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AN ESTIMATED OPEN-ECONOMY DSGE MODEL FOR THE EVALUATION OF CENTRAL BANK POLICY MIX

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ABSTRACT

This paper builds and estimates a small open-economy Dynamic Stochastic General Equilibrium (DSGE) model suitable for the evaluation of central bank policy mix, with a particular application on the Indonesian economy. The model has a rich array of shocks and frictions, including banking and financial frictions. We illustrate how the estimated model can be used to investigate the source of aggregate fluctuations in Indonesia and to evaluate and simulate a policy mix involving monetary and macroprudential policies. Our Bayesian estimation identifies the COVID-19 pandemic shocks as being mainly a combination of adverse supply-side (technology) and demand-side (preference and foreign-output) shocks. We show that a countercyclical capital requirement rule could be a potent addition to Bank Indonesia’s policy mix arsenal. Despite its rich features, the model is scalable and can be readily extended for evaluating other types of central bank policy mix, including monetary-macroprudential-fiscal policy interaction and the inclusion of Central Bank Digital Currency (CBDC).

Keywords: Central bank policy mix; Integrated policy framework; Countercyclical macroprudential policy rule; DSGE model for Indonesia; COVID-19 pandemic; Capital requirement.
JEL Classifications: E12; E32; E58; E61; F41.

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I. INTRODUCTION
In this paper we build and present an open-economy Dynamic Stochastic General Equilibrium (DSGE) model for the evaluation of central bank policy mix and its various implications. We estimate the model on Indonesian data and illustrate how the estimated model can be used to perform various analyses and policy simulations. Indonesia offers a unique setting when it comes to central bank policy mix.\(^1\) Since 2010, Bank Indonesia (BI) has implemented a mix of monetary and macroprudential policies along with capital flow management to support and achieve its institutional mandate as the central bank of Indonesia. This policy mix complements the bank’s Inflation Targeting Framework (ITF) in maintaining price stability consistent with the inflation target, regulating fluctuations in the business and financial cycles, and mitigating the stability risks arising from macro-financial linkages.\(^2\) The policy mix has been largely successful: during the 2010-2020 period real gross domestic product grew robustly by 4.6% per year on average and the inflation rate averaged 4.28% at the annualized rate. Various indicators also show a sound banking and financial sector — for example, non-performing loans ratio has been relatively low and stable, averaging 2.5% from 2012-2020.\(^3\)

Despite this successful implementation, recent events, particularly the COVID-19 pandemic, have created fresh challenges for BI, or for any central bank in general. One pressing challenge is on whether the current form of the policy mix can still be relied upon as the economy enters a new, post-pandemic phase. How effective is the current policy mix in stabilizing the business cycle fluctuations post-pandemic? Should BI include additional policy tools to the current mix? Would these additional tools be welfare-improving and contribute to economic and financial system stability? To answer these and other related questions, one would need a model. Since various parts of the economy are interconnected, the model would need to be a general equilibrium model. It would need to be a structural model—as opposed to non-structural, reduced-form models—to be immune from the Lucas’ critique (Lucas, 1976). Furthermore, the model would need to be dynamic and stochastic to account for short-to-medium term fluctuations in various economic time series.

The core of our model is a small open-economy DSGE model along the lines of Gali and Monacelli (2005) and Monacelli (2005), used for example in Lubik and Schorfheide (2007), Justiniano and Preston (2010), and Lie (2019). To be able to evaluate BI’s monetary- macroprudential policy mix, however, the model needs to include financial and banking frictions. We do so by explicitly modelling the banking sector, i.e., the supply of credit, following the approach of Gerali et al. (2010). Aggregate fluctuations in the model are driven by a rich array of domestic and external (foreign) shocks, taken as exogenous by the optimizing agents. Despite

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\(^1\) Another term for central bank policy mix is Integrated Policy Framework (IPF), as coined by the International Monetary Fund (IMF) – see Adrian et al. (2020) and Basu et al. (2020).

\(^2\) BI’s inflation targets are usually established for three-year periods and announced well in advance. For example, the targets for 2019 (3.5% ±1%), 2020 (3% ±1%), and 2021 (3% ±1%) were officially set and announced in September 2017. There has been a downward trajectory in the targets during the ITF period from 2001 onwards. For example, the targets were 9% ±1% in 2003 and 5% ±1% in 2011.

\(^3\) See Bank Indonesia’s (BI) quarterly-published Financial System Statistics (Statistik Sistem Keuangan Indonesia).
its rich features, the model is scalable enough to be estimated using Bayesian techniques. This allows us to perform various analyses that would otherwise be infeasible under the standard calibration exercise. For example, as shown in the paper, we are able to infer from the data (and the model’s restrictions) the composition of the COVID-19 pandemic shocks hitting the Indonesian economy. The model can be readily extended to include other features relevant for the evaluation of possible enhancements to the current policy mix, e.g., involving the payment systems, the fiscal policy, and a Central Bank Digital Currency (CBDC).

We conduct the following analyses using the estimated model. Based on the posterior estimates, we first compute the conditional forecast-error variance decompositions of several key macroeconomic and financial variables. We find that for all considered forecast horizons, technology, preference, and cost-push shocks are largely responsible for output growth fluctuations in Indonesia during our sample period (2005.Q3-2021.Q2), with monetary-policy shocks also play a non-trivial role. Cost-push shocks are the primary driver of short-term inflation fluctuations, consistent with the results for many other economies. Long-run inflation fluctuations on the other hand are largely driven by technology shocks. On credit growth fluctuations, financial shocks and macroeconomic shocks—technology, cost-push, and monetary-policy—are both important. We also conduct a historical decomposition analysis based on the estimated (smoothed) shocks and are able to identify the COVID-19 shocks as being a combination of adverse supply-side (technology) and demand-side (preference and foreign-output) shocks. This is an important finding, as it contains useful information for the policymaker (BI) in order to formulate the best policy response—both in terms of the best policy mix and the appropriate response size of each policy instrument in the mix—to the pandemic shocks. In terms of the evaluation of central bank policy mix, we show that the model can be used to evaluate the effectiveness of a monetary-macroprudential policy mix wherein the macroprudential policy tool involves a countercyclical capital-to-asset adjustment rule. We show that such a countercyclical rule could be a potent addition to BI’s policy mix arsenal.

Our paper contributes to the literature on the modelling of the Indonesian economy using DSGE models. There has been an explosion of research on this topic, especially in the last decade. Harmanta et al. (2014) build a DSGE model with financial frictions and use it to simulate shocks to policy interest rate, reserve requirement, and bank capital. They find that a shock originated in the banking sector affects business cycle fluctuations and may require a monetary policy intervention by the central bank. Using an estimated, standard small open-economy DSGE model, Dutu (2016) investigates the source of fluctuations in Indonesia’s GDP over the 2004-2014 period and finds that shocks to multi-factor productivity are the main driver. These supply-side shocks are responsible for the decrease in the output growth in Indonesia post-2010, compared to in the preceding decade. Lie (2019) builds and estimates a DSGE model for Indonesia


[5] The focus of the current paper is on model development. Hence, we do not perform a comprehensive analysis of monetary-macroprudential policy mix involving other macroprudential policy instruments, e.g., the loan-to-value (LTV) ratio. We do so in a separate, companion paper.
with observed inflation-target adjustments and shows that such adjustments by Bank Indonesia play a non-trivial role in the fluctuations of inflation and the nominal interest rate in Indonesia during the Inflation-Targeting Framework (ITF) period. Sahminan et al. (2017) construct a small-scale DSGE model calibrated to the Indonesian economy to analyze the impact of higher government infrastructure spendings and find non-trivial spending multiplier and effects on output and welfare. Within an estimated small-scale DSGE model, Zams (2021) shows that a model with money-holding friction fits the Indonesian data better compared to the standard cashless model. Habit formation and backward-looking price indexation, which are standard features in quantitative DSGE models, turn out to be unimportant during the ITF period. Calibrated DSGE models have also been used to analyze the impact of macroprudential policy in Indonesia, e.g., Chawwa (2021) on the impact of reserve requirement and liquidity coverage ratio and Setiastuti et al. (2021) on the impact of a foreign-to-domestic loan ratio (external debt management).

Our paper is differentiated by its focus on building a scalable, readily-extended medium-scale model that can be used to evaluate and simulate any combination of central bank policy mix. This includes not only macroprudential policy, but also potentially fiscal policy, the payment systems, and the central bank digital currency. Except for Chawwa (2021) and Setiastuti et al. (2021), which focus on the interaction between monetary policy and a given macroprudential policy instrument, none of the aforementioned studies constructs a DSGE model suitable for evaluating the relative performance of a central bank policy mix, such as that conducted by Bank Indonesia. Unlike these two studies, however, we estimate the structural parameters of the model using a Bayesian approach. As we show in this paper, estimating the model based on actual data allows us to, among others, identify the source of aggregate fluctuations in the Indonesian economy, including during the COVID-19 pandemic. Such information is useful for policymakers, e.g., for an optimal policy formulation.

We also contribute to the COVID-19 economic literature, particularly on the identification of the make up of the COVID-19 pandemic shocks within an aggregate macroeconomic model. To the best of our knowledge, ours is the first paper that identifies these pandemic shocks within an estimated business-cycle model for the Indonesian economy. The resulting characterization of the pandemic shocks—a combination of adverse technology, preference, and foreign-output shocks—is broadly consistent with those assumed or estimated in various studies in the literature focusing on other countries. These studies (e.g., Eichenbaum et al. (2020), Faria-e Castro (2020), Fornaro and Wolf (2020), McKibbin and Fernando (2021), Cardani et al. (2021)) typically treat or identify the pandemic shocks as a combination of large adverse supply-side and demand-side shocks. We uniquely find, however, that the supply-side (technology) shocks are dominant when it comes to the Indonesian economy. In a broader context, our paper is also related to various studies investigating the influence of COVID-19 on the Indonesian economy. These studies typically focus on empirically examining the impact of

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6 As such, we also contribute to recent efforts to build quantitative models for the evaluation of an integrated policy framework (see the IMF papers, Adrian et al. (2020) and Basu et al. (2020)).
COVID-19 using non-structural, partial-information regression models, see e.g., Ali et al. (2021), Haldar and Sethi (2021), and Rizvi et al. (2021) regarding the impact on the stock market, Iyke et al. (2021) regarding the impact on industrial productivity, or Prabheesh et al. (2021) regarding the implication on the effectiveness of monetary policy transmission. Our paper complements those studies by first identifying the COVID-19 shocks from a structural, full-information (DSGE) model, and then examining the impact of these shocks on the fluctuations of aggregate, business-cycle variables such as inflation and output. Similar to these studies, we show that COVID-19 has a non-trivial, negative impact on the Indonesian economy.

