue that without LSAP, bond yields could have been higher. Also, their research indicates that EM LSAPs do not significantly impact stock markets or inflation expectations.

Another strand of the literature explores the application of LSAP by central banks within formal general equilibrium models. Works by Eggertsson and Woodford (2003), Schmitt-Grohé and Uribe (2014), Auerbach and Obstfeld (2005), and Svensson (2003) are foundational for many general equilibrium models on the topic of central banks asset purchase.

This paper makes four main contributions to the existing literature. First, while there is an extensive body of literature addressing the implementation of LSAP in advanced economies, this study represents a novel approach by focusing on the impact of market imperfections on the effects of LSAP within financial markets in EM. Secondly, the paper adds to the growing body of literature that examines the influence of LSAP on business cycles in EM. Thirdly, unlike studies that concentrate on a panel of EM collectively, this paper shifts its focus to individual effects rather than group or regional effects of EM LSAP. Particularly, I provide evidence on the effects of LSAP on the Philippine sovereign debt market. Finally, whereas many surveyed papers predominantly emphasize shorter frequencies, providing evidence on the short-lived impact of EM LSAP, this paper employs quarterly time series data, which is more relevant for business cycle studies.

While existing literature has conducted comprehensive studies indicating the effectiveness of EM LSAP, there remains a notable gap in evidence presented by the literature regarding the potential efficacy of EM LSAP policies. What is notably absent in surveyed literature is the explicit incorporation of market imperfections as an underlying assumption. The presence of market imperfection is central to our analytical framework and differentiates this paper from the surveyed literature. The presence of market imperfection is evident with EM during the pandemic and the assumption of a perfect market needs to be relaxed. During the pandemic, the sovereign debt market experienced declines in liquidity and an increase in volatility. To capture the increased uncertainty witnessed in the sovereign debt market during the pandemic, this paper incorporates the assumption that financial intermediaries encounter substantial adjustment costs when rebalancing their government bond portfolios. The central bank is then capable of intervening by purchasing long-term government bonds, thereby influencing the supply of these securities, and leading to a reduction in long-term yields. The introduction of costly portfolio adjustments aims to replicate the dynamics observed in numerous EM during the pandemic, characterized by a significant decline in trading volume and liquidity at the peak of the pandemic.

I bring the model to data by employing a Bayesian estimation procedure using various macroeconomic time series. The subsequent section provides an in-depth discussion of this estimation process. Following the estimation, the model is then utilized for conducting counterfactual experiments. In these experiments, the model is tasked with simulating the impulse response of various macroeconomic variables to shocks in asset purchases, monetary policy, and demand under different parametrizations of market imperfections.

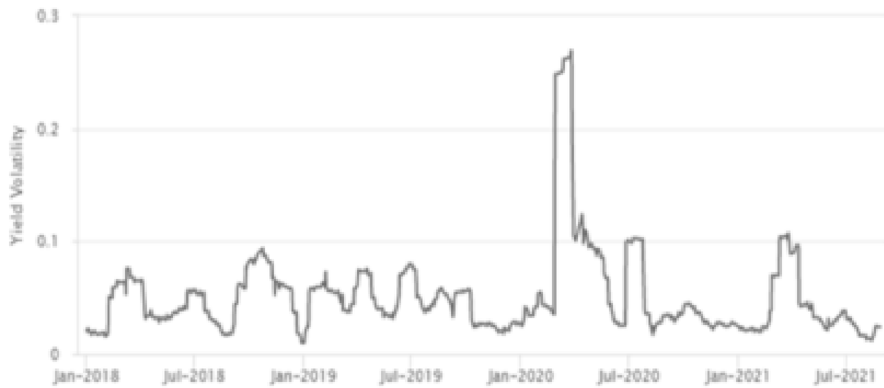
The study found that asset purchase effectively arrests liquidity constraints in the sovereign debt market, matching the observed market participants' reactions following the BSP's LSAP announcement during the pandemic. After the BSP announced the LSAP policy, market confidence was restored, liquidity conditions improved, and yield volatility declined. Furthermore, the results show that large-scale asset purchases can complement conventional monetary policy by increasing output and inflation with small reductions in nominal interest rates. This effect is particularly pronounced in situations characterized by market imperfections during negative demand shocks. The simulations conducted in the study also suggest that the central bank's engagement in asset purchases could serve as an effective alternative tool, especially in instances where conventional monetary policy is constrained or unavailable.

The plan of the paper is as follows. The next section describes the reaction of the sovereign debt market in the Philippines during the pandemic. This provides context for the extent of the pandemic shock on the financial market. This is followed by the introduction of an NK model used for the counterfactual experiment. The next section discusses the estimation procedure. This paper uses Bayesian estimation using time series relevant to the paper topic. The NK model is calibrated to investigate the effectiveness of the EMEs LSAP policy. Then, it follows the results of the paper. Finally, the paper ends with a conclusion.

## II. THE SOVEREIGN DEBT MARKET DURING THE PANDEMIC

This section provides an overview of the sovereign debt market in the Philippines. The data and graphs used in this section are sourced from ADB-Asian Bond Online. One key feature observed during the pandemic was the increase in government bond yields across different maturities, particularly during the early emergence of COVID-19 in March 2020. Figure 1 illustrates that in the early stage of the pandemic, government bond yield volatility had risen the most in the last three years. Yield volatility was calculated by determining the standard deviation of the daily yield over the past 21 trading days, using the 10-year local currency government bond. However, after the implementation of LSAP, the government bond market experienced a less volatile environment.

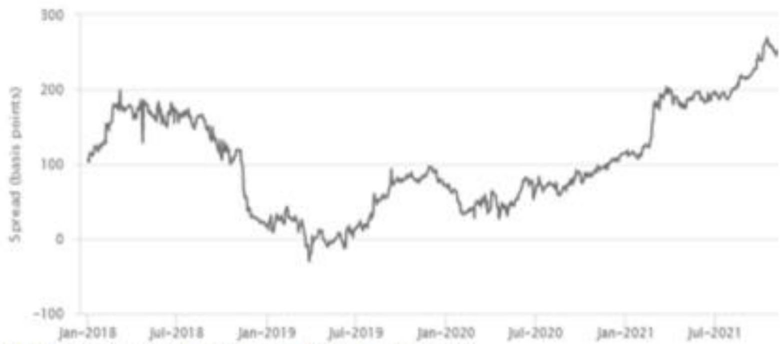
**FIGURE 1 YIELD VOLATILITY**




Source: https://asianbondsonline.adb.org//

As monetary policy remains accommodating, the yield spread between short-term and long-term sovereign bond rates continues to increase. Figure 2 illustrates this trend by displaying the yield spread between the 2-year and 10-year local currency government bonds. The graph indicates a period of yield curve flattening between February and June 2020, which suggests that bond investors were exhibiting risk-off behavior due to the uncertainty caused by the pandemic.

