RESEARCH ARTICLE

On Implementation Delays, Marginal Costs and Price Dynamics: A Theoretical Note With Implications for the Philippines[1]

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Abstract: It has been known that longer implementation delays in public investments result in sluggish accumulation of public capital. In models in which public capital determines firm productivity, the longer the duration of implementation delays, the higher the marginal costs which, in a New Keynesian economy means higher price markups. Consequently, higher markups may increase the inflation rate, leading to an appropriate monetary policy response. Using a dynamic stochastic general equilibrium (DSGE) model, this theoretical note focuses on the relationships among government investments, firm pricing policy, and monetary policy. It addresses some aspects of public investment, and through simulations, characterizes how its effects are propagated throughout the macroeconomy. Using different scenarios pertaining to the duration of implementation delays, we employed stochastic simulations to determine how authorized budget shocks affect output, public investment, interest rates, wages, and prices. Of particular interest is the impact of implementation delays on the firm's marginal costs and pricing dynamics. We found that implementation delays and sudden disbursement stops do condition the dynamic impact of authorized budget shocks. Moreover, we noted that disbursement performance matters for output growth and efficient fiscal response. The model shows how public capital, when included in firms' production functions, may act as a double-edged sword. Given a reinvigorated push for infrastructure spending, this note is expected to generate and discuss important policy implications for the Philippines.

Keywords: Implementation delays, DSGE, Philippines, government investments, marginal costs

JEL Classifications: E62, H31, E31

In studies that investigate the effectiveness of fiscal policy, two modeling strands are apparent. On the one hand, public capital does not enter the production function (Fernandez-Villaverde, 2010b; Leith, Moldovan, & Rossi, 2015; Zubairy, 2014; Cantore, Levine, Melina, & Yang, 2012). On the other hand, public capital plays a huge role in the production of firms(Coenen, Straub, & Trabandt, 2013; Leeper, Walker, & Yang, 2010; Dacuycuy, 2016; Bhattarai & Trzeciakiewicz, 2017). When fiscal authorities face no considerable delays in implementing public investments, public capital accumulation is not impeded, leading to immediate societal benefits such as better infrastructure, efficient bureaucracy, and robust output growth. However, as already noted in the literature, when public investments become subject to considerable delays, the output will either grow slowly until project completion or simply exhibit a suboptimal trajectory. Reductions in private investments will also be more severe, and the impact on labor will be lower.

The response of output to shocks in public investments will also be conditioned by the degree to which public spending is deemed efficient, and it has been shown that disbursement performance is critical in shaping dynamics, especially when rare events associated with legal issues occur (Dacuycuy, 2016; Leeper et al., 2010). This is the common emphasis among studies that have focused on the role of government investments and have acknowledged the possibility that implementation delays will occur.

While embedded as part of DSGE models, there has been little emphasis on the link between implementation delays and supply-related factors such as marginal costs, prices, and wages. The link is plausibly simple. A major government project funded through public investments contributes to public capital that may be utilized by firms. In this case, a positive public investment shock acts as a productivity shock, significantly increasing firm output. In a neoclassical setting, a sudden increase in government investments has implications on fiscal multipliers (Leeper et al., 2010). However, because of the absence of price inertia in neoclassical model economies, there are no markups. In contrast, public capital determines intermediate firms' output in a Keynesian economy. Given delays,firms' marginal costs will rise, which in turn, make prices higher. Thus, there may be plausible implications for monetary authorities to act on.

This note builds upon the idea of implementation delays and sudden stops,a situation wherein disbursement flows are stopped in response to rare legal setbacks. It endeavors to connect shocks to public investments to firms' pricing and wage policies in a New Keynesian setting using a DSGE framework. DSGE models use a general equilibrium framework where behavior in each sector of the economy is derived through dynamic optimization programming. The dynamic properties of DSGE models are then analyzed using impulse response functions (IRF), wherein an impulse is applied to one of the stochastic processes and the response of the model or economy is observed. As calibrated DSGE models have relatively simple dynamic structures, they tend to have a worse fit than estimated models. Hence, the DSGE model developed in the study is not designed to match the quantitative dynamic behavior of the macroeconomic indicators, but rather to conduct different simulations of the economy. While it is mainly theoretical and dependent on stochastic simulation, this note aims to extract some plausible implications for fiscal and monetary policies in the Philippines, given that there is a tremendous drive towards the completion of major infrastructure projects to achieve growth and development objectives.