Finally, our paper also complements previous studies on Bank Indonesia’s central bank policy mix and coordination using other, non-DSGE approaches, particularly involving the interaction between monetary and macroprudential policies (Utari et al. (2012), Harmanta et al. (2012), Wimanda et al. (2012; 2014), Purnawan and Nasir (2015), Simorangkir and Purwanto (2015), Warjiyo (2017)). Recent studies on policy mix in Indonesia also investigate the interaction between monetary and fiscal policy (Rizvi et al., 2021; Juhro et al., 2022) and the possible implications of a CBDC issuance (Harahap et al., 2017; Zams et al., 2019; Syarifuddin and Bakhtiar, 2021). As mentioned above, a differentiating factor of our paper is with regard to the development of a general, estimable DSGE model for Indonesia that can be readily extended to evaluate the relative performance of various policy mix combinations. As such, our model can be applied to verify the findings in those previous studies and to extend their analysis. For example, similar to Wimanda et al. (2012) and Purnawan and Nasir (2015), we find that a macroprudential policy instrument-bank capital requirement ratio in our paper—that reacts countercyclically to credit growth—complements monetary policy in stabilizing the financial and credit cycle. Further to this, the general equilibrium nature of our model also means that the model can be used to analyze the relative performance of various combinations of Bank Indonesia’s policy mix and obtain the welfare implication.

The rest of the paper proceeds as follows. Section II presents the DSGE model. Section III describes the data and the Bayesian estimation procedure and presents the posterior estimates. Section IV computes the implied forecast-error variance decompositions and historical decompositions, given the data and the model’s restrictions. In Section V, we illustrate the usefulness of the model in evaluating the relative performance of a monetary-macroprudential policy mix. Section VI concludes.

II. THE DSGE MODEL: DESCRIPTION AND DERIVATION
The model has two economies: the domestic (home) economy, i.e., the small open economy of interest, and the foreign economy. The domestic economy is small relative to the foreign economy (rest of the world) in a sense that shocks originated in the domestic economy negligibly affect the foreign economy. Foreign shocks, however, propagate to the domestic economy in a non-trivial way. There are 8 types of agents in the domestic economy: households, goods-producing entrepreneurs, domestic-goods retailers, import-goods retailers, capital goods producers, financial intermediaries (banks), the government and the central bank. Aggregate...
fluctuations are driven by 15 stochastic disturbances. 12 of these disturbances or shocks can be considered as macroeconomic shocks: technology, preference, domestic and import cost-push, monetary-policy, housing-demand, investment, government-spending, risk-premium, foreign output, foreign inflation, and foreign interest-rate shocks. The rest of the shocks are financial: shocks to bank balance sheet and Loan-To-Value (LTV) ratios of loans to firms and households. We next describe each economic agent’s decision problem.

A. Households
There are two types of households: patient (type P) and impatient (type I). While both types of households are utility-maximizers, type P households are assumed to have a higher subjective discount factor \((\beta_P > \beta_I)\), as is common in heterogeneous agent models. Each type faces a different budget constraint, reflecting their different degree of impatience.

A.I. Patient Households
Any given (representative) type-P household \(i\) maximizes

\[
E_0 \sum_{t=0}^{\infty} \beta_P^t \left[ (1 - a^P) \varepsilon_{xt}(c^P_t - a^P c^P_{t-1})^{1-\sigma} + \varepsilon_{ht} \log h^P(t) - \frac{n^P_t(1+\phi)}{1+\phi} \right]
\]

(1)

where \(c^P_t, h^P_t, n^P_t, \varepsilon_{xt}, \varepsilon_{ht}\) denote the household’s choice of consumption amount, housing demand, labor hours, the aggregate consumption preference shock, and the housing-demand shock, respectively. The \(a^P c^P_{t-1}\) term represents the type-specific external habit. The parameters \(a^P, \sigma, \phi\) are the degree of habit formation, inverse elasticity of intertemporal substitution, and inverse Frisch labor supply elasticity, respectively. The aggregate consumption good \(c^P_t\) is a composite of home- and foreign-produced goods,

\[
c^P_t = \left[ (1 - \omega) \left( c^P_{H,t} \right)^{\eta^{-1}} + \omega c^P_{F,t} \right]^{\eta^{-1}}
\]

(2)

where \(\omega\) is the share of foreign-produced goods in the consumption basket (i.e., the degree of openness) and \(\eta\) is the elasticity of substitution between home and foreign produced goods. Each of \(c^P_{H,t}\) and \(c^P_{F,t}\) is a standard Constant Elasticity of Substitution (CES) aggregation of intermediate home-produced and imported varieties, respectively, with a common elasticity \(\varepsilon\). Note that we drop the index \(i\) in (2) because all type-\(P\) households are identical, ex-post. The expected-utility maximization above is subject to the following flow budget constraint (in real terms and dropping the index \(i\)):

\[
c^P_t + q^P_h \Delta h^P_t + d^P_t + e_t d^*_t \leq w_t n^P_t + (1 + n^d_{t-1}) \pi^{-1} d^P_{t-1} + e_t (1 + \pi^{-1}) n^P_t - 1 + \pi^{-1} \eta^* d^*_{t-1} + \pi_t + e^P_t
\]

(3)
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Here, $q_t^P, d_t^P, w_t^P, r_t^d, \pi_t$ and $t_t^P$ denote the real house price, real domestic-currency deposits, nominal exchange rate (home-currency price of foreign currency), real wage, interest rate on domestic-currency deposits, gross consumer-price inflation rate ($\pi_t = P_t / P_{t-1}$) and lump-sum government taxes or transfers, respectively. $\Gamma_t$ are transfers that include profits and dividends from domestic firms (producers), importers, and banks, all owned by type-$P$ households. We assume that in addition to making domestic-currency deposits in each period, type-$P$ households can also invest in foreign one-period bonds in the amount of $e_t d_t^*$, paying interest rate $r_t^*$. Following Kollmann (2002) and Schmitt-Grohe and Uribe (2003), this holding of foreign bonds is subject to a debt-elastic interest rate premium,

$$\zeta_t = \exp[-x(e_t^C + a_{t-1})]$$

where $x$ is a scale parameter and $a_t = e_t d_t^*/\bar{y}$ is the real quantity of foreign debt outstanding (in domestic-currency unit) as a fraction of steady-state output, $\bar{y}$. $\zeta_t$ can be interpreted as a relative risk premium: holding other things constant, as $a_t$ increases foreign bonds are more risky compared to previously, resulting in lower $\zeta_t$. This foreign-exchange risk premium is subject to a risk-premium $\epsilon\zeta_t$. The first-order conditions associated with the type-$P$ households’ problem are:

$$\epsilon^C(1 - a^P)(c_t^P - a^P c_{t-1}^P)^{-\sigma} = \lambda_t^P$$

$$\epsilon_t^C(h_t^P)^{-1} = \lambda_t^P q_t^h - \beta_p E_t \lambda_{t+1}^P q_{t+1}^h$$

$$(n_t^P)^\Phi = \lambda_t^P w_t^P$$

$$\lambda_t^P = \beta_p E_t \lambda_{t+1}^P (1 + r_{t}^d)\pi_{t+1}^{-1}$$

$$\lambda_t^P e_t = \beta_p E_t \lambda_{t+1}^P e_{t+1}(1 + r_{t}^d)\pi_{t+1}^{-1}$$

where $\lambda_t^P$ is the associated Lagrange multiplier of the type-$P$ households’ maximization problem. By combining (8) and (9) one can obtain the standard (non-linear) uncovered interest-parity (UIP) equation,

$$E_t \lambda_{t+1}^P \left[ (1 + r_{t}^d) - (1 + r_{t}^*) \right] = 0$$

For simplicity, we assume that patient households can purchase these (foreign-currency-denominated) foreign bonds directly in the international financial markets, without having to go through the domestic banking system.
A.II. Impatient Households

Each impatient (type-I) household $i$ maximizes

$$E_0 \sum_{t=0}^{\infty} \beta_t^t \left[ (1 - \alpha') \frac{c_t(i)^{1-\sigma} - c_{t-1}^{1-\sigma}}{1-\sigma} + \varepsilon_{h,t} \log h_t(i) - \frac{n_t(i)^{1+\phi}}{1+\phi} \right]$$

subject to real flow budget constraint

$$c_t^I(i) + q_t^h h_t^I(i) + (1 + r_{t-1}^{BH}) m_t^I E_t[q_{t+1}^h h_t^I(i) \pi_{t+1}] \leq w_t^I n_t^I(i) + b_t^I(i) + \ell_t^I(i)$$

Hence, type-I households have a similar preference to type-P households, in a sense that their utility increases with consumption and housing services but decreases with their labor effort. Both household types also have external habit formation, but with potentially different habit parameters ($\alpha', \alpha \in [0,1]$), and are subject to the same consumption preference and housing demand shocks, $\varepsilon_{z,t}$ and $\varepsilon_{h,t}$. They are, however, differentiated by their subjective discount factor ($\beta_I < \beta_P$) and their saving decision. Type-I households’ consumption spending and accumulation of housing services have to be financed with labor income ($w_t^I n_t^I(i)$) and borrowing or loans from banks ($b_t^I(i)$). Loans issued at time $t-1$ have to be paid at time $t$ with (nominal) interest rate $r_{t-1}^{BH}$. In addition to the budget constraint (12), households face a borrowing or collateral constraint in the spirit of Kiyotaki and Moore (1997) and Iacoviello and Neri (2010):

$$(1 + r_{t-1}^{BH}) b_t^I(i) \leq m_t^I E_t[q_{t+1}^h h_t^I(i) \pi_{t+1}]$$

$m_t^I$ is the loan Loan-To-Value (LTV) ratio of loans to households (or mortgages), which we assume to be exogenous and follows an AR(1) process in the baseline model for estimation. $t_t^I$ are real government transfers or taxes. Note that the final consumption index $C_t^I(i)$ is aggregated in the same way as in the patient households case (see (2)). For simplicity, we assume that type-I households do not have direct access to the international financial markets and hence do not invest in foreign bonds. Denoting $\lambda_t^I$ as the multiplier attached to the constraint (12) and $\Omega_t^I$ as the multiplier attached to the constraint (13), we have the following first-order conditions with respect to $c_t^I(i), h_t^I(i), n_t^I(i)$ and $b_t^I(i)$:

$$\varepsilon_t^z (1 - \alpha') (c_t^I - a' c_{t-1}^{1-\sigma}) = \lambda_t^I$$

$$\varepsilon_t^z (h_t^I)^{-1} = \lambda_t^I q_t^h - \beta_t E_t \lambda_{t+1}^I q_{t+1}^h - \Omega_t^I m_t^I E_t q_{t+1}^h \pi_{t+1}$$

$$(n_t^I)^{\phi} = \lambda_t^I w_t^I$$

$$\lambda_t^I = \beta_t E_t \lambda_{t+1}^I (1 + r_{t+1}^{BH}) \pi_{t+1}^{-1} + \Omega_t^I (1 + r_t^{BH})$$
B. Entrepreneurs and Domestic Wholesale Goods Production