**FIGURE 2 YIELD SPREAD BETWEEN 2 AND 10 YRS. LOCAL CURRENCY GOVT. BOND**



Source: https://asianbondsonline.adb.org//

## IV. MODEL

The paper follows Harrison's (2012) specification which is a neoclassical model with sticky prices. The economy is lived by a continuum of households and firms. There are three types of firms in the model. The final good firm purchases aggregate goods from monopolistic competitive firms. And lastly, the financial intermediaries sell deposits from households and purchase long and short-term government bonds under costly adjustment mechanisms. Household offers labor and purchase goods from the firms.

### A. Household

Households gain utility by holding a real money balance $M_t$ and consumption $c_t$. And disutility by providing labor $L_t$. Furthermore, the household utility maximization problem can be written as

$$E_t \sum_{s=0}^{\infty} \beta^{t+s}\, \psi_{t+s} \left[ \frac{C_{t+s}^{1-1/\sigma}}{1-\gamma} - \frac{L_{t+s}^{1+\kappa}}{1+\kappa} + \frac{\chi_m^{-1}}{1-\sigma_m} \left( \frac{M_{t+s}}{P_{t+s}} \right)^{1-1/\sigma_m} \right] \qquad (1)$$

Where $\sigma, \kappa, \sigma_m \in (0,1)$ are parameters that represent the inverse relative risk aversion of households, the inverse of the Frisch substitution elasticity of labor, and the real money balance parameter consecutively; $\beta \in (0,1)$ is the household discount factor. Following Harrison (2012), the household budget constraint can be written as

$$A_t + M_t = R_t^A A_{t-1} + M_{t-1} + W_t L_t + T_t + D_t - C_t P_t \qquad (2)$$

The left-hand side of equation (2) represents the household's asset holdings. This consists of the interest-bearing asset $A_t$ and money balance $M_t$. The household net asset holding can be liquated at the value of $R_t^A A_{t-1} + M_{t-1}$. The remaining term on the household budget constraint (2) describes the household's net earnings. Which is the sum of wage-earning $W_t L_t$, transfers from the government $T_t$ , firm's dividend $D_t$ less purchase of consumption $C_t$ .

Household chooses the sequences of consumption, labor, money balance, and nominal assets consecutively $\{c_t, l_t, m_t, a_t\}$.Solving the household first-order condition yields the following:

$$\frac{\psi_t}{C_t^{1/\sigma}} = \mu_t P_t \qquad (3)$$

$$\psi_t l_t^{\kappa} = w_t \mu_t \qquad (4)$$

$$\psi_t \chi_m^{-1} \left(\frac{m_t}{P_t}\right)^{-1/\sigma_m} \frac{1}{P_t} - \mu_t + \beta E_t \mu_{t+1} = 0 \qquad (5)$$

$$-\mu_t + \beta R_{a,t} E_t \mu_{t+1} \qquad (6)$$

where $\mu_t$ is the Langrage multiplier associated with the household optimization problem. Equation (3) defines the household marginal rate of substitution. Equation (4) is the household labor hours' allocation Equation (5) is the household money balance and Equation (6) is the household optimal portfolio of nominal assets. Collectively, Equation (3) to (6) describes the decision rules of the household's optimal resource allocation. Dividing the budget constraint by the price level $P_t$, we can denote in the lowercase letter all real variables in the model. And define gross inflation as

$$\pi \equiv \frac{P_t}{P_{t-1}} \qquad (7)$$

Combining equations (3) and (6) describes the household Euler equation (7), and

$$-\frac{1}{c_t^{1/\sigma}} + \beta R_{a,t} E_t \pi_t^{-1} \frac{\psi_t/\psi_{t+1}}{c_t^{1/\sigma}} = 0 \tag{8}$$

the household Euler equation can be log linearized to give

$$\tilde{c_t} = E_t \tilde{c}_{t+1} - \sigma\left[\tilde{R}_{a,t} - E_t \tilde{\pi}_{t+1} - r_t^*\right] \tag{9}$$

where the tilde variable $\tilde{x}_t \equiv ln(x_t/x)$ denotes the log deviation of the variable $x_t$ from its steady state value $x$. The natural rate of interest assumes to follow an exogenous autoregressive process.

$$r_t^* \equiv\ -E_t\left(\tilde{\psi}_{t+1} - \tilde{\psi}_t\right) \tag{10}$$

B. The Government Budget Constraint and Central Bank Balance Sheet
In this model fiscal policy doesn't play a critical role in the allocation of resources in the economy. Hence there is no government spending and distortionary taxes in the model. This simplification allows us to focus our attention on the transmission mechanism of the LSAP.

$$\frac{T_t}{P_t} = \frac{B_{L,t}}{P_t} + \frac{B_t}{P_t} - \frac{R_{L,t}B_{L,t-1}}{P_t} - \frac{R_{t-1}B_{t-1}}{P_t} + \frac{\Delta}{P_t} \tag{11}$$

In Equation (12), the government finances the lump-sum transfers $T_t/P_t$ with net issuance of government debt, which is issued in two types, short-term debt $B_t$ and long-term bond $B_{L,t}$. And the change in central banks' balance sheets or the central bank's dividend Δ. The consolidated budget constraint is deflated by the price level $P_t$ .

