Large-Scale Asset Purchase and Sovereign Debt Market During the Pandemic *

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Abstract

This paper examines how the large-scale asset purchases program during the pandemic could be an effective alternative monetary policy tool . Using a New Keynesian model, the study investigates 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 BSP's asset purchase program 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.*

1 Introduction

The COVID-19 pandemic has demonstrated that health crises can pose a significant threat to both economic growth and financial stability. The decline in economic activity and the increase in demand for government revenue to fund social welfare led to the deterioration of the national government's fiscal position. As a response, the Bangko Sentral ng Pilipinas (BSP), the Philippine central bank, has implemented an accommodative monetary policy stance by reducing the monetary policy rate. The hope in reducing the policy rate is to encourage spending and alleviate the impact of lockdown measures designed to contain the spread of COVID-19.

The demand shock of the COVID-19 pandemic not only impacted household consumption but also causes a rise in Philippine sovereign bond yield volatility. According to the ADB Bond Report, as shown in Figure 1, during the peak of the pandemic in March 2020, the Philippine sovereign bond yields recorded the highest level of volatility in the last three years. This was due to the perceived increases in Philippine credit risk, investors' risk aversion, and reduced liquidity in the sovereign debt market. The continuous stress in the sovereign debt market led to global market participants reducing their investments

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in emerging sovereign debt and shifting to safer assets such as US Treasury bonds. Given the limited fiscal space and the weakening of the national government's fiscal position, the BSP has implemented large-scale asset purchase (LSAP) to improve national government fiscal solvency and ease liquidity conditions of the sovereign debt market.

During the 2008 global financial crisis, LSAP was a common tool by advanced economies when zero lower bounds constrained conventional monetary policy instruments. At the peak of the pandemic, in considering the severe impact of the COVID-19, emerging economies like the Philippines have started to use LSAP as part of the central bank's emergency monetary policy tool. The hope of many emerging market central banks is that LSAP can provide additional support during the pandemic and complement existing policy rate reductions. Since the effects of LSAP on emerging markets are untested, policymakers in emerging markets must remain cautious. Despite the LSAP's success as an unconventional tool during the 2008 financial crisis, its effects on monetary policy transmission in emerging markets remain unproven.

Even though the pandemic continues to subside, evaluating the use of LSAP as a potential instrument in the BSP's monetary policy toolkit is important. It is essential to examine its impact on alleviating financial market risks and if LSAP could blur the delineation between the role of fiscal and monetary authorities during the counter-cyclical policy. There is also the concern that using LSAP to monetize debt may pose significant risks to fiscal dominance. Therefore, it is crucial to closely examine the effects of LSAP not only on the sovereign debt market but also as a potential instrument in which financial condition could be a channel for monetary policy transmission to influence the real economy. These questions require careful consideration as the BSP pursues policy measures in the shifting post-pandemic era.

Initial evidence shows the effectiveness of LSAP in easing the financial conditions of the sovereign debt market. However, there are still many risks from the potential negative externalities of LSAP. One area of uncertainty is how LSAP affects the transmission of monetary policy in the real economy. This raises questions about the effectiveness of monetary policy when unconventional tools like LSAP are at work. Additionally, it is important to examine the role of LSAP in restoring the function of the sovereign debt market during the pandemic. These questions require careful consideration, which this paper seeks to investigate by studying the role of LSAP in easing financial conditions in the sovereign debt market.

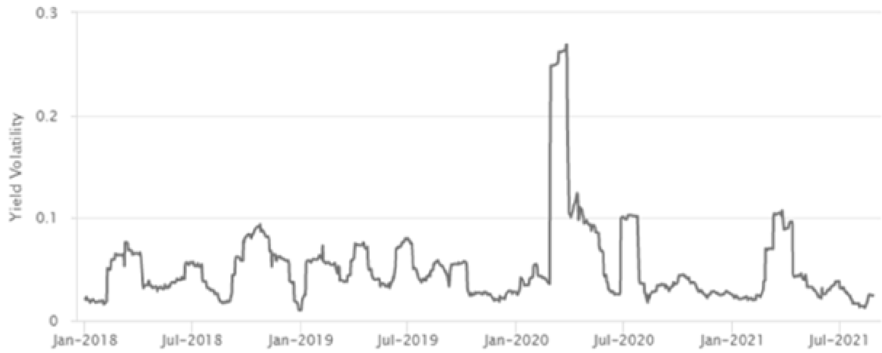
Fortunately, simulating solutions for this difficult question can be done using a macroeconomic model. In this paper, a stylized new Keynesian dynamic stochastic general equilibrium (NK DSGE) model was used to evaluate the effects of LSAP. The paper deviates from the canonical assumptions of the New Keynesian model for the LSAP to have effects on the financial markets and real activities. The standard assumption in the NK DSGE model is the use of single financial assets and asset prices which is the short-term interest rate in the economy. The premise is that the short-term nominal interest rate is enough information for a household's decision on consumption and investment. This makes the short-term nominal interest rate an important instrument for central banks to influence the economy.