Entrepreneurs in the model are responsible for the production of domestic wholesale, intermediate goods $y_t$ using the production function $y_t^E$ using the production function

$$y_t^E(i) = \epsilon_t^E \left( k_{t-1}^E(i) \right)^\alpha \left( n_t^E(i) \right)^{1-\alpha} \tag{18}$$

where $\epsilon_t^E$ is the exogenous aggregate level of technology (total factor productivity), $k_{t-1}^E(i)$ is the physical capital input, and $n_t^E(i)$ composite labor input that include labor inputs from type-$P$ households, $n_t^{E,P}(i)$, and from type-$I$ households $n_t^{E,I}(i)$,

$$n_t^E(i) = \left( n_t^{E,P}(i) \right)^\mu \left( n_t^{E,I}(i) \right)^{1-\mu} \tag{19}$$

Each entrepreneur $i$ in each period $t$ chooses the amount of consumption $c_t^E(i)$, capital $k_t^E(i)$, labor inputs $n_t^{E,P}(i)$ and $n_t^{E,I}(i)$ loans from banks $b_t^E(i)$ to maximize the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_t^E \left[ (1 - a_E) \left( c_t^E(i) - a_E c_{t-1}^E \right)^{1-\sigma} \right] \tag{20}$$

subject to the (real) budget constraint

$$c_t^E(i) + w_t^E n_t^{E,P}(i) + w_t^I n_t^{E,I}(i) + \left( 1 + r_{t-1}^E \right) n_t^E(i) + q_t^k k_t^E(i) \leq \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k (1-\delta) k_{t-1}^E(i) \tag{21}$$

and a collateral constraint

$$\left( 1 + r_{t-1}^E \right) b_t^E(i) \leq m_t^E E_t \left[ q_{t+1}^k \pi_{t+1}(1-\delta) k_t^E(i) \right] \tag{22}$$

Hence, in addition to the proceed from the sale of wholesale goods $\frac{y_t^E}{x_t}$ ($\frac{1}{x_t}$ is the relative price of $y_t^E$), entrepreneurs may also borrow from banks to finance the production of goods and their own consumption $c_t^E$ (a composite consumption index similar to (2)). The amount of the borrowings plus the interest payments, $(1+r_t^E) b_t^E$, cannot exceed the expected value of existing capital, used as a collateral for the loans. Here, in (22), $m_t^E$ is the LTV ratio of the loans to firms, $q_t^k$ is the market price of capital, and $\delta$ is the capital depreciation rate. We also assume that the labor markets are perfectly competitive and there is no friction in wage setting (i.e.

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8 We also assume implicitly that entrepreneurs have a unit measure ($\gamma^E=1$), just as we assume unit measures for patient and impatient households ($\gamma^P=\gamma^I=1$).
flexible wages). This means that the real wages of type-\(P\) and type-\(I\) labor, \(w^P_t\) and \(w^I_t\), are equal to their respective marginal rate of substitution between consumption and labor. Entrepreneurs are also assumed to only be able to borrow from banks in domestic currency and are therefore not exposed to exchange rate fluctuations in their borrowing activity.\(^9\) For the first-order conditions of the entrepreneurs’ problem, we refer the reader to the online technical appendix of the paper.

C. Domestic Final Goods Retailers

There is a continuum of monopolistically-competitive retailers in the economy, indexed by \(j \in [0,1]\). These retailers buy intermediate goods from domestic producers (entrepreneurs) at wholesale price \(P^w_t\), differentiate them at no cost, and sell the differentiated retail goods to patient and impatient households and entrepreneurs, and government for consumption purpose. These goods are also purchased by capital producers to create new capital goods and by foreign households for consumption purpose. Denoting \(P_{H,t}(j)\) as the nominal price of good or variety \(j\) and \(P^H_t\) as the aggregate domestic producer (retailer) price index, the total demand for any given variety \(j\) at time \(t\) is given by

\[
y_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P^H_t}\right)^{-\varepsilon} y_{H,t} \tag{23}
\]

where \(y_{H,t} = c^p_j + c^c_j + c^i_j + c^g_j + c^*_{H,t}\) is the aggregate demand for domestically-produced retail goods, comprising of demands from domestic household \((c^p_j + c^c_j)\), entrepreneurs \((c^i_j)\), capital producers \((c^g_j)\), the government \((c^*_{H,t})\), and foreign households \((c^*_H)\).\(^10\)

Retailers face an infrequent opportunity to optimally reset their prices, based on the standard Calvo (1983) setup. Here, only a \((1-\theta_H)\in [0,1]\) fraction of the retailers are allowed to optimally adjust their prices at any given time period. Retailers that are not allowed to adjust optimally, with probability \(\theta_H\), are assumed to index their prices according to the indexation rule

\[
P_{H,t}(j) = P_{H,t-1}(j) \pi_{H,t-1}^{\delta_H} \bar{\pi}_{H,t}^{1-\delta_H} \tag{24}
\]

where \(\pi_{H,t-1} = P_{H,t-1}/P_{H,t-2}\) is the lagged (time \(t-1\)) domestic producer-price inflation and \(\bar{\pi}_{H,t}\) is the steady-state domestic producer-price inflation. \(\delta_H\) is the degree of indexation to past inflation.\(^11\) The profit-maximization problem of the “optimal-price” retailers is thus given by

\[
\max_{\bar{\pi}_{H,t}} \sum_{k=0}^{\infty} \theta^k Q^H_t \left( \bar{P}_{H,t} X_{k,t} - P^w_{t+k} \right) \bar{\pi}_{H,t+k}^{1-\varepsilon} y_{H,t+k} \tag{25}
\]

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\(^9\) See e.g., Setiastuti et al. (2021) for a model in which entrepreneurs can also borrow from abroad.

\(^10\) Each of these consumption indexes is a CES aggregation of all available domestic goods varieties \(j \in [0,1]\), with a common elasticity \(\varepsilon\).

\(^11\) (24) is a commonly-applied price indexation mechanism in the literature see e.g., Adolfson et al. (2007) and Feve et al. (2010).
with

\[ X_{k,t} = \begin{cases} 
1 & \text{if } j = 0 \\
\prod_{m=0}^{k-1} \left( \pi_{H,t+m}^{\delta_H} \right) & \text{if } j \geq 1 
\end{cases} \quad (26) \]

Here, \( Q_{t+k}^H \) is the stochastic discount factor of patient households (who own the retailers) between time \( t \) and \( t+k \) and \( \hat{P}_{H,t} \) is the time-\( t \) optimal price. After solving the maximization problem and log-linearizing the first-order condition (see the paper’s technical appendix), we can obtain the (New Keynesian) Phillips curve equation for domestic-price inflation,

\[
\hat{\pi}_{H,t} - \delta_H \hat{\pi}_{H,t+1} = \beta_p P_{t} [\hat{\pi}_{H,t+1} - \delta_H \hat{\pi}_{H,t}] + \frac{(1-\theta_H)(1-\theta_H \beta_p)}{\theta_H} \bar{m}c_t + \hat{\varepsilon}_t^H \quad (27)
\]

where \( \hat{\pi}_{H,t} \equiv \pi_{H,t} - \pi^\delta_H \) and \( \bar{m}c_t \) is a measure of retailers’ real marginal cost.\(^{12}\) We add a cost-push shock \( \hat{\varepsilon}_t^H \) in (27) to capture inefficient variations in retailers’ markups.

**D. Importers**

Import-goods retailers import foreign differentiated goods from abroad to be sold in the domestic market. We assume that the law of one price holds at the docks for these goods. However, importers are assumed to have some market power (monopolistically competitive) and hence, can charge a markup over the original purchase price. This setup means the law of one price does not hold at the retail level. We also assume that the import retail goods are only purchased for the purpose of consumption by patient and impatient households and entrepreneurs, which means an importer \( j \in [0,1] \) faces a demand function.

\[
c_{F,t}(j) = \left[ \frac{p_{F,t}(j)}{p_{F,t}} \right]^{-\varepsilon} c_{F,t} \quad (28)
\]

where \( p_{F,t}(j) \) is the nominal domestic-currency price of import goods \( j \) and \( c_{F,t} \equiv c_{F,t} + c_{F,t} + c_{F,t}^\delta \) represents the aggregate demand for these goods from households \( (c_{F,t} + c_{F,t}) \) and entrepreneurs \( (c_{F,t}^\delta) \).\(^{13}\) These importers face a Calvo pricing problem with an optimal-price reset probability \( (1-\theta_p) \in [0,1] \). With probability \( \theta_p \), they fully index their prices to a mixture of past import-price inflation \( \pi_{F,t-1}^{p} P_{F,t-1} / P_{F,t} \) (with indexation degree \( \delta_f \)) and the steady-state import-price inflation \( \bar{\pi}_F \) in a similar manner to domestic-goods retailers in (24). We could

\(^{12}\) To be more precise, \( \bar{m}c_t = \bar{t}_t - \bar{\pi}_t \) where \( \bar{t}_t \) is the log deviation of the real price of wholesale goods \( \left( \bar{t} \equiv \frac{1}{\bar{x}_t} \right) \) and log deviation of the wedge between producer and consumer price \( \bar{\pi}_t \equiv P_{H,t} / P_t \) from their respective steady-state values.