The change in the central bank balance sheet can be described as

$$\frac{\Delta}{P_t} = \frac{M_t - M_{t-1}}{P_t} - \left[\frac{Q_t}{P_t} - \frac{R_{L,t}Q_{t-1}}{P_t}\right] \tag{12}$$

where the first term of Equation (13) is the seigniorage revenue in issuing currency and the second term is the net change in central bank holdings of government bonds. The LSAP policy is executed by varying the central bank's holding of long-term government debt in its balance sheet by following the asset purchase rule as

$$Q_t = q_t B_{L,t} \tag{13}$$

Combining equations (12) to (13) yields the real consolidated government budget constraint deflated by the price index

$$b_t + m_t + (1 - q_t)b_{L,t} = \pi_t^{-1}\left[m_{t-1} + R_{t-1}b_{t-1} + (1 - q_{t-1})R_{L,t}b_{L,t-1}\right] + \tau_t \tag{14}$$

and the inflation rate and real transfer can be written as,

$$\pi \equiv \frac{P_t}{P_{t-1}} \tag{15}$$

$$\tau_t \equiv \frac{T_t}{P_t} \tag{16}$$

C. Monetary Authority

There is a central bank that conducts monetary policy. The monetary authority conducts conventional monetary policy by reducing the interest rate $\breve{R}_t$ and performs LSAP by manipulating the fraction of long-term government bonds in central banks' balance sheet $q$. I assume that the central bank uses a simple Taylor Rule in the below form like Harrison's (2012) specification

$$\tilde{R}_t = \rho_R \tilde{R}_{t-1} + (1 - \rho_R)(\alpha_\pi \tilde{\pi}_t + \alpha_x \tilde{x}_t) + \epsilon_t^R \tag{17}$$

Where $\tilde{x}_t \equiv y_t - y_t^{pot}$ is the output gap, defined as the deviation of current output from its potential level. The parameter $\rho_R$ is the autoregressive coefficient for interest rate smoothing. And the parameter $\alpha_\pi$ and $\alpha_x$ are coefficients for inflation and the output gap. The asset purchase policy follows a simple autoregressive process

$$q_t = \rho_q q_{t-1} + \epsilon_t^q \tag{18}$$

where $\rho_q$ is the autoregressive coefficient for the LSAP policy. In the paper's counterfactual experiment, the central bank has two policy instruments: (1) Equation (18) which is the conventional interest rate instrument, and (2) Equation (19) which is the LSAP (QE) policy. During the peak of the pandemic, the BSP provided an accommodative policy stance and purchased large quantities of government debt both in the primary and secondary markets to ease the liquidity problem in the government securities market. This policy action of the BSP can be represented by Equations (18) and (19).

D. Financial Intermediaries

The financial intermediary accepts one-period deposits from the household and pays at the rate $R_t^A$. The fund raised from the deposit is used to finance the purchase of short-term $B_t$ and long term $B_{L,t}$ government debt. The maximization problem of the financial intermediary is

$$maxE_t\left[R_tB_t + R_{L,t+1}B_{L,t} - \left(R_t^AA_t + \frac{\upsilon}{2}\left(\delta\frac{B_t}{B_{L,t}} - 1\right)^2 P_t\right)\right] \tag{19}$$

subject to

$$A_t = B_t + B_{L,t} \tag{20}$$

The financial intermediaries maximize profit by having a positive difference between the returns they earn from their asset holding and the deposit return paid to the customers. The model assumes that the intermediaries bear the quadratic cost of rebalancing their portfolio of short and long-term government debt. The parameter $\delta$ which is the inverse steady state of the intermediary's portfolio of government bond $B_t/B_{L,t}$. This means at a steady state the intermediary's cost must be zero. The relative importance of cost adjustment is driven by the parameters $\upsilon$, the larger this parameter the more costly it is for the intermediaries to adjust their portfolio. Combining (20) and (21) yield (22), which describe the financial intermediary's maximization problem.

$$maxE_t\left[R_tB_t + R_{L,t+1}B_{L,t} - \left(R_{a,t}\left(B_t + B_{L,t}\right) + \frac{\upsilon}{2}\left(\delta\frac{B_t}{B_{L,t}} - 1\right)^2 P_t\right)\right] \tag{21}$$

The intermediary's first-order condition

$$R_t - R_t^A - \upsilon\delta\left(\delta\frac{b_t}{b_{L,t}} - 1\right)\frac{b_t}{b_{L,t}}\frac{1}{b_{L,t}} = 0 \tag{22}$$

$$E_tR_{L,t+1} - R_t^A - \upsilon\delta\left(\delta\frac{b_t}{b_{L,t}} - 1\right)\frac{b_t}{b_{L,t}}\frac{1}{b_{L,t}} = 0 \tag{23}$$

Log linearizing Equations (23) and (24) gives

$$R\tilde{R}_t - R\tilde{R}_t^A - \frac{\upsilon\delta}{b_L}\delta\frac{b}{b_L}\left(\check{b}_t - \tilde{b}_{L,t}\right) = 0 \tag{24}$$

$$RE_t\tilde{R}_{L,t+1} - R\tilde{R}_t^A + \frac{\upsilon\delta b}{b_L^2}\delta\frac{b}{b_L}\left(\check{b}_t - \tilde{b}_{L,t}\right) = 0 \tag{25}$$

Noting that $\frac{b_L}{b} = \delta$ and $R = \beta^{-1}$ in a steady state with a zero-inflation environment. This means that Equations (25) and (26) can be rearranged to give.

$$\tilde{R}_t^A = \tilde{R}_t - \beta \frac{\upsilon\delta}{b_L} \left(\breve{b}_t - \tilde{b}_{L,t}\right) \tag{26}$$

$$\tilde{R}_t^A = E_t \tilde{R}_{L,t} + \beta \frac{\upsilon}{\delta b_L} \left(\breve{b}_t - \tilde{b}_{L,t}\right) \tag{27}$$

The linear combination of Equations (27) and (28) reveals that household portfolio return can be written as

$$\tilde{R}_t^A = \frac{1}{1+\delta}\tilde{R}_t + \frac{\delta}{1+\delta} E_t \tilde{R}_{L,t} \tag{28}$$

where Equation (29) defines the rate of return that household receives in their investment of short-term and long-term government bonds. This also appears in the household Euler equation. Combining Equations (25) and (26) yields

$$\tilde{R}_t = E_t \tilde{R}_{L,t} + \beta \frac{\upsilon\delta}{b_L}\left(\frac{1}{\delta^2} + 1\right)\left(\breve{b}_t - \tilde{b}_{L,t}\right) \tag{29}$$

$$= E_t \tilde{R}_{L,t} + \nu\left(\breve{b}_t - \tilde{b}_{L,t}\right) \tag{30}$$

Where $\nu \equiv \beta \, {}^{\upsilon\delta}/_{b_L}$. Notice that the parameter $\nu$ dictates the cost of adjusting the household portfolio between short and long-term government bonds. Decreasing the supply of long-term government bonds, other things equal makes the relative price of long-term government bonds increase. Hence, decreases its yield.