The Model

The model's closed-economy structure is familiar. It combines New Keynesian structures with several elements of fiscal policy such as government investments, authorized budgets, implementation delays, and disbursement sudden stops (Coenen et al., 2013; Fernandez-Villaverde, 2010a, 2010b; Leeper et al., 2010; Fernandez-Villaverde & Ramirez, 2006; Dacuycuy, 2016). Using Calvo pricing, a fraction of households set their own wages while a fraction of firms will be able to set their optimal prices. The fiscal sector implements fiscal policy and stabilization tools, but we emphasize government investments and the evolution of public capital. Public capital accumulates, depending on the speed of completion of a representative government project. Its dynamic properties, in turn, determine the trajectory of marginal costs, which to a certain extent, drive price dynamics. Finally, the model includes a monetary sector tasked to implement a Taylor rule on nominal interest rates.

Households

We assumed a continuum of households categorized into Ricardian and Non-Ricardian households. Ricardian households can optimize utility by choosing consumption, labor, and investments. Non-Ricardian households cannot optimize, as they rely solely on current income to consume. No investment activities are undertaken by such households. However, both households have the same number of hours worked.

Ricardian households maximize the following objective function:

$$E_0\left[\sum_{t=0}^{\infty}\beta^t\,\epsilon_t^C\left(\frac{(c_{ht}^R-hc_{ht-1}^R)^{1-\sigma}}{1-\sigma}-\epsilon_t^L\psi\,\frac{l_{ht}^{1+\xi}}{1+\xi}\right)\right] \tag{1}$$

where β denotes the discount factor, h represents the degree of external habit formation in consumption, σ represents the inverse of the relative risk aversion parameter, and ξ is the inverse of the Frisch substitution elasticity. ϵ_t^C and ϵ_t^L represent autoregressive shocks to preferences and labor supply, respectively.

The processes are given by

$$log(\epsilon_t^C) = \rho_c log(\epsilon_{t-1}^C) + \varepsilon_{c,t}, \varepsilon_{c,t} \sim N(0,1) \quad (2)$$

$$log(\epsilon_t^L) = \rho_L log(\epsilon_{t-1}^L) + \varepsilon_{L,t}, \varepsilon_{L,t} \sim N(0,1) \quad (3)$$

where ρ_C and ρ_L represent the respective degrees of persistence in consumption and labor supply.

The budget constraint of the Ricardian household is given by

$$(1+\tau_t^C)c_{ht}^R + i_{ht}^R + \frac{B_{ht+1}^R}{P_t}$$
$$= (1-\tau_t^L-\tau_t^{SS})w_{ht}l_{ht}^R + (1-\tau_t^K)\left(r_t u_{ht} - \mu_t^{-1}a(u_{ht})\right)k_{ht-1}^R$$
$$+ R_{t-1}\frac{B_{ht}^R}{P_t} + TR_t^R \quad (3)$$

where P_t is the price of a unit of consumption good c_t. In the budget, households are levied consumption taxes τ_t^C, social security taxes τ_t^{SS}, and pay labor earnings taxes τ_t^L as well. Following Fernandez-Villaverde (2010a), $\mu_t^{-1}a(u_{ht})$is interpreted as the physical cost associated with the use of capital in resource terms. μ_t is an investment-specific technological shock. Ricardian households also receive transfers TR_t^R. Households use part of their budget to purchase domestic bonds and undertake private investments i_{ht}^R. Previous earnings from said bonds, $R_{t-1}\frac{B_t}{P_t}$, however, are not subject to tax.

Compared with their Ricardian counterparts, a non-Ricardian household's nominal consumption is given by

$$c_t^{NR} = \frac{(1-\tau_t^l)w_t l_t^{NR} + TR_t^{NR}}{(1+\tau_t^C)} \quad (5)$$

With θ representing the proportion of non-Ricardian households, total consumption is

$$TC_t = (1-\theta)C_t^R + \theta C_t^{NR} \quad (6)$$

Because they do not optimize, non-Ricardian households consume all their earned income plus transfers. However, they still pay consumption and labor earning taxes. It is explicit that both types of households supply the same amount of labor but receive different amounts of transfers due to the introduction of distinct transfer processes rather than relying on a single transfer rule.

Capital accumulation, k_{ht}^R is given by the following process:

$$k_{ht}^R = [1-\delta]k_{ht-1}^R + \mu_t\left(1 - S\left(\frac{i_{ht}^R}{i_{ht-1}^R}\right)\right)i_{ht}^R \quad (7)$$

where δ is the depreciation rate and $S(\cdot)$ represents an adjustment cost function, and it is specified as $\frac{\kappa}{2}\left(\frac{i_{ht}^R}{i_{ht-1}^R} - \Lambda_{i^R}\right)^2$, where Λ_{i^R} is the long run growth of investment. Following Fernandez-Villaverde and Ramirez (2006), the investment-specific technological shock is given by the process:

$$\mu_t = \mu_{t-1}exp(\Lambda_t + \varepsilon_{\mu,t}) \quad (8)$$

Labor Market

Based on Fernandez-Villaverde and Ramirez (2006), there is a competitive firm that aggregates labor for intermediate good producers. These firmshire labor supplied by households, some of whom have the market power to set their own wage. The aggregation function is given by

$$l_t^d = \left(\int_0^1 l_{ht}^{\frac{\epsilon_h - 1}{\epsilon_h}} dh\right)^{\frac{\epsilon_h}{\epsilon_h - 1}} \quad (9)$$

where $0 \le \epsilon_h < \infty$ is the elasticity of substitution among different types of labor.