In evaluating the importance of portfolio balance effects as a channel for LSAP to influence the household's consumption and investment decision in the model. This paper introduced simple financial friction, where households have access to heterogeneous assets and purchased deposits from financial intermediaries. Financial intermediaries invested the deposits in a portfolio of short and long-term government securities. In addition, financial intermediaries also face portfolio adjustment costs in rebalancing their holdings of assets, inducing the "portfolio balance effect" of Andres et. al. (2004). This modeling strategy allows financial friction to propagate shocks from the financial sector to the economy. In the model, the central banks can alter the supply of government securities and hence its prices by pursuing LSAP in the secondary market. When central banks in emerging economies like the BSP purchase long-term government bonds, it reduces the supply available to the public and increases its prices, which resulted in a reduction of long-term yield. The persistent fall of long-term interest rates stimulates demand and leads to the rise of inflation through the New Keynesian Philips Curve. The section on the literature review surveyed further the theoretical and empirical argument on the mechanism of how LSAP can be used as an alternative countercyclical instrument.

2 The Philippine Sovereign Debt Market During the Pandemic

This section provides an overview of the sovereign debt market. 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



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

3 Portfolio Balance Effect and Financial Friction

For asset purchase to have effects on the real economy deviation from the standard canonical New Keynesian model is necessary. One of them is the introduction of financial friction in the model and its role in amplifying shocks in the economy. The early research on these topics started with Bernanke and Gertler (1989) and Bernanke, Gertler, and Gilchrist (1999) on the theory of financial accelerator and external finance premium. Their research on financial factors affecting the economy provides the basis for subsequent research on financial friction in a general equilibrium model. In the early years, economic theorists abstracted the economy under the assumption of market completeness. Under such an assumption, a firm's choices of financing whether equity or debt is irrelevant Modigliani and Miller (1958). This is far from experience, as the lesson from the global financial crisis shows that financial conditions and shocks from the financial market are important sources of fluctuation in business cycles. Christiano, Motto, and Rostagno (2013) introduced financial friction into the standard dynamic stochastic general equilibrium (DSGE) model. In their work, the credit spread fluctuates with the volatility of the entrepreneurs' net worth. These features allow entrepreneurs' net worth or balance sheet drives business cycles. Lastly, Gertler and Kiyotaki (2015)and Kiyotaki and Moore (1997) emphasized the importance of bank capital in intermediating credit in the economy. In their model, bank net worth and liquidity mismatch between banks' assets and liabilities makes banks susceptible to bank runs in the emergence of a crisis. Their results show that the procyclical movement of banks' balance sheets produces a countercyclical cost of credit.

Aside from the rise of studies on incorporating the financial sector into the economy, the subsequent literature focuses on the effectiveness of unconventional policy tools such as QE as a stabilization policy. Cúrdia and Woodford (2011) in their study on how the central bank uses its balance sheet as a policy instrument showed that QE as a policy instrument has marginal benefit even if the zero lower bounds are not binding. However, they clarify that this result holds conditional on the absence of market imperfection. Also, they suggested that the central bank credit policy, which targeted the purchase of assets other than treasury such as mortgage back security (MBS), is a superior stabilization policy when financial markets are sufficiently impaired. The key to Cúrdia and Woodford (2011) results is the assumption of market completeness. Results on credit policy benefits will not be true if the market is functioning perfectly.

Wallace (1981) showed that the mixes of central bank securities holding do not matter in determining the equilibrium of resources in the economy, as the open market operation is a mere exchange of financial assets between the central bank and the private sector, and will not change the real quantity of resources in the economy. However, central bankers argue that open market operation has some effects on the market price of securities by choosing to purchase one type of securities over the others. This influences the relative price of assets as it induces the holders of those assets to change the composition of their portfolios. For example, if the central bank purchases treasury securities, this will increase the price, hence decreasing its yield. For that reason, the investors who demand higher yields will tilt their portfolios towards riskier assets such as equity and high-yielding bonds.This is called the "portfolio balance effect" in the literature. In justifying the absence of Wallace Irrelevance on QE program of central banks, Chen, Cúrdia, and Ferrero (2012) introduced market segmentation and transaction cost in a standard new Keynesian model. In their model, unconstrained households can purchase long-term government bonds. This segmentation generates dynamics for QE to have effects on long-term yield. In this environment, asset purchase decreases the long-term yield by households valuing present consumption more than future ones and encourages investment. On the other hand, Harrison (2012) introduced bond-in-utility to allow QE to have an effect in his model. Since bonds directly infuse in household Euler equation, the central bank's asset purchase affects consumer choice hence output. In his paper, this can be accomplished by influencing the supply of long-term bonds. Falagiarda (2013) using the stylized DSGE model to study the "portfolio balance effect", showed that large asset purchases from the central banks had beneficial effects on lowering the long-term yield and higher output.