E. Firms

I divided the firm sector between perfectly competitive final goods firms and monopolistic competitive intermediate goods firms. There is a continuum of intermediate goods index by $j$ which is distributed over an interval of $[0,1]$ that is being sold by the monopolistic competitive firm to the final goods firm.

The final good firms used Dixit-Stiglitz's (1977) technology in aggregating intermediate goods.

$$Y_t = \left[\int_0^1 \left(y_{j,t}\right)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{31}$$

where $y_t^j$ is the quantity of intermediate goods $j$ used at time $t$ and $\varepsilon$ is the elasticity of substitution between different goods. In every period the final good firms maximize their profit by

$$\max\left[P_t Y_t - \int_0^1 p_{j,t} y_{j,t}\, dj\right] \tag{32}$$

Solving Equation (9) given (8) yields the demand for intermediate goods and the price index

$$y_{j,t} = \left(\frac{p_{j,t}}{P_t}\right)^{-\varepsilon} Y_t\ ; \tag{33}$$

$$P_t = \left[\int_0^1 \left(p_{j,t}\right)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}} \tag{34}$$

The intermediate goods firm purchases labor and capital from the household sector and produces intermediate goods using Cobb-Douglas production technology.

$$y_{j,t} = A_t {k_{j,t}}^{\alpha} l_{j,t}^{1-\alpha} \tag{35}$$

$$\min_{k_{j,t-1}, l_{jt}} r_t k_{j,t} + w_t l_{j,t} \tag{36}$$

Solving (37) given (36) yields the intermediate firms' demand for labor and capital.

$$r_t = \frac{\alpha w_t}{(1-\alpha)} \frac{l_{jt}}{k_{j,t}} \tag{37}$$

Rewriting (38) as $r_t^P k_{jt}^P = \frac{\alpha l_{jt} w_t}{(1-\alpha)}$ and substituting it with (37) yields the real cost of the intermediate firms.

$$w_t l_{jt} + \frac{\alpha w_t l_{jt}}{(1-\alpha)} = \frac{w_t l_{jt}}{(1-\alpha)} \tag{38}$$

Substituting (39) to (36) and letting it equal to 1, exploiting the fact that each intermediate firm uses constant return to scale (CRS) technology, like Fernandez-Villaverde and Ramirez (2006), yields

$$l_{jt} = \frac{r_t}{w_t}\frac{(1-\alpha)}{\alpha} k_{j,t} \tag{39}$$

Again, substituting (40) into (37) gives the intermediate firm's marginal cost.

$$mc_t = \left(\frac{1}{(1-\alpha)}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} \frac{w_t^{1-\alpha} r_t^{\alpha}}{A_t} \tag{40}$$

Using Calvo pricing, $(1-\theta)$ a fraction of the firms will optimize their price and the rest of the firms will index their price from past inflation. The indexation parameter $\chi \in [0,1]$ governs the relative desire of a non-optimizing firm to index its price. Given the optimal demand for intermediate goods,

$$y_{jt+\omega} = \left(\prod_{s=1}^{\omega} \pi_{t+s-1}^{\chi} \frac{P_{jt}}{P_{t+\omega}}\right)^{-\varepsilon} y_{t+\omega} \tag{41}$$

The firm's problem is to maximize (43) subject to (42)

$$\max_{P_{jt}} E_t \sum_{\omega=0}^{\infty} (\beta\theta)^{\omega} \frac{\lambda_{t+\omega}}{\lambda_t} \left( \prod_{s=1}^{\omega} \pi_{t+s-1}^{\chi} \frac{p_{jt}}{p_{t+\omega}} - mc_{t+\omega} \right) y_{jt+\omega} \tag{42}$$

Where $\frac{\lambda_{t+\omega}}{\lambda_t}$ is the firm's discount factor for valuing its future profits. Taking the first-order condition of the firm's problem leads to

$$\begin{aligned} E_t \sum_{\omega=0}^{\infty} (\beta\theta)' \lambda_{t+\omega} \Bigg\{ (1-\varepsilon) \left( \prod_{s=1}^{\omega} \frac{\pi_{t+s-1}^{\chi}}{\pi_{t+s}} \frac{P_t^*}{p_t} \right)^{1-\varepsilon} \frac{p_t^*}{p_t} \\ + \varepsilon \left( \prod_{s=1}^{\omega} \frac{\pi_{t+s-1}^{\chi}}{\pi_{t+s}} \right)^{-\varepsilon} mc_{jt+\omega} \Bigg\} y_{jt+\omega} = 0 \end{aligned} \tag{43}$$

Considering the result of the firm's pricing decision, the price index evolves according to the following rule:

$$p_t^{1-\xi} = \theta \left( \pi_{t-1}^{\chi} \right)^{1-\xi} p_{t-1}^{1-\xi} + (1-\theta) p_t^{*(1-\xi)} \tag{44}$$

Rearranging (45) implies that

$$1 = \theta \left[ \frac{\pi_t^{\chi}}{\pi_{t+1}} \right]^{-\varepsilon} + (1-\theta) \pi_t^{*(1-\varepsilon)} \tag{45}$$

## V. ESTIMATION PROCEDURE

In this paper, I used the Bayesian method to estimate the parameters in the DSGE model. There are several formal estimations and econometric procedures in the literature that evaluate the empirical fit of DSGE models. Christiano and Eichenbaum (1992) use generalized methods of moments to estimate the equilibrium relationship in the model. Other works, like Rotemberg and Woodford (1998) and Christiano, Eichenbaum, and Evans (1992) exploit the difference between the impulse response function between DSGE and VAR. Classical estimation procedures such as maximum likelihood and general methods of moments have inherent limitations in solving complex DSGE models. Due to this very complexity, even a small-scale DSGE model has issues in fitting the model's result with stylized facts observed with the data. In the interest of space, interested readers can read the exposition of An and Schorfheide (2007a) in providing details surveys on Bayesian estimation. And for the sake of consistency in this section, the paper will follow their notation.

What is novel to this paper is, that by using sovereign debt yield data, the paper wishes to estimate the parameter $\nu$ which dictates the elasticity long long-term sovereign yield to short-term yield. In Harrison (2012) this parameter is set to 0.1. This value is based on the experience of the Bank of England in its asset purchase program. In understanding the experience of the Philippines, we wish to compare the parameter value of $\nu$ using data before and after the COVID-19 pandemic. Dacuycuy (2021) made a similar exercise in understanding the effects of the exclusion of extreme data points during the pandemic in estimating a DSGE model. In his study, he showed that parameter estimation will continue to be identified despite the inclusion of extreme data points from the pandemic.