\(^{13}\) Implicit in (28), \( c_{F,t}^\delta, c_{F,t}^\delta, \) and \( c_{F,t}^\delta \) are each a CES aggregation (with elasticity \( \varepsilon \)) of all import goods \( j \in [0,1] \). Here, we drop the index \( i \) for households.
then solve a similar profit-maximization problem as in (25) and obtain a (log-linearized) Phillips curve equation for import-price inflation,

\[
\left[ \hat{\pi}_{F,t} - \delta_F \hat{\pi}_{F,t+1} \right] = \beta_F E_t \left[ \hat{\pi}_{F,t+1} - \delta_F \hat{\pi}_{F,t} \right] + \left( 1 - \theta_F (1 - \theta_F \beta_F) \right) \hat{\psi}_{F,t} + \epsilon_t^F
\]  

(29)

Here \( \hat{\pi}_{F,t} \equiv \pi^{F,t} - \pi^{F} \) and \( \epsilon_t^F \) is an (import-goods) cost-push shock. The relevant measure of real marginal cost for importers is the law of one price (LOP) gap, \( \psi_{F,t} = \frac{e_t^F P^*_F}{P^*_F} \), i.e. the gap between domestic-currency price of import goods at the dock, \( e_t^F P^*_F \) (\( P^*_F \) is the foreign-currency price of these goods), and the aggregate domestic-currency import price at the retail level, \( P^*_F \).  \( \psi_{F,t} \) in (29) is the log deviation of \( \psi_{F,t} \) from the steady-state value.

E. Banks and Banking Frictions

The setup of banks and the banking frictions is largely identical to that in Gerali et al. (2010). Here, we only describe main, selective elements of the banking sector. For more detailed descriptions and derivations, we refer the reader to Gerali et al. (2010) and the technical appendix of our paper. Each bank’s operation comprises a wholesale unit, which manages the bank’s balance sheet position, and retail units responsible for collecting deposits and issuing loans. The wholesale unit operates in a perfectly-competitive setting and needs to ensure that the balance-sheet constraint

\[ B_t = (1 - \theta_t)D_t + K^b_t \]  

(30)

is satisfied in each period. Here, \( B_t \) is the bank’s assets (total loans issued), \( K^b_t \) is bank capital, and \( (1 - \theta_t)D_t \) is the bank’s liabilities (deposits collected) net the required reserve. Banks are required to hold cash reserves at the central bank in the amount of \( \theta_t D_t \), where \( \theta_t \) is the reserve requirement ratio. We assume that banks do not hold excess reserves and these reserves pay no interest. To maintain the balance-sheet position, the wholesale unit may accumulate bank capital out of retained earnings \( \left( j^{b}_{t-1} \right) \):

\[ \pi_t K^b_t = (1 - \delta^b) \epsilon_t^{KB} K^b_{t-1} + j^{b}_{t-1} \]  

(31)

where \( \epsilon_t^{KB} \) is a balance-sheet shock. The bank capital depreciation rate \( \delta^b \) can be thought as the cost of managing and operating the wholesale unit. The wholesale unit also has a target capital-to-assets ratio \( v^t = \bar{v} \), which we assume to be constant (and exogenous) in the baseline model. Whenever the actual capital-to-assets ratio \( K^b_t / B \) deviates from the target value \( v^t \), the bank is required to pay a quadratic adjustment cost (Rotemberg, 1982) that is proportional to the level of bank capital:

\[ \psi_{F,t} = \text{1 if the law of one price also holds at the retail level (since } P_{F,t} = e_t P^*_F). \]
with $\kappa_{Kb}$ is the cost scale parameter. The two retail units operate in a monopolistically-competitive setting and also face quadratic costs of adjusting the deposit rate and the loan rates. This setup means the following: (i) all the retail rates are sticky; (ii) the retail deposit rate is a markdown from the wholesale rate; and (iii) the loan rates are a markup over the wholesale rate. We relegate the details of the profit-maximization problems of the retail units to the paper’s technical appendix and only present here the resulting (log-linearized) optimal retail deposit rate ($\hat{r}_t^d$) and retail loan rates ($\hat{r}_t^{bs,s} \in \{H,E\}$):

$$\frac{\kappa_{Kb}}{2} \left( \frac{k_t^b}{b_t} - v_t \right)^2 K_t^b$$

(32)

$$\hat{r}_t^d = \left( \frac{\kappa_d}{1-\varepsilon_d + (1+\beta_p)\kappa_d} \right) \hat{r}_{t-1}^d + \left( \frac{\beta_p \kappa_d}{1-\varepsilon_d + (1+\beta_p)\kappa_d} \right) E_t \hat{r}_{t+1}^d + \left( \frac{1-\varepsilon_d}{1-\varepsilon_d + (1+\beta_p)\kappa_d} \right) \hat{R}_t^d$$

(33)

and

$$\hat{r}_t^{bs} = \left( \frac{\kappa_{bs}}{1-\varepsilon_{bs} + (1+\beta_p)\kappa_{bs}} \right) \hat{r}_{t-1}^{bs} + \left( \frac{\beta_p \kappa_{bs}}{1-\varepsilon_{bs} + (1+\beta_p)\kappa_{bs}} \right) E_t \hat{r}_{t+1}^{bs} + \left( \frac{1-\varepsilon_{bs}}{1-\varepsilon_{bs} + (1+\beta_p)\kappa_{bs}} \right) \hat{R}_t^b$$

(34)

where $s \in \{H,E\}$, each for loans to households and loans to entrepreneurs. The parameters $\kappa_d, \kappa_{bs},$ and $\kappa_{bs}$ govern the size of the adjustment cost for the deposit rate, the loan rate to households, and the loan rate to firms, respectively, and hence, govern the stickiness of these rates. The elasticities $\varepsilon_d, \varepsilon_{bs},$ and $\varepsilon_{bs}$ directly influence the degree of monopoly power in the banking sector and hence, the size of the deposit rate markdown and loan rate markups. $\hat{R}_t^d$ is the wholesale deposit rate and $\hat{R}_t^b$ is the wholesale loan rate.

F. Capital Goods Producers

Physical capital, used in the wholesale goods production by entrepreneurs, are produced by perfectly-competitive capital goods firms. These firms are owned by entrepreneurs. In each period, they buy back the previous-period undepreciated capital from entrepreneurs, produce new capital, and then sell the new amount of capital at market price $q_t^k$ back to entrepreneurs to be used for goods production (see the budget constraint (21)). They produce new capital from final domestic goods (with one-to-one conversion), subject to a quadratic adjustment (installment) cost. Specifically, physical capital accumulates according to

$$k_t = (1-\delta)k_{t-1} + \left[ 1 - \frac{\kappa_t}{Z} \left( i_t \tilde{q}_t^k \left( \frac{i_t \tilde{q}_t^k}{i_{t-1}} - 1 \right) \right)^2 \right] i_t$$

(35)

where $\kappa_t$ is the adjustment cost scale parameter and $i_t \tilde{q}_t^k$ is an investment adjustment or efficiency cost. These firms solve the following problem:
subject to (35). $E_t \Lambda^E_{t,t+j}$ is the entrepreneurs’ (who own the capital producers) stochastic discount factor between time $t + j$ and $t$ ($j \geq 0$). Solving this maximization problem and combining the resulting first-order conditions yields the following efficiency condition:

$$0 = -1 + q^k_t \left[ 1 - \frac{\kappa_t}{2} \left( \frac{i_t q^k_t}{i_{t-1}} - 1 \right)^2 \right] - q^k_t \kappa_t \left( \frac{i_t q^k_t}{i_{t-1}} - 1 \right) + \beta E_t \left[ \frac{\lambda^E_{t+1}}{\lambda^E_t} q^k_{t+1} \kappa_t \left( \frac{i_{t+1} q^k_{t+1}}{i_{t+1}} - 1 \right) \left( \frac{i_{t+1} q^k_{t+1}}{i_t} \right)^2 \varepsilon^{q^k}_{t+1} \right]$$

(37)

G. The Central Bank and Government (Monetary, Macroprudential, and Fiscal Policies)

The central bank is assumed to conduct monetary policy according to a Taylor-type rule

$$(1 + r_t) = (1 + \bar{r})^{1-\phi_R} (1 + r_{t-1}) \Phi_R \left( \frac{\pi_t}{\pi} \right) \phi_{\pi} \left( \frac{\pi_t}{\pi} \right) \phi_y \left( \frac{\gamma_t}{\gamma_{t-1}} \right) \phi_{\Delta y} \left( \frac{\Delta y_t}{\Delta y_{t-1}} \right) \phi_e \left( \frac{\epsilon^e_t}{\epsilon_{t-1}} \right) \epsilon^r_t$$

(38)

Here, $\phi_R$ is the degree of interest-rate smoothing and $\phi_{\pi}, \phi_y, \phi_{\Delta y},$ and $\phi_e$ are the feedback coefficients on inflation deviation from the target $\left( \frac{\pi_t}{\pi} \right)$, the output level deviation $\left( \frac{\gamma_t}{\gamma_{t-1}} \right)$, the growth rate of output $\left( \frac{\Delta y_t}{\Delta y_{t-1}} \right)$, and the nominal exchange-rate depreciation $\left( \frac{\epsilon^e_t}{\epsilon_{t-1}} \right)$, respectively.\(^{15}\) $\epsilon^r_t$ is the (unsystematic) monetary-policy shock.

In the baseline model for estimation, we assume that the central bank does not conduct any active macroprudential policy. That is, the capital requirement ratio (or capital-to-assets ratio) $\theta \geq 0$ is assumed to be constant. The reserve requirement $\theta$, which is traditionally a monetary policy instrument, is also assumed to be constant, equal to $\bar{\theta} \geq 0$.\(^{16}\) The two LTV ratios $m_t^F$ and $m_t^E$, which in principal could be regulated by the central bank, are each assumed to follow an exogenous AR(1) process. In terms of fiscal policy, we simply assume government spending $g_t$ follows an AR(1) process.

\(^{15}\) We assume that the central bank can only influence nominal exchange rate fluctuations through its policy interest-rate management, based on the Taylor rule (38). In practice, central banks may also intervene in the foreign exchange market using other means such as through capital flow management — we leave this extension for future research.

\(^{16}\) In spite of this assumption, any change in the capital requirement or in the reserve requirement ratio would be captured in the estimation (in a reduced-form fashion) by the balance-sheet shock $\epsilon^e_t$.
where \( \eta_{g,t} \sim i.i.d. N(0, \sigma_g^2) \) is the government-spending shock. While (39) is by no means an accurate representation of the Indonesian government’s fiscal policy, it could still capture important developments in government spending such as fiscal subsidies in response to the COVID-19 pandemic, provided that actual government spending data are used in the model estimation.