On the contrary, the Preferred Habitat framework refutes the existence of Wallace's Irrelevance on QE. In this framework, individuals have a particular desire for certain maturity or habitat. And investors shall be compensated by offering a higher yield to hold bonds with greater maturity than what they desire. In other words, there is a segment of the household have needs to match the duration of its asset with the duration of its liabilities. Investors with a strong preference for long-dated bonds such as pension funds and insurance companies are reluctant to substitute their holding of a long-maturing asset for short-term assets. The yield of long-maturing securities needs to rise to induce this market participant to rebalance their portfolio by selling their holding of long-term assets and abandoning their habitat. Alternatively, if many companies are issuing long-term bonds relative to the investor who prefers them, a premium must be offered to investors for them to hold those long-term bonds. The financial condition can be influenced by QE primarily by changing the mix of assets held by the public. Under the presumption that certain investors prefer specific maturity or habitat, a decrease in the supply of assets relative to its investor demand pushes yield downward (Andrés, López-Salido, & Nelson, 2004; Christensen & Rudebusch, 2012; Hamilton & Wu, 2012; Vayanos & Vila, 2009).

4 Model

The paper follows Harrison (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 completive 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.

4.1 Household

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

$$E_t \sum_{s=0}^{\infty} \beta^{t+s} \psi_{t+s} \left[\frac{C_{t+s}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \frac{N_{t+s}^{1+\kappa_n}}{1+\kappa_n} + \frac{\chi_m^{-1}}{1-\sigma_m} \left(\frac{M_{t+s}}{P_{t+s}} \right)^{1-\frac{1}{\sigma_m}} \right] \tag{1}$$

Where $\sigma,\ \kappa_n, \sigma_m\ \in (0,1)$ are parameters that represent the household relative risk aversion, 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; ψ is the shock on the household utility function. Following Harrison (2012), the household budget constraint can be written as

$$A_t + M_t = \ R_{t-1}^{A} A_{t-1} + M_{t-1} + W_t N_t + T_t + D_t - C_t P_t \tag{2}$$

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 $R_{t-1}^{A} A_{t-1} + M_{t-1}$, where R_{t-1}^{A} is the rate of return on the household asset portfolio from the previous period. The remaining term on the household budget constraint Equation (2) describes the household's net earnings. Which is the sum of wage-earning $W_t N_t$, 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 asset consecutively $\{c_t,\ n_t, m_t, a_t\}$.Solving the household first-order condition yields the following:

$$\frac{\psi_t}{c_t^{1/\sigma}} = \ \mu_t P_t \tag{3}$$

$$\psi_t n_t^{\kappa_n} \ = \ w_t \mu_t \tag{4}$$

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

$$-\mu_t + \beta R_t^{A} E_t \mu_{t+1} \tag{6}$$

Where μ_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 and Equation (5) is the household money balance and

Equation (6) is the household optimal portfolio of nominal assets. Collectively, Equation (3) to Equation (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,

$$\pi \equiv \frac{P_t}{P_{t-1}} \tag{7}$$

Combining Equation (3) and Equation (6) describes the household Euler Equation (8), and

$$-\frac{1}{c_t^{\frac{1}{\sigma}}} + \beta R_t^A E_t \pi_t^{-1} \frac{\frac{\psi_t}{\psi_{t+1}}}{c_t^{\frac{1}{\sigma}}} = 0 \tag{8}$$

The household Euler equation can be log linearized to give

$$\widetilde{c}_t = E_t \widetilde{c}_{t+1} - \sigma \left[\widetilde{R^A}_t - E_t \widetilde{\pi}_{t+1} - r_t^* \right] \tag{9}$$

Where the tilde variable $\widetilde{c}_t \equiv ln\left(\frac{c_t}{x}\right)$ denotes the log deviation of the variable c_t from its steady state value c. The natural rate of interest can be defined as

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

and assume to follow an exogenous autoregressive process

$$r_t^* = \rho r_{t-1}^* + \varepsilon_t \tag{11}$$

The labor supply condition Equation (4) can be log linearize

$$\kappa_n \widetilde{n}_t = \check{w}_t - \sigma^{-1} \widetilde{c}_t \tag{12}$$

And the money demand can be constructed as,

$$\psi_t \chi_m^{-1} m_t^{\frac{-1}{\sigma_m}} - \Lambda_t + \beta E_t \pi_{t+1}^{-1} \Lambda_{t+1} = 0 \tag{13}$$

Which can be log linearize

$$\widetilde{m}_t = \frac{\sigma_m}{\sigma} \check{c}_t - \frac{\beta \sigma_m}{1-\beta} \widetilde{R}_t^A \tag{14}$$

Where $\Lambda_t = \mu_t P_t$ is the real langrage multiplier.