### A. Model State Space Representation and Solution

The equations in the model form a nonlinear rational expectation system equation driven by a vector of innovations in the model. Before we can estimate the DSGE model in our paper, this rational expectation system of the equation needs to be solved. The solution for the model of a rational system of equations takes the form of

$$s_t = \Phi\,(s_{t-1}, \epsilon_t, \theta) \tag{46}$$

where $s_t$ is a vector of the model's endogenous variables, $\epsilon_t$ is the vector of model innovation which is assumed to be following the autoregressive process and $\theta$ which is the vector of model parameters in which the interest of our estimation. Since the model is a system of nonlinear system of equations. It is common to log linearize Equation (47) into a system of linear equations. We can rewrite Equation (47) as

$$\hat{s}_t = \Phi\,(\hat{s}_{t-1}, \epsilon_t, \theta) \tag{47}$$

where $\hat{s}_t = s_t - \bar{s}$ is the deviation of the endogenous variables from their steady state. There are several solution methods for solving Equations (48) in DSGE models.

Look at the example proposed by Blanchard and Kahn (1980), Binder and Pesaran (1997), Kings and Watson (1998), Uhlig (2001), Anderson (2010), Kim (2000), Christiano (2002) and Sims (2002) as an example. In this paper, I used Dynare (2021) to solve and estimate the NK DSGE model I propose. Dynare relies on the perturbation method to solve for numerical solutions (Fernández-Villaverde & Rubio-Ramírez, 2006) which is an acceptable method for numerical solutions.

B. Data Gathering and Measurement Equation

Central to the estimation of the DSGE model is linking the likelihood function of the endogenous variables in the model to the observable variables. This is accomplished by constructing a measurement equation that maps the observable variables to the model's state variables.

Particularly, we are interested in the parameter $\nu$ which dictates the elasticity of long-term sovereign yield to short-term yield. This parameter reflects the cost of rebalancing the household asset portfolio, which provides information on the degree of financial friction in the economy. The measurement equation is constructed and written as:

$$y_t^{Obs} = \mu_Y + 100(\hat{y}_t - \hat{y}_{t-1}) \tag{48}$$

$$R_t^{Obs} = \mu_R + 100(\hat{r}_t) \tag{49}$$

$$\pi_t^{Obs} = \mu_\pi + 100(\hat{\pi}_t) \tag{50}$$

where $\mu_Y$ is the trend growth rate of output and $\mu_R$ and $\mu_\pi$ are the mean of the short-term rate of the T-Bill and the mean of inflation consecutively. And where $y_t^{Obs}$ and $\pi_t^{Obs}$ are time series observations on output and inflation. Lastly, $R_t^{Obs}$ is the observation of the 91 Treasury Bill.

In constructing the measurement equation, I obtained quarterly time series from the Philippine Statistic Authority, BSP, and Bureau of Treasury. For the observable, I used gross domestic output deflated by the constant price (based on 2018), the applicable Consumer Price Index is used to compute for inflation and 91 days Treasury rates are used for the computation of the short-term interest rate. All-time series were demeaned, seasonalize, and taken the first difference to ensure stationarity.

C. The Priors

Dynare is used in evaluating the parameters' posterior distribution. Dynare estimates the parameters' posterior distribution using the likelihood of observing the data given the parameters and the prior distribution. The parameter prior is the belief about the parameter that is used to update the posterior estimation. This paper follows the procedure by Herbst and Schorfheide (2016) in constructing the set of priors. Generally, in their procedure, the model parameters can be grouped into three. The first group consists of the parameters related to the model intercept; the second one consists of parameters of the endogenous variables; the final group consists of the parameters related to the models' exogenous shocks.

The parameter $\sigma$ dictates the curvature of the household utility function, with this property, $\sigma$ describes the uncertainty of household consumption. I follow Rubaszek and Skrzypczyński (2008) prior for $\sigma$, $\mathrm{Normal}(1{,}0.38)$. I choose $\mathrm{Beta}(0.29{,}0.15)$ for the slope of Philip's curve, $\kappa$. I follow Harrison (2012) for this parameter. For the elasticity of money demand, $\sigma^m$ I follow Moghaddam (2010) which is $\mathrm{Beta}(0.88{,}0.003)$. In this model, the central bank follows a simple Taylor rule to respond to inflation and the output gap. I follow Rubaszek and Skrzypczyński (2008) for both the Taylor rule coefficient, $\alpha_\pi$ $Norma(1.70{,}0.25)$ and $\alpha_x$ $Normal(1{,}0.05)$. The prior for the inflation coefficient is consistent with literature describing the respond of the inflation targeting central bank.

The parameters that dictate financial friction follow Harrison (2012). The steady-state long-term bond, $\delta$ $Normal(0.50{,}0.05)$ and the elasticity of the long-term government bond on asset portfolio, $\upsilon$ $Normal(0.10{,}0.20)$. I follow, Dacuycuy (2022) for the priors of output shock, $\epsilon^x$ $Inverse\ Gamma(3{,}2)$ and monetary policy shock, $\epsilon^R$ $Inverse\ Gamma(0.50{,}2)$. For the asset purchase shock, $\epsilon^q$ I follow Harrison (2012), $Inverse\ Gamma(0.25{,}2)$.

The priors for the AR shock process of the monetary policy shock $\rho_R$ $Uniform(0.00{,}1)$, output shock $\rho_X$ $Uniform(0.00{,}1)$ and the persistence of the asset purchase shocks, $\rho_q$ $Uniform(0.00{,}1)$.

D. Posterior Estimation

Following the usual Bayesian estimation procedure in the literature (An & Schorfheide, 2007b), I constructed two blocks of Markov Chain Monte Carlo (MCMC) simulation with 500,000 draws each. The algorithm draws samples from a probability distribution and each draw sample is dependent on the previous sample. In other words, each draw of states which is hidden creates a chain of states dependent on each draw. This characteristic allows MCMC fitted in estimating high dimensional probability distribution such as common in DSGE models. I perform the usual convergence and identification tests to ensure the robustness of the estimation results.

## III. RESULTS AND DISCUSSION

This section comprises four subsections. The first subsection discusses the results of the Bayesian estimation. The second subsection discusses the transmission mechanism of both the conventional interest rate and unconventional asset purchase policy. The third subsection discusses the impulse response to a negative demand shock. The final subsection discusses the historical shock decomposition of output and inflation.