Maximizing profits subject to the production function, the labor packer solves $\max_{l_{ht}} w_t l_t^d - \int_0^1 w_{ht} l_{ht} dh$. The derived input demand function is

$$l_{ht} = \left(\frac{w_{ht}}{w_{t+\tau}}\right)^{-\epsilon_h} l_t^d \quad (10)$$

In a Calvo setting, only a proportion $(1-\theta_h)$ of households can optimally set their wages in each period. The rest can index their wages by past inflation. Based on Fernandez-Villaverde and Ramirez (2006), indexation is determined by the parameter χ_h. An implication of wage indexation is that if the household cannot change the wage for τ periods, the normalized wage after τ periods is $\prod_{s=1}^{\tau}\frac{\pi_{t+s-1}^{\chi_h}}{\pi_{t+s}}w_{ht}$. Following Fernandez-Villaverde and Ramirez (2006), the maximization problem of the household is given by

$$\max_{w_t(j)} E_t \sum_{\tau=0}^{\infty} (\beta\theta_h)^\tau \left\{ -\epsilon_t^L \psi \frac{l_{ht}^{1+\xi}}{1+\xi} + \lambda_{ht+\tau} \prod_{s=1}^{\tau} \frac{\pi_{t+s-1}^{\chi_h}}{\pi_{t+s}} w_{ht} l_{ht+\tau} \right\} \tag{11}$$

Subject to the following constraint:

$$l_{ht+\tau} = \left(\prod_{s=1}^{\tau} \frac{\pi_{t+s-1}^{\chi_h}}{\pi_{t+s}} \frac{w_{ht}}{w_{t+\tau}} \right)^{-\epsilon_h} l_{t+\tau}^d$$

The first order condition is given by

$$\frac{(\epsilon_h - 1)}{\epsilon_h} w_t^* E_t \sum_{\tau=0}^{\infty} (\beta\theta_h)^\tau \left\{ \lambda_{ht+\tau} \left(\prod_{s=1}^{\tau} \frac{\pi_{t+s-1}^{\chi_h}}{\pi_{t+s}} \frac{w_{ht}}{w_{t+\tau}} \right)^{1-\epsilon_h} \left(\frac{w_t^*}{w_{t+\tau}} \right)^{-\epsilon_h} l_{t+\tau}^d \right\} \tag{12}$$

$$= E_t \sum_{\tau=0}^{\infty} (\beta\theta_h)^\tau \epsilon_t^L \psi \left(\prod_{s=1}^{\tau} \frac{\pi_{t+s-1}^{\chi}}{\pi_{t+s}} \frac{w_t^*}{w_{t+\tau}} \right)^{-\epsilon_h(1+\xi)} \left(l_{t+\tau}^d \right)^{(1+\xi)}$$

Following Fernandez-Villaverde and Ramirez (2006), a fraction of households will set their optimal wage and those who cannot will partially index by past inflation in a symmetric equilibrium.

$$w_t^{1-\epsilon_h} = \theta_h \left(\frac{\pi_{t-1}^{\chi_h}}{\pi_t} \right)^{1-\epsilon_h} w_{t-1}^{1-\epsilon_h} + (1-\theta_h) w_t^{*1-\epsilon_h} \tag{13}$$

Firms

Assume that there is a continuum of intermediate goods firms indexed by j. New Keynesian models assume a single final goods producer that aggregates intermediate goods to produce output y_t. This aggregation function is specified as:

$$y_t = \left(\int_0^1 y_{jt}^{\frac{\epsilon_f - 1}{\epsilon_f}} dj \right)^{\frac{\epsilon_f}{\epsilon_f - 1}} \tag{14}$$

where ϵ_f is a time-invariant elasticity of substitution across intermediate goods.

Given a perfectly competitive final goods firm, the optimal demand for the j^{th} intermediate good, y_{jt},is given by

$$y_{jt} = \left(\frac{p_{jt}}{p_t} \right)^{-\epsilon_f} y_t \tag{15}$$

where p_{jt} is the price of the intermediate good produced by firm j.