4.2 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.

$$\frac{T_t}{P_t} = \frac{B_{L,t}}{P_t} + \frac{B_t}{P_t} - \frac{R_{L,t} B_{L,t-1}}{P_t} - \frac{R_{t-1} B_{t-1}}{P_t} + \frac{\Delta}{P_t} \tag{15}$$

In Equation (15), the government finances the lump-sum transfers $\frac{T_t}{P_t}$ 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,

$$\frac{\Delta}{P_t} = \frac{M_t - M_{t-1}}{P_t} - \left[\frac{Q_t}{P_t} - \frac{R_{L,t} Q_{t-1}}{P_t} \right] \tag{16}$$

Where the first term of Equation (16) 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

$$Q_t = q_t B_{L,t} \tag{17}$$

Combining equations Equation (15) to Equation (16) yields the real consolidated government budget constraint deflated by the price index.

$$b_t + m_t + (1 - q_t)\, b_{L,t} = \ \pi_t^{-1} \left[m_{t-1} + R_{t-1} b_{t-1} + (1 - q_{t-1})\, R_{L,t} b_{L,t-1} \right] + \tau_t \tag{18}$$

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

$$\pi \equiv \frac{P_t}{P_{t-1}} \tag{19}$$

$$\tau_t \ \equiv \ \frac{T_t}{P_t} \tag{20}$$

4.3 Monetary Authority

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

$$\widetilde{R}_t = \ \rho_R \widetilde{R}_{t-1} + (1 - \rho_R)\, (\alpha_\pi \widetilde{\pi}_t + \alpha_x \widetilde{x}_t) + \ \epsilon_t^R \tag{21}$$

Where $\widetilde{x}_t \ \equiv \ y_t - y_t^{\text{pot}}$ is the output gap, defined as the deviation of current output from its potential level. The parameter ρ_R is the autoregressive coefficient for interest rate smoothing. ϵ_t^R is the Taylor rule shock that follows an autoregressive process. And the parameter α_π and α_x are coefficients for inflation and the output gap. The asset purchase policy follows a simple autoregressive process

$$q_t = \rho_q q_{t-1} + \ \epsilon_t^q \tag{22}$$

Where ρ_q is the autoregressive coefficient for the LSAP policy. In the paper's counterfactual experiment, the central bank has two policy instruments: (1) Equation (21) which is the conventional interest rate instrument, and (2) Equation (22) which is the LSAP (QE) policy. During the peak of the pandemic, the BSP provide an accommodative policy stance and purchase 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 (21) and (22).

4.4 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

$$\max E_t \left[R_t B_t + R_{L,t+1} B_{L,t} - \left(R_t^A A_t + \frac{\upsilon}{2} \left(\delta \frac{B_t}{B_{L,t}} - 1 \right)^2 P_t \right) \right] \tag{23}$$

subject to

$$A_t = B_t + B_{L,t} \tag{24}$$

The financial intermediaries maximize profit by having a positive difference between the returns it earns from its asset portfolio 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 δ which is the inverse steady state of the intermediary's portfolio of government bond $\frac{B_t}{B_{L,t}}$. This means at a steady state the intermediary's cost must be zero. The relative importance of cost adjustment is driven by the parameters υ, the larger this parameter the more costly it is for the intermediaries to adjust their portfolio. Combining Equation (23) and Equation (24) yields Equation (25), which describes the financial intermediary's maximization problem.

$$\max E_t \left[R_t B_t + R_{L,t+1} B_{L,t} - \left(R_{a,t} \left(B_t + B_{L,t} \right) + \frac{\upsilon}{2} \left(\delta \frac{B_t}{B_{L,t}} - 1 \right)^2 P_t \right) \right] \tag{25}$$