A. Estimation Results

Table 1 presents the prior and the posterior mean used in the simulation of the model. The parameter $\beta = 0.9998$ is calibrated in the model.

**TABLE 1**
**PRIOR DISTRIBUTION AND FULL SAMPLE ESTIMATION RESULT**

| Parameter | Prior Type | Prior Mean | Post. Mean | 90 % HPD Interval | Post Std Dev |
|---|---|---|---|---|---|
| *Structural Parameter* | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The inverse of Intertemporal Substitution | $\sigma$ | Normal | 1.0000 | 1.0239 | 1.0144 | 1.0376 | 0.3800 |
| Slope of Philips Curve | $\kappa$ | Beta | 0.2900 | 0.7162 | 0.7020 | 0.7312 | 0.1500 |
| Money Demand Elasticity | $\sigma_m$ | Beta | 0.8800 | 0.8747 | 0.8743 | 0.8752 | 0.0030 |
| *Monetary Policy Rule* | | | | | | | |
| Taylor Rule Coefficient Inflation | $\alpha_\pi$ | Normal | 1.7000 | 1.5246 | 1.5201 | 1.5288 | 0.2500 |
| Taylor Rule Coefficient Output Gap | $\alpha_x$ | Normal | 1.0000 | 0.8605 | 0.8461 | 0.8738 | 0.0500 |
| *Asset Portfolio* | | | | | | | |
| Steady State Long and Short-Term Bond | $\delta$ | Normal | 0.5000 | 0.5590 | 0.5540 | 0.5629 | 0.0500 |
| Elasticity of Long-Term Bond on Asset Portfolio | $\nu$ | Normal | 0.1000 | 0.3137 | 0.3075 | 0.3200 | 0.2000 |
| *Observable Trend* | | | | | | | |
| Output Trend | | Normal | 0.3000 | 0.4599 | 0.4424 | 0.4779 | 0.0900 |
| T-Bill Growth Rate | | Gamma | 1.0000 | 0.0052 | 0.0000 | 0.0120 | 1.000 |
| Inflation Constant | | Gamma | 1.0000 | 0.6971 | 0.6694 | 0.7264 | 0.2000 |
| *Shock Persistence* | | | | | | | |
| Persistence of Monetary Policy | $\rho_R$ | Uniform | 0.5000 | 0.5414 | 0.5365 | 0.5450 | 0.2887 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Persistence of Output | $\rho_x$ | Uniform | 0.5000 | 0.4881 | 0.4852 | 0.4910 | 0.2887 |
| Persistence of Asset Purchase Policy | $\rho_q$ | Uniform | 0.5000 | 0.9998 | 0.9997 | 1.0000 | 0.2887 |

Source: Author’s calculation. This table provides the result of the Bayesian estimation. The parameters and their values presented in Table 1 were used for the model calibration.

## B. The Transmission Mechanism

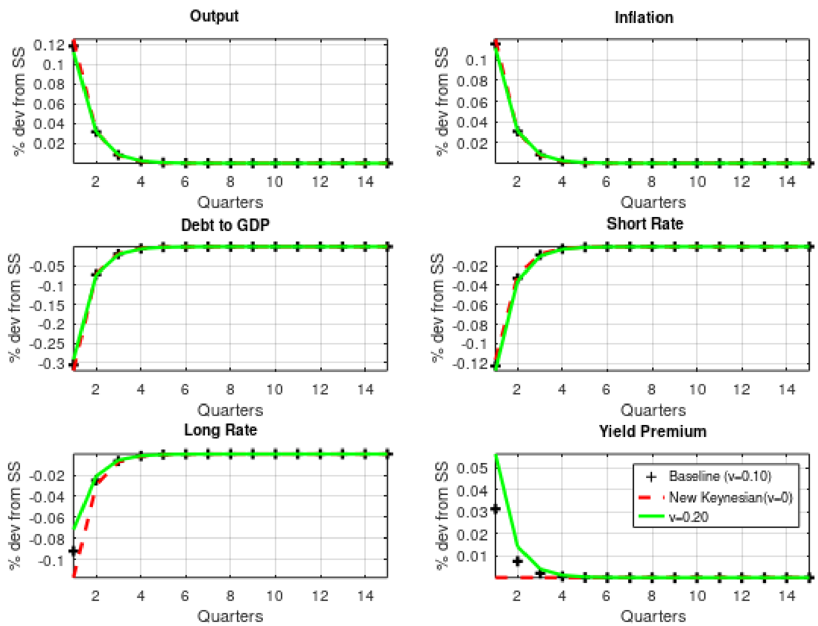
This section explores the transmission mechanisms of conventional interest rate policy and the unconventional policy of asset purchase.

### *Interest Rate Policy*

Figure 3 displays the effect of monetary policy accommodation under different parameterizations of market imperfection. The figure shows how several economic variables, including output, inflation, the debt-to-GDP ratio, short-term and long-term rates, and the yield premium, respond to a negative shock to the Taylor rule. In this experiment, the central bank reduces the policy rate by 5 percent in the current quarter. In the standard model, the reduction in nominal interest rates leads to a decrease in real interest rates due to price rigidity. This decline in real rates stimulates demand and inflation through the Philips Curve.

The impact of market imperfection on economic variables' movement remains unchanged despite variations in the portfolio elasticity parameterization. The decrease in nominal interest rates results in short-term output growth, stimulating inflation through the Philips Curve. This growth improves GDP and reduces the debt-to-GDP ratio, increasing government revenue. Additionally, the accommodative policy reduces the financing cost of government debt as financial intermediaries decrease their holding of short-term government debt, resulting in a reduction in short-term yield. The yield premium, determined by the fixed supply of government bonds and a function of short- and long-term debt, is also affected by the reduction in sovereign debt financing costs, causing a rise in the yield premium.

**FIGURE 3**
**IMPULSE RESPONSE TO THE INTEREST POLICY SHOCK**




The impulse response in Figure 3 represents a 5 percent reduction in monetary policy rate $\epsilon_t^R = -0.05$

The response of the model variables in Figure 3 can be interpreted as a stylized version of the textbook description of open market operations. When the central bank purchases government bonds, it injects reserves into the banking system, increasing overall liquidity conditions in the financial market. This increased liquidity leads to a decrease in nominal interest rates, which, in turn, boosts output.