**H. Aggregations, Market Clearing and Other Equilibrium Conditions**

**H.I. Resource Constraint**

Aggregating across agents, the domestic goods market-clearing condition is given by

\[
y_{H,t} = v_t^{-\eta} \left[ (1 - \omega) c_t + q_t^\eta y_t^\gamma \right] + i_t + g_t
\]

where \( c_t = c_t^P + c_t^I + c_t^E \) is aggregate domestic consumption, \( q_t \) is the real exchange rate, and \( y_t^\gamma \) is foreign output (GDP). \( v_t = P_{H,t}/P_t \) is the wedge between aggregate producer price \( P_{H,t} \) and consumer price \( P_t \), which is related to the real exchange rate \( q_t \), terms of trade \( S_t \) (ratio of import prices to export prices) and the LOP gap \( \psi_{F,t} \) through

\[
v_t = q_t \left( S_t \psi_{F,t} \right)^{-1}
\]

Aggregate price level restriction implies

\[
1 = (1 - \omega) v_t^{1-\eta} + w(q_t \psi_{F,t}^{-1})^{1-\eta}
\]

Given the production function (18) and CES demand functions, the aggregate technology restriction is

\[
y_t^E = \Delta_t y_{H,t}
\]

where \( \Delta_t \) denotes a measure of price dispersion (relative-price distortion) or domestically-produce goods. This dispersion can be expressed recursively as

\[
\Delta_t = (1 - \theta_H) \left( \bar{P}_{H,t} \right)^{-\varepsilon_H} + \theta_H \left( \bar{P}_{H,t-1} \bar{P}_{H,t-1} \right)^{-\varepsilon_H} \Delta_{t-1}
\]

given the Calvo setup.

**H.II. Banking Aggregates and Housing**

In equilibrium, we have \( B_t = b^I_t + b^H_t \) and \( D_t = d^I_t \). Housing is assumed to be in fixed supply \( (\hat{h}) \), so that \( h^I_t + h^H_t = \hat{h} \). Other relevant equilibrium conditions are provided in the technical appendix.
I. Stochastic Processes and the Foreign Economy

Except for the monetary-policy shock $\epsilon_t^m$ which is assumed to be i.i.d., all the other exogenous shock processes are assumed to follow an AR(1) process. For example, the technology shock follows

$$\log(\epsilon_t^s) = (1 - \rho_a) \log(\epsilon_{t-1}^a) + \rho_a \log(\epsilon_{t-1}^a) + \eta_{a,t}$$  \hspace{1cm} (45)

with $\eta_{a,t} \sim i.i.d.N(0,\sigma_a^2)$. Finally, following Justiniano and Preston (2010) and Lie (2019), we assume that the foreign economy, which is exogenous to the domestic economy, is sufficiently characterized by a vector autoregressive process of order two in foreign inflation $\pi_t^*$, foreign output $y_t^*$ and foreign nominal interest rate $r_t^*$. 

III. ESTIMATION PROCEDURE AND RESULTS

We estimate the structural parameters of the model using a Bayesian approach. This approach also allows us to identify the structural shocks hitting the economy during the sample period—including the COVID-19 pandemic shocks—implied by the data and model restrictions. The model’s equilibrium equations are linearized and fitted to 14 quarterly macroeconomic and financial time series (observables) over the 2005.Q3-2021.Q2 period, with the starting period of the sample coincides with the formal implementation of an Inflation Targeting Framework (ITF) by Bank Indonesia.\textsuperscript{17} 11 of the observables consist of Indonesian (domestic) time series: the log difference of real GDP, real investment, real government spending, real exchange rate, terms of trade, real housing price, real deposits, real loans to households and real loans to firms, consumer-price inflation rate (% per year), and the Bank Indonesia (BI) rate (% per year). Foreign time series—proxied by US real GDP (in log difference), inflation rate (log difference in GPD deflator), and the federal funds rate—make up the rest of the observables.\textsuperscript{18} More information on the linearized equations, the data and measurement equations is provided in the technical appendix.

A. Calibrated Parameters and Prior Distributions

Table 1 reports the values of those parameters that are calibrated.\textsuperscript{19} The patient households’ discount factor $\beta^p$ is calibrated to 0.9942 in order to match the average inflation rate and BI rate in our sample. The other two discount factors $\beta^I$ and $\beta^E$, along with patient households’ labor income share $\mu$ and housing weight in the utility function $\epsilon_{u,h}$ are set as in Gerali \textit{et al.} (2010). Both the inverse elasticity

\textsuperscript{17} Bank Indonesia (BI) has formally adopted an Inflation Targeting Framework (ITF) since 2005. In 2011 BI started implementing a more flexible ITF, which has been further developed into a more integrated Central Bank Policy Mix (CBPM). While the CBPM is currently the main policy strategy, BI continues to rely on inflation targeting as the main objective of monetary policy (Juhro and Goeltom (2015) and Warjiyo and Juhro (2019)).

\textsuperscript{18} Note that all these time series are already stationary, hence there is no need to demean or filter them.

\textsuperscript{19} Some of the parameters, e.g., the elasticity $\epsilon$, are not identified in the linearized model used in the estimation.
of intertemporal substitution $\sigma$ and Frisch labor supply elasticity $\phi$ are set to 1, as is standard ($\sigma=1$ is consistent with the balanced growth path). The openness parameter, $\omega$, is set equal to the average share of imports and exports as a fraction of GDP in our sample. $\eta=1.4$ is consistent with the posterior mean estimate of the elasticity of substitution between domestic and imported goods in Lie (2019). The risk-premium scale parameter $\chi$ is calibrated as in Justiniano and Preston (2010). The calibrated values of capital share in production $\alpha$, capital depreciation rate $\delta$, and goods market elasticity $\varepsilon$ are commonly used in the literature. We also calibrate the Taylor rule’s smoothing parameter to $\phi_R=0.75$, which is consistent with the posterior mean in Harmanta et al. (2014) for the Indonesian economy. The steady-state inflation rate and government spending-to-output ratio are consistent with the upper end of Bank Indonesia’s inflation target in 2021 (3±1% per annum) and the average spending-to-output ratio in our sample, respectively.

### Table 1. Calibrated Parameters

This table presents the calibration of the non-estimated structural parameters of the model --- the rest of the parameters are estimated using a Bayesian method (see Table 2). Impatient households’ and entrepreneurs’ habit coefficients are set equal to patient households’ ($a^P = a^I = a^E$). The measure of each agent is set to unity.

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient HHs’ subjective discount factor</td>
<td>$\beta^P$</td>
<td>0.9942</td>
</tr>
<tr>
<td>Impatient HHs’ subjective discount factor</td>
<td>$\beta^I$</td>
<td>0.975</td>
</tr>
<tr>
<td>Entrepreneurs’ subjective discount factor</td>
<td>$\beta^E$</td>
<td>0.975</td>
</tr>
<tr>
<td>Labor income share of patient HHS</td>
<td>$\mu$</td>
<td>0.80</td>
</tr>
<tr>
<td>Housing weight in HHs’ utility</td>
<td>$\varepsilon_H$</td>
<td>0.20</td>
</tr>
<tr>
<td>Inv. elas. of intertemporal substitution</td>
<td>$\sigma$</td>
<td>1</td>
</tr>
<tr>
<td>Inverse Frisch elas. of labor supply</td>
<td>$\phi$</td>
<td>1</td>
</tr>
<tr>
<td>Share of imports in consumption basket</td>
<td>$\omega$</td>
<td>0.22</td>
</tr>
<tr>
<td>Elas. of subs. domestic and imported goods</td>
<td>$\eta$</td>
<td>1.40</td>
</tr>
<tr>
<td>Risk-premium scale parameter</td>
<td>$\chi$</td>
<td>0.01</td>
</tr>
<tr>
<td>Capital share in goods production</td>
<td>$\alpha$</td>
<td>0.30</td>
</tr>
<tr>
<td>Physical capital depreciation rate</td>
<td>$\delta$</td>
<td>0.05</td>
</tr>
<tr>
<td>Goods market elasticity (markup)</td>
<td>$\varepsilon$</td>
<td>6</td>
</tr>
<tr>
<td>Taylor rule’s int. rate. smoothing</td>
<td>$\phi_R$</td>
<td>0.75</td>
</tr>
<tr>
<td>Steady-state quarterly net inflation rate</td>
<td>$\bar{\pi}$</td>
<td>1%</td>
</tr>
<tr>
<td>Steady-state govt. spending-to-output ratio</td>
<td>$\bar{g}/\bar{y}$</td>
<td>0.085</td>
</tr>
<tr>
<td>Impatient HHs’ steady-state LTV ratio</td>
<td>$m^I$</td>
<td>0.70</td>
</tr>
<tr>
<td>Entrepreneurs’ steady-state LTV ratio</td>
<td>$m^E$</td>
<td>0.45</td>
</tr>
<tr>
<td>Target capital-to-assets ratio</td>
<td>$\bar{y}$</td>
<td>0.086</td>
</tr>
<tr>
<td>Deposit rate elasticity (markdown)</td>
<td>$\varepsilon^d$</td>
<td>-6.54</td>
</tr>
<tr>
<td>Loan rate to HHs elasticity</td>
<td>$\varepsilon^H$</td>
<td>1.80</td>
</tr>
<tr>
<td>Loan rate to entrepreneurs elasticity (markup)</td>
<td>$\varepsilon^E$</td>
<td>2.08</td>
</tr>
<tr>
<td>Bank’s capital depreciation rate</td>
<td>$\delta$</td>
<td>0.24</td>
</tr>
<tr>
<td>Bank’s retained earnings ratio</td>
<td>$\varrho_b$</td>
<td>1</td>
</tr>
<tr>
<td>Steady-state required reserve ratio</td>
<td>$\theta$</td>
<td>0.065</td>
</tr>
</tbody>
</table>

---

20 The average inflation rate in our sample (2005.Q3-2021.Q2) is 5.2% per annum.
Regarding the financial market parameters, we do not have reliable information on aggregate LTV ratios in Indonesia (there is no specific regulation on these ratios). Hence, we set $m^y = 0.7$ as in Gerali et al. (2010) and $m^x = 0.45$, which is the mid value of the calibration used in Gerali et al. (2010) and in Chawwa (2021). The value of the target capital-to-assets ratio $v$ is in line with the average capital-to-asset ratio in Indonesia. The elasticity parameters $\{\varepsilon^d, \varepsilon^{bH}, \varepsilon^{bE}\}$ which determine the markdown on deposit rate and the markups on loan rates, are consistent with the interest rates on deposits and loans to households and firms in our sample. The calibrated value of the depreciation rate of bank capital (or cost for managing the bank’s capital position) ensures that the steady-state bank’s capital-to-asset ratio is equal to the target (0.086). Finally, we set the steady-state required reserve ratio to $\bar{\theta} = 0.065$, consistent with the average reserve requirement ratio in Indonesia.