The intermediary's first-order condition

$$R_t - R_t^A - \upsilon\delta\left(\delta\frac{b_t}{b_{L,t}} - 1\right)\frac{b_t}{b_{L,t}}\frac{1}{b_{L,t}} = 0 \tag{26}$$

$$E_t R_{L,t+1} - R_t^A - \upsilon\delta\left(\delta\frac{b_t}{b_{L,t}} - 1\right)\frac{b_t}{b_{L,t}}\frac{1}{b_{L,t}} = 0 \tag{27}$$

log linearizing Equations (26) and Equation (27) gives

$$R\widetilde{R}_t - R\widetilde{R}_t^A - \frac{\upsilon\delta}{b_L}\delta\frac{b}{b_L}\left(\check{b}_t - \widetilde{b}_{L,t}\right) = 0 \tag{28}$$

$$RE_t\widetilde{R}_{L,t+1} - R\widetilde{R}_t^A + \frac{\upsilon\delta b}{b_L^2}\delta\frac{b}{b_L}\left(\check{b}_t - \widetilde{b}_{L,t}\right) = 0 \tag{29}$$

Noting that $\frac{b_L}{b} = \delta$ and $R = \beta^{-1}$ in a steady state with a zero-inflation environment. This means that Equations (28) and (29) can be rearranged to give.

$$\widetilde{R}_t^A = \widetilde{R}_t - \beta\frac{\delta\upsilon}{b_L}\left(\check{b}_t - \widetilde{b}_{L,t}\right) \tag{30}$$

$$\widetilde{R}_t^A = E_t\,\widetilde{R}_{L,t+1} + \beta\frac{\upsilon}{\delta b_L}\left(\check{b}_t - \widetilde{b}_{L,t}\right) \tag{31}$$

The linear combination of Equations (30) and (31) reveals that household portfolio return can be written as

$$\widetilde{R}_t^A = \frac{1}{1+\delta}\widetilde{R}_t + \frac{\delta}{1+\delta}E_t\widetilde{R}_{L,t} \tag{32}$$

Where Equation (32) 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 (30) and (31) yields

$$\widetilde{R}_t = E_t\widetilde{R}_{L,t+1} + \beta\frac{\delta}{b_L}\left(\frac{1}{\delta^2} + 1\right)\left(\check{b}_t - \widetilde{b}_{L,t}\right) \tag{33}$$

$$= E_t \widetilde{R}_{L,t+1} + \nu \left(\check{b}_t - \widetilde{b}_{L,t} \right) \tag{34}$$

Where $\nu \equiv \beta \frac{\delta v}{b_L}$. Notice that the parameter ν 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 increases. Hence, decreases its yield.

4.5 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 and Stiglitz (1977) technology in aggregating intermediate goods.

$$Y_t = \left[\int_0^1 (y_{j,t})^{\frac{\varepsilon-1}{\varepsilon}} \, \mathrm{dj} \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{35}$$

Where $y_{j,t}$ is the quantity of intermediate goods j used at time t and ε is the elasticity of substitution between different goods. In every period the final good firms maximize its profit by

$$\max \left[P_t Y_t - \int_0^1 p_{j,t} y_{j,t} \, \mathrm{dj} \right] \tag{36}$$

Solving Equation (36) given (35) yields the demand for intermediate goods and the price index

$$y_{j,t} = \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} Y_t \; ; \tag{37}$$

$$P_t = \left[\int_0^1 (p_{j,t})^{1-\varepsilon} \, \mathrm{dj} \right]^{\frac{1}{1-\varepsilon}} \tag{38}$$

The intermediate goods firm purchases differentiated labor $n_{j,t}$ from the household sector and produces intermediate goods using Cobb-Douglas production technology.

$$y_{j,t} = A_t n_{j,t} \tag{39}$$

Where A_t is the productivity shock that follows an autoregressive process. The intermediate firm faces quadratic cost adjustments similar to Rotemberg (1982).

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta_t \left[p_{j,t} y_{j,t} - W_t n_{j,t} - \frac{\chi_p}{2} \left(\frac{p_{j,t}}{p_{j,t-1}} - 1 \right)^2 P_t Y_t \right] \tag{40}$$

Subject to

$$y_{j,t} = \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} Y_t \; ; \tag{41}$$

$$y_{j,t} = A_t n_{j,t}; \tag{42}$$

Where W_t is the gross wage in the economy. The influence of the quadratic cost on gross inflation is measured by the parameter χ_p, in cases where $\chi_p = 0$ the model collapses into a flexible price economy.