Figure 3 illustrates the impact of market imperfection on the effectiveness of conventional monetary policy instruments, as demonstrated by the portfolio balance effect. The solid line on the graph, which corresponds to a higher market imperfection parameter ($\upsilon$=0.20), indicates a greater reduction in nominal interest rates compared to the Baseline and New Keynesian scenarios. However, the response of output and inflation is weaker in this case, suggesting a loss in efficiency in the transmission of monetary policy. These findings suggest that central banks may need to take additional measures to achieve their desired outcomes when market imperfections are present.

The findings of the study are relevant to emerging economies like the Philippines where market inefficiencies and restricted access to capital markets are common. Insufficient liquidity and shallow capital markets can cause market inefficiencies and impede the transmission of monetary policy, as illustrated in the research. Additionally, since numerous companies in emerging economies have limited access to bank funding, a properly functioning capital market may provide them with a stable and cost-effective financing source. As a result, policymakers in emerging economies must address market inefficiencies and foster the growth of their capital markets to promote economic development and stability.

*Asset Purchase Policy*

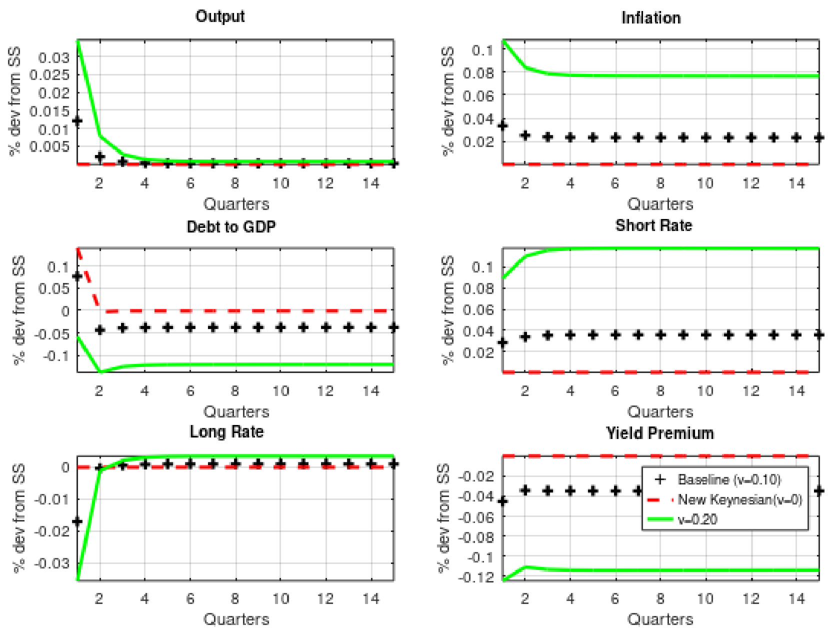
Figure 4 shows the response of the model variables to shock on long-term bond asset purchases of the central bank. Equations (14) and (19) describe the mechanism of the central bank asset purchase policy. In this experiment, the model experiences a positive shock on the asset purchase rule equal to $\epsilon_t^q = 0.25$, which under this parameter value indicates the central bank purchased 25 percent of the outstanding stock of long-term government bonds.

When the central bank purchases long-term government bonds, it causes a change in financial intermediaries' asset mix by shifting towards short-term government bonds. With increased liquidity from the reserves provided by the central bank, the premium on long-term government bonds decreases, causing their prices to rise and their yield to fall. This lower yield on long-term government bonds results in an improvement in output and an increase in inflation. The decrease in the long-term yield reduces the rate of return on household savings and borrowing, leading to a boost in aggregate demand.

Increasing market liquidity also helps the government to lower the cost of financing its debt. As the yield on government bonds decreases due to increased liquidity, the government can replace its high-yield outstanding debt with lower-yield bonds. This exchange leads to a temporary rise in government debt.

Comparing the effects of different levels of portfolio balance effect. Despite the effectiveness of the asset purchase on output and inflation, the presence of market imperfection shows that output and inflation respond more when $\nu = 0.20$. under the environment of an imperfect financial market, asset purchase complements existing reductions in monetary by inducing higher output and inflation with fewer reductions in nominal interest rate.

**FIGURE 4**
**RESPONSE TO THE ASSET PURCHASE SHOCK**




The impulse response in Figure 4 represents a 25 percent increase in LSAP policy $\epsilon_t^q = 0.25$. This represents 25 percent of outstanding government securities.

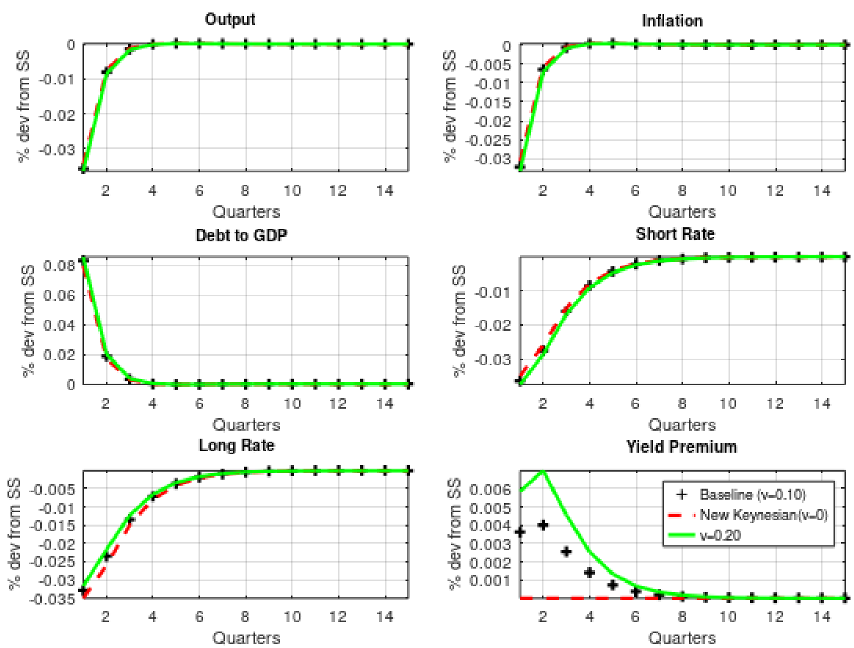
The findings in this study are in line with Harrison's (2012) research on the Bank of England's QE program. Harrison's model showed that when monetary policy is constrained, but asset purchase policy is in operation, the response of output and inflation is stronger. Their paper provides support for the effectiveness of asset purchase policies even when conventional monetary policy is not available or limited.