Table 2 contains information on our priors for estimation. Overall, these priors are standard and commonly used in the literature. The priors for investment, deposit and loan rates, and bank leverage adjustment cost parameters follow those in Gerali et al. (2010). We use identical priors as in Lie (2019) for the rest of the structural parameters. As for the exogenous processes, the autoregressive coefficients and standard errors are assumed to follow Beta and Inverse-Gamma prior distributions, respectively.

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Distr.</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Mean</th>
<th>95% Prob. Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habit coefficient (patient household)</td>
<td>$\beta^p$</td>
<td>Beta</td>
<td>0.50</td>
<td>0.25</td>
<td>0.24</td>
<td>[0.09, 0.39]</td>
</tr>
<tr>
<td>Index. to past inflation, domestic firms</td>
<td>$\delta^H$</td>
<td>Beta</td>
<td>0.50</td>
<td>0.25</td>
<td>0.19</td>
<td>[0.04, 0.41]</td>
</tr>
<tr>
<td>Index. to past inflation, importers</td>
<td>$\delta^F$</td>
<td>Beta</td>
<td>0.50</td>
<td>0.25</td>
<td>0.04</td>
<td>[0.00, 0.09]</td>
</tr>
<tr>
<td>Calvo price stickiness, domestic firms</td>
<td>$\theta^H$</td>
<td>Beta</td>
<td>0.60</td>
<td>0.10</td>
<td>0.65</td>
<td>[0.58, 0.72]</td>
</tr>
<tr>
<td>Calvo price stickiness, importers</td>
<td>$\theta^F$</td>
<td>Beta</td>
<td>0.60</td>
<td>0.10</td>
<td>0.59</td>
<td>[0.54, 0.64]</td>
</tr>
<tr>
<td>Taylor rule coefficients</td>
<td>$\phi_\pi$</td>
<td>Gamma</td>
<td>1.90</td>
<td>0.30</td>
<td>1.33</td>
<td>[1.18, 1.46]</td>
</tr>
<tr>
<td></td>
<td>$\phi_y$</td>
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<td>St. Dev.</td>
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### Exogenous (shock) processes

**Autoregr. coefficients**

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**Standard deviations (%)**

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### B. Posterior Estimates

The last two columns of Table 2 report the posterior mean, along with the [5.95]% probability bands. Overall, the data appears to be quite informative on virtually all the parameters and the stochastic disturbances, as indicated by the lower variances of the posterior distributions over the prior distributions across the board. On the behavioral parameters, the patient households’ habit parameter is relatively low (0.24 at the posterior mean), largely consistent with the finding in Zams (2021) and Lie (2019). The mean estimates of the two price indexation parameters are
smaller compared to the corresponding estimates in Lie (2019), suggesting that
indexation is not an important feature of the Indonesian economy during the ITF
period. The two Calvo price stickiness parameters are both higher than those in
Lie (2019), e.g., our Calvo domestic price stickiness parameter (probability of nonoptimal price adjustment $\theta_H$) has a posterior mean of 0.65 versus 0.6 in Lie. Hence,
the additional frictions imposed in our model appear to non-trivially affect the
structural parameter estimates.

On the Taylor-rule parameters, the mean estimate of the inflation response $\phi_\pi$ is estimated to be 1.33, which is on the low side compared to other estimates using the Indonesian data (e.g., Harmanta et al., 2014; Dutu, 2016; Lie, 2019). This again highlights the importance of the additional frictions imposed in our model. Consistent with that in Lie (2019), however, we estimate a higher response coefficient on the output growth ($\phi_{\Delta y}$) than the response on the output level ($\phi_y$). The non-zero mean estimate of $\psi_e$ implies that Bank Indonesia appears to engage
in some degree of exchange rate interventions during the ITF period through the
management of its policy rate. On the adjustment costs, all five of them appear to
be non-trivial, i.e. each has a non-zero posterior mean and the [5.95]% probability
band does not include zero. This suggests the existence of non-trivial frictions in
the capital market and in the banking sector.

In terms of the posterior distributions of the stochastic disturbances, one
striking finding is regarding the very high persistence of the technology shocks:
the posterior mean is 0.99 with a quite tight probability band. This is a much
higher estimate compared to that in Lie ($\rho_a=0.56$), albeit with a higher posterior
mean standard deviation than ours ($\sigma_a=2.94%$ vs.0.77%). Housing-demand
shocks are also estimated to have high mean persistence and standard deviation.
However, these shocks appear to only materially affect the variations in the credit
growth and have little effect on the fluctuations of macroeconomic variables (see
the discussion on forecast-error variance decomposition in the next section).
Preference shocks are estimated to have a moderate level of persistence ($\rho_z=0.68$),
but with a relatively high standard deviation ($\sigma_z=7.17%$). Financial shocks appear
to have high persistence, particularly the two LTV shocks.

IV. MODEL APPLICATION: IMPLICATIONS ON THE SOURCE OF
AGGREGATE FLUCTUATIONS
In this section we apply the estimated model to conduct two analyses regarding
the source of aggregate fluctuations in the Indonesian economy. The first analysis
concerns conditional, forecast-error variance decompositions, which address the
question of which shocks are the main driving forces for each variable. Here, we
limit the discussion to the driving forces of output growth, inflation, nominal
(policy) interest rate, and credit growth. In the second analysis we compute
the historical contribution (decomposition) of each shock, which allows us to
determine the make up of the COVID-19 pandemic shocks.

21 Compared to the model in Lie (2019), our model has additional financial and banking frictions
and physical capital accumulation. We do not, however, incorporate time-varying inflation target
adjustments.
A. Forecast-Error Variance Decompositions

Table 3 reports the posterior mean forecast error variance decompositions of several key endogenous variables—output (GDP) growth, inflation, the monetary policy interest (BI) rate, and credit growth—at various horizons. Out of the macro shocks, technology, preference, and cost-push shocks are largely responsible for output growth fluctuations. The combined contributions of these three shocks range from 69-73% in the considered forecast horizons. Monetary-policy shocks play some role, but their contributions are less than 10%. The other macro shocks do not appear to be materially important. Financial shocks’ contributions are non-trivial: even at 10-year (40-quarter) forecast horizon, they are responsible for 16% of the fluctuations in the output growth.

Table 3. Forecast Error Variance Decompositions

This table presents the forecast error variance decompositions of selective aggregate variables, based on the posterior mean estimates. All entries are in %. Cost-push shocks include both domestic and import cost-push shock. Financial shocks include LTV shocks and balance-sheet shock. Foreign shocks include foreign-output, foreign-inflation, foreign interest-rate, and exchange-rate risk premium shocks. Sample period: 2005.Q3-2021.Q2.

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We group the balance-sheet and the two LTVs shocks together and term them financial shocks. Foreign shocks on other hand represent the combined effects of foreign output, foreign inflation, foreign interest rate, as well as foreign-exchange risk-premium shocks.
We note that this output decomposition result is somewhat different than that estimated in Lie (2019) for the Indonesian economy. There, technology shocks and monetary-policy shocks are overwhelmingly responsible for output fluctuations. This difference stems from the inclusion of physical capital accumulation (investment), financial frictions and shocks, and the domestic cost-push shock in our model. When capital is absent and labor is the only input into production, technology shocks would pick up the effect of fluctuations in capital stocks. Including financial frictions and shocks in the model further reduce the contribution of technology (and monetary-policy) shocks. Interestingly, these additional model elements also imply that preference shocks are important for output fluctuations, in contrast to the finding in Lie. Overall, these discrepancies suggest that the choice of frictions and shocks in the estimated model has an important implication for variance decompositions.

Short-term inflation fluctuations appear to be largely caused by cost-push shocks, but with reduced contribution as the forecast horizon increases. This importance of cost-push (price-markup) shocks for inflation variations in the short-run is also found by Smets and Wouters (2003) and Copaciu et al. (2015) for the Euro area and Romania, respectively. Technology shocks are also important for inflation fluctuations, more so at longer horizons.

Financial and (unsystematic) monetary-policy shocks appear to contribute little to inflation fluctuations at all considered horizons. The relative unimportance of monetary-policy shocks for inflation variations, however, is consistent with the finding in Adolfson et al. (2007) for the Euro area. Regarding the fluctuations of the nominal interest (BI) rate, we find that technology and cost-push shocks to be the most important driver. For example, at the 1-quarter horizon, cost-push shocks are responsible for almost half of policy interest rate fluctuations. The contributions of all the other shocks are minimal.

On credit growth variations, we find important contributions of technology, cost-push, financial, and monetary-policy shocks. The contribution of technology shocks appears to be increasing as the forecast horizon increases. Despite this, the contributions of cost-push, financial, and monetary-policy shocks are still non-trivial, even at 40-quarter horizon. Out of the three financial shocks—shocks to bank balance sheet, households’ and firms’ LTV ratios—the shocks to firms’ LTV ratio appear to be the most important. These shocks make up to about three quarters of the financial shocks’ contribution. Housing-demand shocks’ contribution to credit growth appear to also be non-trivial. Not surprisingly, these shocks affect total credit growth through their effect on loans to households, which is consistent with finding in Gerali et al. (2010) in the context of the US data.

Overall, for these four key variables we consistently find important contributions of technology and cost-push shocks. The importance of technology shocks for aggregate fluctuations is perhaps not surprising, given the high persistence of the shock \( \rho = 0.99 \) at the posterior mean. As we shall see next, technology shocks appear to also play an important role in the Indonesian economy during the COVID-19 pandemic.

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B. Historical Shock Decompositions and COVID-19 Shocks

Figures 1-3 depict the historical shock decompositions of output growth and inflation, as well as credit (total loans) growth. As these three variables are used as observables in the Bayesian estimation, the smoothed variables depicted by the black line in each of Figures 1-3 reflect the actual data (plotted as deviation from the sample average). The decomposition of output growth in particular allows us to identify the COVID-19 pandemic shocks implied by the data and the model restrictions.

Figure 1.

**Historical Decomposition of Output Growth**

The figure presents the historical posterior-mean variance decomposition of output growth. The contribution unit of each shock is in % per quarter. The top panel shows the decomposition for the whole sample period (2005Q3-2021Q2), the bottom panel zooms on the recent 2019.Q1-2021.Q2 period. The black line plots the actual (smoothed) quarterly output growth, shown as deviation from the sample average (1.2%). Cost-push shocks include both domestic and import cost-push shocks. Financial shocks include LTV shocks and balance-sheet shock. Foreign shocks include foreign-output, foreign-inflation, foreign interest-rate, and exchange-rate risk premium shocks.