The intermediate firm profit maximation can be written as,

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta_t \left[\left(p_{j,t} - \frac{W_t}{A} \right) \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} - \frac{\chi_p}{2} \left[\frac{p_{j,t}}{p_{j,t-1}} - 1 \right]^2 P_t \right] Y_t \tag{43}$$

Taking the first order condition

$$Y_t \left[(1-\varepsilon) \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} + \varepsilon \frac{W_t}{A} \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} \frac{1}{p_{j,t}} - \chi_p \left[\frac{p_{j,t}}{p_{j,t-1}} - 1 \right] \frac{P_t}{p_{j,t-1}} \right] \tag{44}$$

$$= -\beta \chi_p E_t \left[\frac{P_{j,t+1}}{p_{j,t}} - 1 \right] \frac{P_{t+1} p_{j,t+1}}{p_{j,t}^2} Y_{t+1} \tag{45}$$

This becomes as written below in symmetric equilibrium

$$(1-\varepsilon)+\frac{\varepsilon w_t}{A}-\chi_p\left[\pi_t-1\right]\pi_t=-\beta\chi_p \underset{t}{E}\left[\pi_{t+1}-1\right]\pi_{t+1}^2\frac{Y_{t+1}}{Y_t} \tag{46}$$

Since $\frac{w}{A}=\frac{(\varepsilon-1)}{\varepsilon}$ log linearizing Equation (46) yields

$$\check{\pi}_t=\beta E_t\check{\pi}_{t+1}+\frac{\varepsilon-1}{\chi_p}\check{w}_t \tag{47}$$

Imposing the output gap term in Equation (47) is trivial since labor is the only input of production in the economy and given that the marginal product of labor is wage. Equation (47) can be written to the familiar New Keynesian Philips Curve.

$$\check{\pi}_t=\beta E_t\check{\pi}_{t+1}+\kappa\check{x}_t \tag{48}$$

Where $\check{x}_t=y_t-y_t^{\text{Pot}}$ is the output gap, the difference between actual from potential output and $\kappa=\frac{\varepsilon-1}{\chi_p}$.

5 Bayesian Estimation and Data Collection

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 model. Christiano and Eichenbaum (1992) use generalized methods of moments to estimate the equilibrium relationship in the model. Other works, like Rotemberg and Woodford (1998), 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 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 (2007) in providing details surveys on Bayesian estimation. And for sake of consistency in this section, the paper will follow their notation.

What is novel to this paper is, by using sovereign debt yield data, the paper wishes to estimate the parameter ν which dictates the elasticity 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 estimate the parameter value of ν using data during the COVID-19 pandemic.

5.1 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

$$s_t = \Phi \left(s_{t-1}, \epsilon_t, \theta\right) \tag{49}$$

Where s_t is a vector of the model's endogenous variables, ϵ_t is the vector of model innovation which is assumed to be following the autoregressive process and θ 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 (49) into a system of linear equations. We can rewrite Equation (49) as

$$\widehat{s}_t = \Phi \left(\widehat{s}_{t-1}, \epsilon_t, \theta\right) \tag{50}$$

Where $\widehat{s}_t = s_t - \overline{s}$ is the deviation of the endogenous variables from their steady state. There are several solution methods for solving Equations (50) in DSGE model.

Look at the example proposed by Blanchard and Kahn (1980) , Binder and Pesaran (1997), King and Watson (1998), Uhlig (2001), Anderson (2010), Kim (2000), Christiano (2002) and Sims (2002) as an example. In this paper, I used Dynare (Adjemian et al., 2023) 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.

5.2 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. And 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 ν 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:

$$y_t^{\text{Obs}} = \mu_Y + 100\,(\widehat{y}_t - \widehat{y}_{t-1}) \tag{51}$$

$$R_t^{\text{Obs}} = \mu_R + 100\,(\widehat{r}_t) \tag{52}$$

$$\pi_t^{\text{Obs}} = \mu_\pi + 100\,(\widehat{\pi}_t) \tag{53}$$

Where μ_Y is the trend growth rate of output and μ_R and μ_π are the mean of the short-term rate of the T-Bill and the mean of inflation consecutively. And where y_t^{Obs} and π_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 2001:Q1 to 2022:Q2 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 take the first difference to ensure stationarity.

5.3 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 model' exogenous shocks.

The parameter σ dictates the curvature of the household utility function, with this property, σ describes the uncertainty of household consumption. I follow Rubaszek and Skrzypczyński (2008) prior for σ, Normal$(1, 0.38)$. I choose Beta$(0.29, 0.15)$ for the slope of Philip's curve, κ. I follow Harrison (2012) for this parameter. For the elasticity of money demand, σ^m I follow Moghaddam (2010) which is 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, α_π Norma$(1.70, 0.25)$ and α_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, δ Normal$(0.50, 0.05)$ and the elasticity of the long-term government bond on asset portfolio, υ Normal$(0.10, 0.20)$. I follow, Dacuycuy (2021) for the priors of output shock, ϵ^x Inverse Gamma$(3, 2)$ and monetary policy shock, ϵ^R Inverse Gamma$(0.50, 2)$. For the asset purchase shock, ϵ^q I follow Harrison (2012), Inverse Gamma$(0.25, 2)$.