C. Effect of Demand Shock

In this section, the response of the model to a negative demand shock is discussed, which is presented in Figure 5. The shock results in a decrease in real interest rates, leading to a decline in both demand and inflation. To counteract these effects, the central bank adopts an accommodative policy by reducing the nominal interest rate. This reduction in nominal interest rates helps to mitigate the negative impact of the demand shock on output.

The decline in output resulting from the negative demand shock puts pressure on the government's fiscal position by reducing government revenue and increasing demand for government subsidies. This scenario is similar to what many economies have experienced during the pandemic, as governments have resorted to debt-financed deficits to support the economy in the face of weakened demand.

**FIGURE 5**
**RESPONSE TO THE NEGATIVE DEMAND SHOCK**




The impulse response in Figure 4 represents a 25 percent increase reduction in productivity $\epsilon_t^* = -0.25$.

The reduction in nominal interest rates translated to less low long-term yield compared to other parametrizations of market imperfection. In other words, for this observation, in response to a negative shock in demand, the central bank has reduced the nominal interest rate more but has fewer effects on the long-term yield. This led to the conventional policy of the central bank generating similar smaller effects on output and inflation.

D. Shocks Decomposition of Output and Inflation

This paper presents the outcomes of the shock decomposition both for output and inflation. During the early stage of the COVID-19 pandemic, the Philippine economy experienced contraction, amounting to nearly 20 percent of GDP. In response to this, the BSP started policy interventions to mitigate the effects of the pandemic. Figure 6 presents the shock decomposition for output. Notably, the impact of these negative demand shocks appears to be relatively subdued, underscoring the efficacy of the BSP’s comprehensive policy measures as shown by the marginal contribution of negative demand shock. The shocks on the conventional policy of reducing interest rates and unconventional policy such as LSAP are proven to be the most important shocks for output.

**FIGURE 6**
**SHOCK DECOMPOSITION OF OUTPUT**

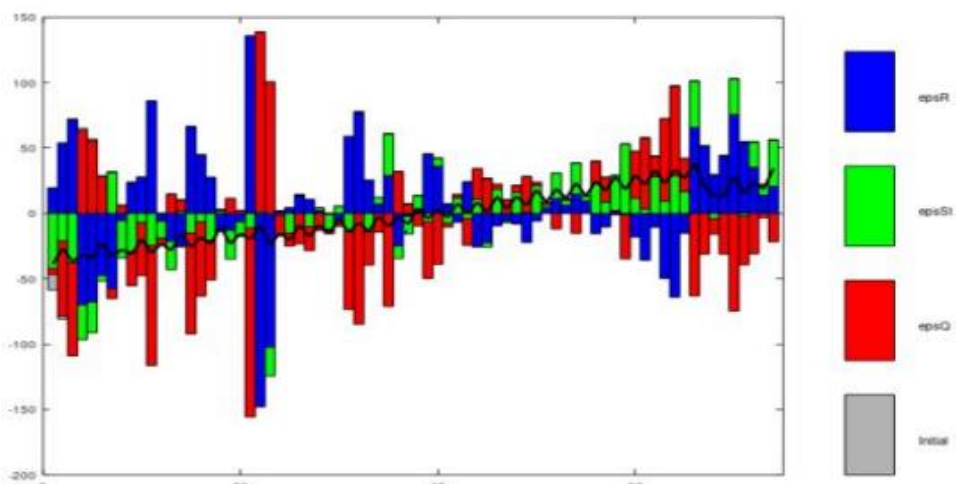
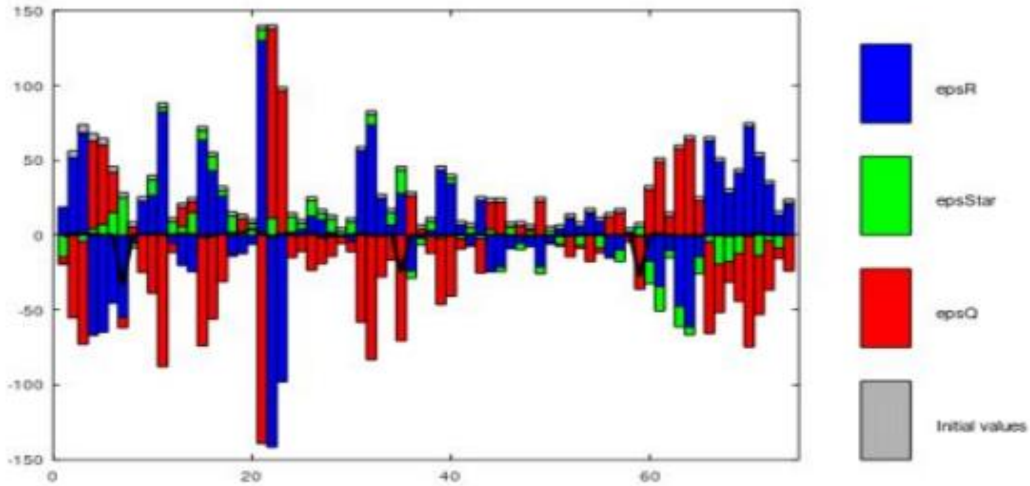



Figure 7 presents the shock decomposition for inflation. The paper’s findings suggest that during the COVID-19 pandemic, the shocks with interest rates and LSAP are the most significant influences on inflation dynamics. Comparing Figures 6 and 4 further highlights the marginal impact of demand shocks on inflation, The effects of demand shocks on inflation are far less compared to the effects of demand shocks on output.

**FIGURE 7**
**SHOCK DECOMPOSITION OF INFLATION**




## IV. CONCLUSION

This paper shows evidence of the effectiveness of asset purchase policies in improving liquidity conditions in the financial market. In addition, the counterfactual experiment produces proof that large-scale asset purchases of BSP can be effective even when conventional monetary policy is limited or not available. The paper shows that the presence of market imperfections, such as imperfect substitutability between short- and long-term bonds, proves that large-scale asset purchases can complement existing monetary policy by inducing higher output and inflation with smaller reductions in nominal interest rates. The results of this paper improved policymakers' understanding of the policy question and solution, and rank the effectiveness of conventional monetary policy and asset purchase policy.

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