**A. Decomposition for the 2005Q3-2021Q2 Sample Period**

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24 Since we impose an identical measure for impatient households and firms \( (\gamma^h=\gamma^f=1) \) in the model, the smoothed credit growth represents the growth rate of the unweighted sum of loans to households and loans to firms.
Figure 1.  
Historical Decomposition of Output Growth (Continued)

B. Decomposition for the 2019Q1-2021Q2 Sample Period

<table>
<thead>
<tr>
<th>Year</th>
<th>Init.</th>
<th>Tech.</th>
<th>Pref.</th>
<th>Cost push</th>
<th>Inv.</th>
<th>Hs. price</th>
<th>Govt. spending</th>
<th>Mon. pol.</th>
<th>Financial</th>
<th>Foreign</th>
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Figure 2.  
Historical Decomposition of Inflation

The figure presents the historical posterior-mean variance decomposition of inflation. The contribution unit of each shock is in % per quarter. The top panel shows the decomposition for the whole sample period (2005.Q3-2021.Q2), the bottom panel zooms on the recent 2019.Q1-2021.Q2 period. The black line plots the actual (smoothed) inflation rates, shown as deviation from the sample average (5.3%). Cost-push shocks include both domestic and import cost-push shocks. Financial shocks include LTV shocks and balance-sheet shock. Foreign shocks include foreign-output, foreign-inflation, foreign interest-rate, and exchange-rate risk premium shocks.

A. Decomposition for the 2005Q3-2021Q2 Sample Period

<table>
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<tr>
<th>Year</th>
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<th>Tech.</th>
<th>Pref.</th>
<th>Cost push</th>
<th>Inv.</th>
<th>Hs. price</th>
<th>Govt. spending</th>
<th>Mon. pol.</th>
<th>Financial</th>
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Figure 2.
Historical Decomposition of Inflation (Continued)

B. Decomposition for the 2019Q1-2021Q2 Sample Period

Figure 3.
Historical Decomposition of Credit Growth

The figure presents the historical posterior-mean variance decomposition of credit growth. The contribution unit of each shock is in % per quarter. The top panel shows the decomposition for the whole sample period (2005.Q3-2021.Q2), the bottom panel zooms on the recent 2019.Q1-2021.Q2 period. The black line plots the actual (smoothed) credit growth rates, shown as deviation from the (unweighted) sample average (2.2%). Cost-push shocks include both domestic and import cost-push shocks. Financial shocks include LTV shocks and balance-sheet shock. Foreign shocks include foreign-output, foreign-inflation, foreign interest-rate, and exchange-rate risk premium shocks.

A. Decomposition for the 2005Q3-2021Q2 Sample Period
B.I. Output Growth

The top panel of Figure 1 plots the posterior mean decomposition of the output growth for the whole sample period (2005.Q3-2021.Q2). Overall, the historical decomposition result is consistent with the variance decomposition in Table 3: technology, preference, cost-push, and financial shocks are largely responsible for the fluctuations of the output growth historically. It is notable that unlike the decomposition for the U.S. economy reported in Gerali et al. (2010), financial shocks do not appear to be the dominant driver for output fluctuations during the height of the Global Financial Crisis (GFC) in 2008. This finding is consistent with the fact that the Indonesian economy was not particularly exposed by the 2008 GFC.

Zooming in on the recent 2019.Q1-2021.Q2 period (the bottom panel), we find that the decline in output in the 1st quarter of 2020 (a -0.9% quarter-to-quarter growth rate) is fueled by a combination of preference and financial shocks, and foreign shocks to some extent. The largest pandemic-induced output contraction occurs in 2020.Q2—around the time when the economic effect of the COVID-19 pandemic began to take hold in Indonesia— where output declines by 6.7% compared to the previous quarter. Our estimated model attributes this huge output decline mainly to technology, preference, and foreign (mainly, foreign-output) shocks. Domestic cost-push shocks also appear to non-trivially contribute to the negative output growth in 2020.Q2, although to a smaller degree compared to the aforementioned three shocks. Interestingly, the (positive) contribution of monetary-policy shocks to the negative growth rate in this quarter appears to be non-trivial. This, however, does not necessarily mean that Bank Indonesia’s...
monetary policy stance at the time was too tight. Such a positive contribution, however, does imply that monetary policy is tighter than if the central bank strictly follows the Taylor rule in (38) when setting the policy rate.

Our estimates attribute the huge output growth reversal in 2020.Q3 to a combination of positive foreign-output, preference, technology, and to some extent, positive financial and government-spending shocks. Hence, timely fiscal subsidies by the Indonesian government in response to the pandemic, as proxied by a positive government spending shock in 2020.Q3, are a contributing factor to the swift output growth reversal. Absent a negative investment adjustment shock in 2020.Q3, however, the positive output growth would have been higher. From 2020.Q4-2021.Q2, a combination of adverse technology and preference shocks serves as a drag to the economic recovery, even though the growth rate of output is positive in each of these quarters.

We interpret the finding in Figure 1 as a characterization of the COVID-19 pandemic shocks as a combination of adverse technology, preference, and foreign-output shocks, especially in light of the decomposition evidence in 2020.Q2. We believe this is a reasonable characterization. Technology shocks in the model are supply shocks that encompass labor supply shocks. Hence, an adverse technology shock captures an aggregate supply reduction due to supply-chain disruptions and large-scale social and economic restrictions instituted by the Indonesian government in response to the pandemic. Adverse preference shocks capture the aggregate consumption and investment spending decrease due to various layouts, firm exits, and scores of people voluntarily reducing their labor supply because of the risk of infection. In addition, a negative preference shock also serves as a proxy for an increase in households’ precautionary saving in response to heightened, pandemic-induced income uncertainties. Negative foreign-output shocks on the other hand serve as a proxy for the decline in import demands and the global reduction in the international trade volume.

Our characterization of the COVID-19 pandemic shocks is also consistent with those assumed in various papers in the literature. For example, Fornaro and Wolf (2020) treat the COVID-19 shock as an adverse productivity growth rate shock. Faria-e Castro (2020) assumes that the pandemic is an adverse demand-side shock that affects the contact-intensive service sector. McKibbin and Fernando (2021) translate the pandemic as a combination of labor supply, equity risk premium, production cost, and consumer spending shocks. In the context of the Indonesian economy, Lie (2021) models the COVID-19 shocks as a combination of preference (consumer-spending) and labor supply shocks. In a similar decomposition analysis using an estimated DSGE model for the Euro area, Cardani et al. (2021) also find a dominant role of the supply-side “lockdown” shocks during the pandemic.

26 These restrictions are called Pembatasan Sosial Berskala Besar (PSBB) in Indonesia when it was first instituted in 2020.Q2. These restrictions have since been revised and the term has been renamed to Pemberlakuan Pembatasan Kegiatan Masyarakat (PPKM), which is effectively a partial lockdown.
27 The outstanding amount of saving and time deposits (up to 24-month maturity) did increase in 2020.Q3 by 4.5% compared to the previous quarter, which is markedly higher than the 1.8% average growth rate in our sample from 2005.Q3-2021.Q2.
B.II. Inflation and Credit Growth

Figure 2 plots the historical decomposition of inflation. For the whole sample period, technology and cost-push shocks appear to play a dominant role. Financial shocks also appear to non-trivially affect the historical inflation rates, especially in the recent periods. One notable ending is regarding the source of huge inflation spike in 2005.Q4, which was primarily due to the Indonesian government’s huge cut in the fuel price subsidy at the time. Our model attributes the spike largely to (mainly, domestic) cost-push shocks, as is traditional in the Phillips curve literature. Interestingly, investment-adjustment shocks also seem to play a role in inflation variations, including the negative contributions during the COVID-19 period (bottom panel). In spite of this, consistent with our characterization of the COVID-19 shocks, adverse technology shocks during the COVID-19 period appear to have important, positive contribution to inflation (an adverse supply or technology shock leads to higher prices and a higher inflation rate). Adverse preference shocks drag inflation down starting in 2020.Q1, but the overall effect seems to be minimal.

As for credit growth, once again we find a dominant role of adverse technology shocks during the COVID-19 period, as plotted in the bottom panel of Figure 3. These shocks are largely responsible for the muted credit growth rates during the COVID period. Financial shocks appear to also be quite important in 2020.Q1, but the contributions are minimal from 2020.Q2 onward, especially relative to the contribution of technology shocks. Adverse preference shocks, on the other hand, positively contribute to credit growth (i.e., they lead to higher aggregate loan amounts), capturing the effect of an increase in precautionary saving during the pandemic.

V. INVESTIGATING THE IMPLICATIONS OF A MONETARY-MACROPRUDENTIAL POLICY MIX: AN EXAMPLE

As an illustration of the model’s usefulness as a tool to evaluate the relative performance of any given policy mix, we now investigate the implications of a monetary-macroprudential mix involving a countercyclical capital requirement (or capital buffer) regulation, in comparison to the baseline case where the central bank only conducts monetary policy through an overnight interest-rate management (using the Taylor rule (38)). Specifically, under the policy mix the central bank adjusts the capital requirement ratio (CR) using the following rule:

\[ v_t = \bar{v}^{(1-\rho_v)} v_{t-1}^{\rho_v} \left( \frac{B_t}{B_{t-1}} \right)^{\psi_v (1-\rho_v)} \]  \hspace{1cm} (46)

When there is an increase in the growth rate of credit (total loans outstanding) \( B_t/B_{t-1} \), the central bank using the CR rule (39) would countercyclically increase the capital requirement \( v_t \) thus stabilizing the financial cycle. The strength of this response (hence, the strictness of such a policy) depends on policy-feedback coefficient \( \psi_v \geq 0 \). The above rule also features a degree of instrument smoothing, captured by the parameter \( \rho_v \in [0,1] \).
In subsequent analysis, we set $\rho_v = 0.75$ and $\psi_v = 10$ (all other parameter values are set to their posterior means). These numbers are admittedly ad hoc, though not unreasonable. However, our purpose in this section (and in this paper) is to illustrate how the model can be used to perform a policy mix evaluation rather than a comprehensive analysis of a given policy mix.\textsuperscript{28} For that reason, we also limit our investigation below to the standard impulse response analysis and a counterfactual simulation involving the COVID-19 shocks identified in Section IV.

### A. Impulse Responses

Figures 4-5 plot the impulse responses to a negative 1% preference (consumer-spending) shock and a negative 1% technology shock, respectively. We focus on these two shocks since they appear to be the dominant shocks during the COVID-19 pandemic in Indonesia (see Section IV).