The priors for the AR shock process of the monetary policy shock ρ_R Uniform$(0.00, 1)$, output shock ρ_X Uniform$(0.00, 1)$ and the persistence of the asset purchase shocks, ρ_q Uniform$(0.00, 1)$.

5.4 Posterior Estimation

Following the usual Bayesian estimation procedure in the literature (An & Schorfheide, 2007), 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 another word, 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 model. I perform the usual convergence and identification tests to ensure the robustness of the estimation results.

6 Results and Discussion

6.1 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. Please note that the slope of the Philip's Curve $\kappa = \frac{\varepsilon-1}{\chi_p}$ is a composite parameter.

6.2 The Transmission Mechanism

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

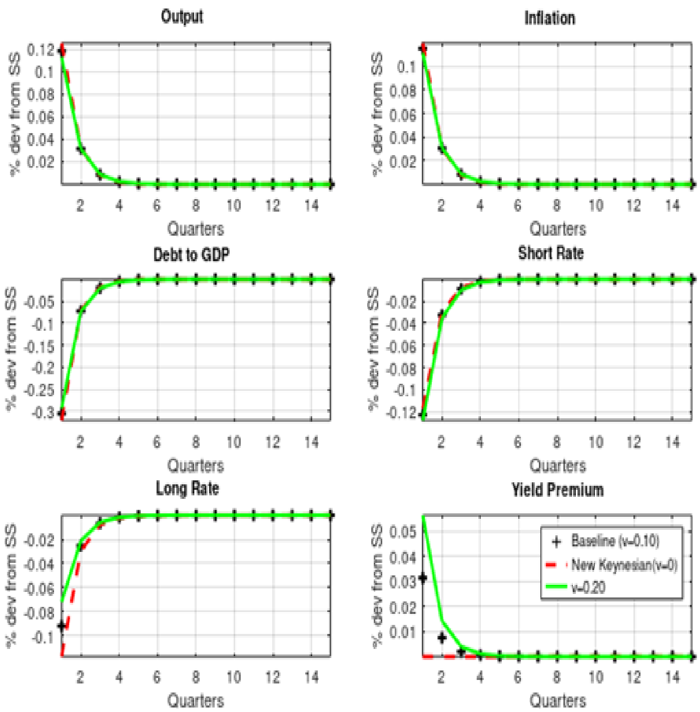
Interest Rate Policy

Figure 3 displays the effect of monetary policy accommodation under different parameterization 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 the price rigidity. This decline in real rates stimulates demand and inflation through the Philips Curve.

Table 1: Estimated Coefficient of Monetary Rule

Parameter	Prior Type	Prior Mean	Post Mean	90% HPD Interval	Std Dev
Structural Parameters					
Risk Aversion (σ)	Normal	1.0000	1.0239	1.0144 1.0376	0.3800
Philips Curve (κ)	Beta	0.2900	0.7162	0.7020 0.7312	0.1500
Money Demand (σ_m)	Beta	0.8800	0.8747	0.8743 0.8752	0.0030
Monetary Policy Rule					
Inflation Coeffient (α_π)	Normal	1.7000	1.5246	1.5201 1.5288	0.2500
Output Gap Coefficient (α_x)	Normal	1.0000	0.8605	0.8461 0.8738	0.0500
Asset Portfolio					
Long-Short Bond Ratio (δ)	Normal	0.5000	0.5590	0.5540 0.5629	0.0500
Asset Portfolio Elasticity (ν)	Normal	0.1000	0.3137	0.3075 0.3200	0.2000
Observable Constant					
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					
Monetary Policy (ρ_R)	Uniform	0.5000	0.5414	0.5365 0.5450	0.2887
Output (ρ_x)	Uniform	0.5000	0.4881	0.4852 0.4910	0.2887
Asset Purchase Policy (ρ_q)	Uniform	0.5000	0.9998	0.9997 1.0000	0.2887

Figure 3: Response to the Interest Policy Shock ($\epsilon_t^R = -0.05$)



The decrease in nominal interest rates leads to an increase in output in the short term, while the increased demand stimulates inflation through the Philips Curve. The resulting improvement in GDP growth increases government revenue and reduces the debt-to-GDP ratio. The accommodative policy also helps to reduce the financing cost of government debt. Since the supply of long term government bond is fix. The reduce financing cost resulted into decrease supply of short term government debt. The financial intermediaries reduce their holding of short-term government debt due to the reduction in short-term yield and shift their portfolio holding toward long term government bond. The yield premium increases due to changes in the supply of short term government debt and increase demand for long term government debt

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 the overall liquidity conditions in the financial market. The increase in liquidity leads to a decrease in nominal interest rates, which, in turn, induce expansion in 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 ν=0.20, shows a greater reduction in nominal interest rates compared to the Baseline and New Keynesian scenarios. However, the response of output and inflation is weaker when ν=0.20 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

Figure 4 shows the response of the model variables to shock in long-term bond asset purchases of the central bank. Equations (21) and (22) describe the mechanism of the central bank asset purchase policy. In this experiment, the model experience 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 the outstanding stock of long-term government bonds.

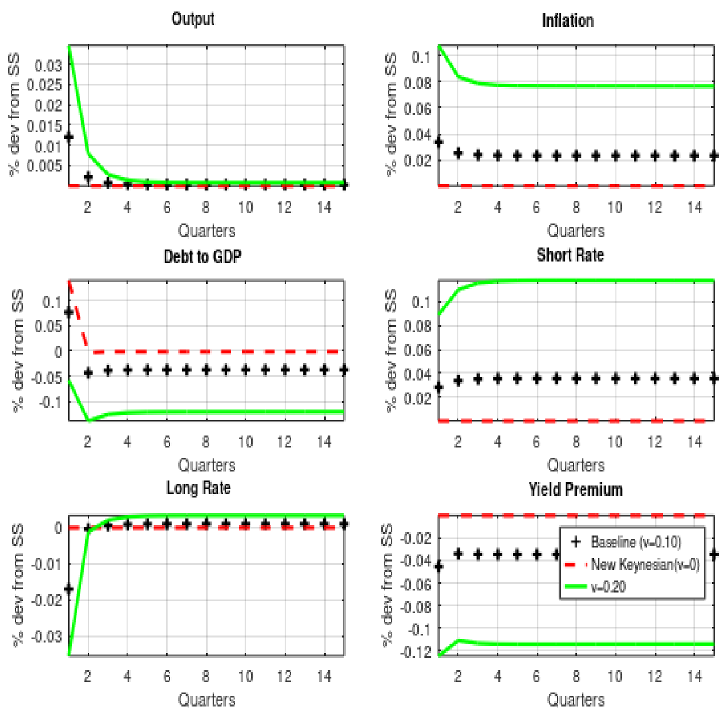
When the central bank purchases long-term government bonds, it causes a change in financial intermediaries' asset mix by shifting towards short-term government bonds. With increased liquidity from the reserves provided by the central bank, the premium on long-term government bonds decreases, causing the prices of long-term government bonds to rise and its yield to fall. The 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 leads to a temporary rise in government debt, increasing debt-to-GDP.

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 (

$\epsilon_t^q = 0.25$)



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.

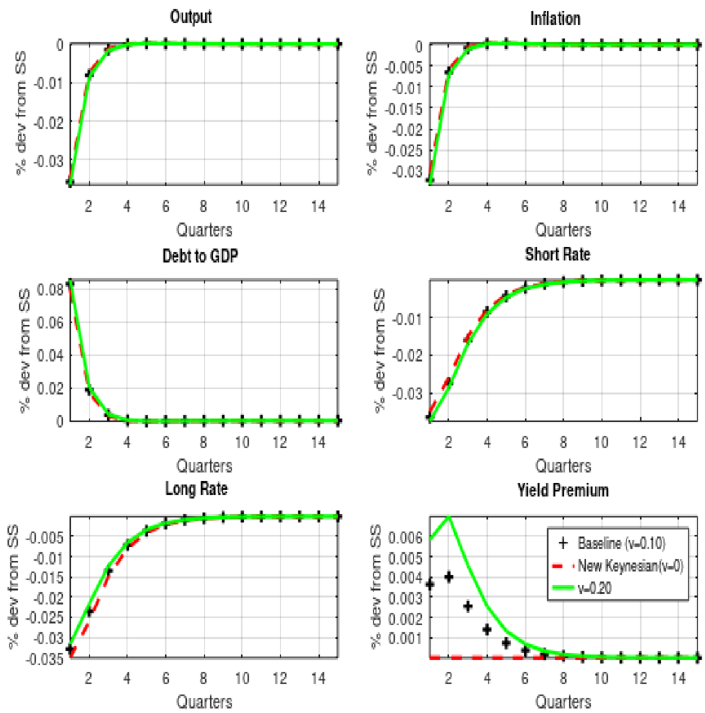
6.3 Effect of Demand Shock

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 (

$\epsilon_t^* = -0.25)$



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.

7 Conclusion

The results of this paper improved policymakers' understanding of the policy question and the solution, and rank the effectiveness of conventional monetary policy and asset purchase policy.

This paper shows evidence 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 BSP's asset purchase program could serve as an alternative tool even when conventional monetary policy is limited or unavailable.

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