#### Figure 4.
**Impulse Responses to a Negative 1% Preference Shock**

This figure presents the impulse responses to a -1% preference shock. The preference shock follows an AR(1) process with persistence $\rho = 0.68$, per the posterior mean. MP and CR refer to monetary policy and capital requirement (bank capital-to-assets ratio), respectively.
Figure 4.
Impulse Responses to a Negative 1% Preference Shock (Continued)

Inflation

% deviation p.a.

0 2 4 6 8 10
%-0.2 -0.15 -0.1

Nominal (policy) rate

% deviation p.a.

0 2 4 6 8 10
%-0.25 -0.2 -0.15 -0.1

Policy instrument

level dev (%)

0 2 4 6 8 10
0 0.1 0.2 0.3 0.4

MP MP+CR

Rate on loans to firms

% deviation p.a.

0 2 4 6 8 10
%-0.25 -0.2 -0.15 -0.1

Figure 5.
Impulse Responses to a Negative 1% Technology Shock

This figure presents the impulse responses to a -1% technology shock. The technology shock follows an AR(1) process with persistence $\rho = 0.99$, per the posterior mean. MP and CR refer to monetary policy and capital requirement (bank capital-to-assets ratio), respectively.
A.I. Preference Shock

The adverse preference (demand) shock causes domestic output and consumption to contract under both policy mix cases (MP and MP+CR). After the impact period (period 0), investment goes up in subsequent periods as the market price of capital decreases in response to higher accumulated savings (not shown). The consumer-price inflation rate also goes down, as expected. In response to the output contraction and lower inflation, the central bank attempts to stimulate the economy by immediately cutting the nominal policy interest rate by about 0.2%
(per annum) in the baseline MP case (solid blue line). These responses look to be qualitatively similar across the two cases. There appears, however, to be some disparities quantitatively, which can be explained by the development in the credit market.

In both cases, the total amount of credit (loans) in the economy goes up on impact and in subsequent periods. This credit expansion is largely caused by lower household and loans rates, stimulated by the policy rate cut. The size of the decrease in the loan rates, however, differs across the two policy mix cases. As shown in bottom right panel of Figure 4, the interest rate on loans to firms decrease by less under the MP+CR case than that in the baseline MP case. The same pattern also occurs for the rate on loans to households (not shown). The reason behind this stems from how the CR regulation affects the credit market. A CR regulation affects the credit market through the credit supply channel. That is, when the central bank increases the required capital-to-assets ratio (bottom left panel of Figure 4), the supply of credit (loanable funds) would decrease, which in turn causes the loan rates to increase (ceteris paribus). This is the reason why all in all, the loan rates would decrease by less under the MP+CR policy. The countercyclical CR rule can therefore better stabilize the credit (financial) cycle compared to standard MP case where there is no active macroprudential policy. Looking back at the output responses, such a policy mix also appears to stabilize output more, i.e., output decreases by slightly less under the MP+CR case. Overall, however, when the economy is hit by a preference shock, the impact of the CR regulation in (39) on the business cycle fluctuations appears to be minimal.

A.II. Technology Shock
When the economy is hit by an adverse technology (supply) shock, we observe overall contractions in output, consumption, and investment. There is, however, an increase in the price level (higher inflation) since the adverse supply shock causes an increase in the real marginal cost of production. In response to this, the central bank increases the nominal (policy) interest rate. As in the preference shock case, we observe a qualitatively-similar response pattern across the policy mixes. The development in the credit market once again leads to some quantitative disparities. The adverse technology shock leads to a reduction in the overall credit in the economy. In response to this, the central bank conducting a countercyclical CR regulation using the rule (39) would decrease the required capital-to-assets ratio (bottom left panel of Figure 5). Such a policy response increases the supply of loanable funds (ceteris paribus), which in turn causes the loan rates to increase by less (bottom right panel). This more subdued response of the loan rates means a smaller effect of a given negative supply shock: output, consumption, investment, and credit contract by less while inflation increases by less, relative to that in the baseline MP case. In addition, there is a feedback loop between inflation and the policy and the loan rates: the smaller increase in inflation means that the central bank would not need to increase the policy rate as much to stabilize the business cycle (e.g., inflation and output) fluctuations, causing a further subdued increase in the loan rates.
Comparing Figure 4 and Figure 5, it is apparent that the quantitative disparities between the two policy cases are much larger in the latter. Hence, the countercyclical CR regulation is a more effective stabilization tool when the main drivers of fluctuations are technology (supply) shocks instead of preference (demand shocks). Put another way, the effect of a given macroprudential policy is shock specific (state dependent), consistent with the finding in Unsal (2018).29

B. Counterfactual Analysis
We next perform a counterfactual analysis based on the countercyclical CR rule (39) and the estimated (smoothed) shocks during the COVID-19 pandemic period. For this analysis, we assume that up to 2019.Q4 the central bank has been conducting monetary policy without the support of active countercyclical macroprudential regulations, per the assumption in our estimation. This implies that up to that quarter, all the variables are equal to their smoothed values (as estimated using the Kalman filter based on the posterior means). Starting from 2020.Q1 onward, however, the central bank is assumed to conduct a monetary-macroprudential policy mix with a countercyclical CR policy per the rule in (39). Throughout the counterfactual periods from 2020.Q1-2021.Q2, the economy is subjected to the same smoothed shocks identified in the estimation. The counterfactual results are depicted in Figure 6 by the dashed red line. For comparison purpose, we also plot the actual, smoothed variables produced by the Kalman filter under the MP case, represented by the solid blue line. (Note that since the data on output, credit (total loans), investment, CPI inflation, and the BI (policy) rate are used as observables in the Bayesian estimation, these smoothed variables match the actual data.)

Figure 6.
Smoothed Variables, Policy-Mix Counterfactuals, and COVID-19 Shocks
The figure presents the evolution of selective variables under the benchmark estimated policy (monetary policy only, MP) versus a monetary-macroprudential policy mix involving a countercyclical bank capital requirement, or capital-to-asset, ratio (MP+CR). In the MP+CR case, the central bank is assumed to adopt the policy mix starting from 2020.Q1 onwards. In the MP case, since output, credit, investment, inflation, and the nominal policy (BI) rate data are used as observables in the Bayesian estimation, these variables match the actual data.

29 Unsal (2018) considers capital flows management as a macroprudential policy tool and finds that the optimal policy is state dependent.
First, from the MP case we can clearly see the devastating impact of the COVID-19 pandemic. This is especially true in the 2nd quarter of 2020: output (GDP) contracted by 6.7%, accompanied by a sharp drop in consumption and investment activities. While the recovery came swiftly (starting in 2020.Q3), the subsequent expansions were quite mild relative to the sharp reduction in 2020.Q2. Here, the levels of output, consumption, and investment in our latest quarter (2021.Q2) are still lower than their sample averages. Lower real economic activities...
also led to a decrease in the CPI inflation rate, both in 2020.Q2 and 2020.Q3. The inflation rate started to pick up again in 2020.Q4, however, due to the swift recovery. In response to the pandemic-induced contraction, Bank Indonesia has gradually cut its policy rate — it stands at 3.5% in 2021.Q2.

If the central bank additionally adopted the countercyclical CR rule starting in 2020.Q1, output, consumption and investment would have been higher overall during the pandemic. At the end of our sample period in 2021.Q2 for example, each of these variables would have been higher by 0.5%, 1.4%, and 9.8%, respectively. Inflation and the nominal policy rate would be lower throughout the counterfactual periods. Armed with the capital requirement ratio as an additional policy instrument, the central bank would progressively lower the ratio from 2020.Q1 up to 2021.Q1, before increasing it again in 2021.Q2. These findings stem from the dominant effect of (adverse) technology shocks during the pandemic. This is true even though we have characterized the pandemic shocks as a combination of technology shocks and other—preference, foreign-output and cost-push—shocks.30 When the effect of technology shocks is dominant, as we can see from the impulse responses in Figure 5, the countercyclical CR rule (39) could be a potent addition to the policy mix.

In spite of our counterfactual results, we note that a macroprudential policy regulation does not necessarily lead to better stabilization outcomes (welfare-improving). Whether a countercyclical rule such as (39) is welfare-improving depends on a confluence of factors, e.g., the policy response parameters, the specific macroprudential policy instrument, and the combination of shocks hitting the economy. It is not clear from our counterfactual results, for example, whether the MP+CR policy mix leads to a higher aggregate welfare compared to the MP case. It appears to be the case, but one cannot be certain without a proper welfare comparison. We plan to investigate this important issue in a separate, companion paper.

VI. CONCLUSION AND FUTURE DIRECTIONS
This paper builds and estimates a small open-economy Dynamic Stochastic General Equilibrium (DSGE) model suitable for the evaluation of central bank policy mix, with a particular application on the Indonesian economy. The model has a rich array of shocks and frictions, including banking and financial frictions. We illustrate how the estimated model can be used to investigate the source of aggregate fluctuations in Indonesia and to evaluate and simulate a policy mix involving monetary and macroprudential policies. We notably find that with regard to the COVID-19 pandemic shocks, the data and the DSGE model restrictions identify these shocks to be largely a combination of adverse supply-side (technology) and demand-side (preference and foreign-output) shocks. Our evaluation and simulation of a countercyclical capital requirement rule shows that such a macroprudential policy rule could be a potent addition to Bank Indonesia’s

30 Since $\rho_a=0.99$ (at the posterior mean), each occurrence of a technology shock is highly persistent and has a lasting effect on aggregate variables.
policy mix arsenal. This is especially true when technology shocks are a dominant driver of aggregate fluctuations, as is the case during the COVID-19 pandemic.

Our main focus in this paper is on model development. As such, we limit the policy mix analysis to a monetary-macroprudential policy mix involving one macroprudential policy instrument (bank capital requirement). The model, however, can be used to evaluate the relative performance of other macroprudential policy instruments, e.g., loan-to-value ratio or liquidity coverage ratio. Furthermore, due to the structural nature of our model, we could conduct a proper welfare comparison between various policy mix combinations. We plan to address these issues in a separate, companion paper.

One could also readily extend the model to evaluate other types of policy mix, not just a monetary-macroprudential policy mix. For example, we could investigate whether the optimal policy mix involves direct foreign exchange intervention and capital controls, or whether the inclusion of a Central Bank Digital Currency (CBDC) is welfare-improving. The COVID-19 pandemic also uncovers the need for a better coordination between monetary, macroprudential, and fiscal policy authorities to mitigate the economic impact of future similar adverse events. Future research should look into this more-integrated policy framework. Our model can be used as a base model for such analyses.
REFERENCE


An Estimated Open-economy DSGE Model for the Evaluation of Central Bank Policy Mix


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