Following Fernandez-Villaverde and Ramirez (2006), the price level consistent with the zero-profit condition can be derived. This is given by the following price aggregation rule:

$$p_t = \left(\int_0^1 p_{jt}^{1-\epsilon_f} dj \right)^{\frac{1}{1-\epsilon_f}} \tag{16}$$

Based on Coenen et al. (2013), each monopolistically competitive intermediate goods firm uses the following Cobb-Douglas production technology:

$$y_{jt} = A_t {k_{jt-1}}^{\alpha} {l_{jt}}^{1-\alpha} (k_{t-1}^G)^{\alpha_G} - \phi z_t \tag{17}$$

where ϕ is the fixed cost of production, $z_t = A_t^{\frac{1}{1-\alpha}} \mu_t^{\frac{\alpha}{1-\alpha}}$; $A_t = A_{t-1} exp(\Lambda_A + z_{A,t})$ is the productivity shock; and k_{t-1}^G is the level of public capital. As defined by Leeper et al. (2010), α_G is the efficiency parameter associated with fiscal spending. The inclusion of public capital means that output dynamics will also be affected by factors that impede or expedite public capital accumulation. This means that disbursement sudden stops, which primarily determine the level of government investments, will affect intermediate firm output in the aggregate.

Given the presence of nominal rigidity in the goods market, we assumed Calvo pricing for a group of firms which can reoptimize their prices relative to another group that can only index prices to past inflation.

Intermediate goods firms are assumed to minimize a linear cost function subject to their production technology specified in (17). Following Fernandez-Villaverde and Ramirez (2006), this is given by

$$\min_{k_{jt-1}, l_{jt}^d} r_t \, k_{jt-1} + w_t l_{jt}^d \tag{18}$$

Solving the above problem yields demand functions for labor and capital.

$$r_t = \frac{l_{jt}^d}{k_{jt-1}} \frac{\theta w_t}{(1-\theta)} \tag{19}$$

Rewriting (19) as $r_t k_{jt-1} = \frac{\theta l_{jt}^d w_t}{(1-\theta)}$, the real cost, as noted by Fernandez-Villaverde and Ramirez (2006) is given by

$$w_t l_{jt}^d + \frac{\alpha}{(1-\alpha)} w_t l_{jt}^d = \frac{1}{(1-\alpha)} w_t l_{jt}^d \tag{20}$$

Following Fernandez-Villaverde and Ramirez (2006), the marginal cost can be derived by exploiting its constant returns to scale (CRS) properties.

By letting (17) be equal to 1 and substituting,

$$l_{jt}^d = \frac{\left[\frac{\alpha}{(1-\alpha)} \frac{w_t}{r_t}\right]^{-\alpha} (k_{t-1}^G)^{-\alpha_G}}{A_t}$$

Substituting l_{jt}^d into (20), we have the expression for marginal cost .

$$mc_t = \left(\frac{1}{(1-\alpha)}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} \frac{w_t^{1-\alpha} r_t^{\alpha}}{A_t (k_{t-1}^G)^{\alpha_G}} \tag{21}$$

Based on the above equation, it is apparent that the level of public capital may affect marginal costs and as we will determine later, may indirectly affect optimal pricing decisions.

Following Fernandez-Villaverde and Ramirez (2006), we now present the second stage in the firm's optimization process. Essentially, intermediate goods firms chose the price that will maximize discounted profits. A fraction $(1-\theta_f)$ will be able to change their prices, and the remainder of firms will index their prices by past inflation. The indexation is controlled by the parameter .

Subject to the optimal demand $y_{jt+\tau} = \left(\prod_{s=1}^{\tau} \pi_{t+s-1}^{\chi_f} \frac{p_{jt}}{P_{t+\tau}}\right)^{-\epsilon_f} y_{t+\tau}$, the firm's objective is

$$\max_{p_{jt}} E_t \sum_{\tau=0}^{\infty} (\beta\theta_f)^{\tau} \frac{\lambda_{t+\tau}}{\lambda_t} \left(\prod_{s=1}^{\tau} \pi_{t+s-1}^{\chi_f} \frac{p_{jt}}{p_{t+\tau}} - mc_{t+\tau} \right) y_{jt+\tau} \tag{22}$$

Substituting the constraints into the objective function and getting the first order condition, we have

$$E_t \sum_{\tau=0}^{\infty} (\beta\theta_f)^{\tau} \lambda_{t+\tau} \left\{ (1-\epsilon_f) \left(\prod_{s=1}^{\tau} \frac{\pi_{t+s-1}^{\chi_f}}{\pi_{t+s}} \frac{{p_t}^*}{p_t} \right)^{1-\epsilon_f} \frac{{p_t}^*}{p_t} + \epsilon_f \left(\prod_{s=1}^{\tau} \frac{\pi_{t+s-1}^{\chi_f}}{\pi_{t+s}} \right)^{-\epsilon_f} mc_{jt+\tau} \right\} y_{t+\tau} = 0 \tag{23}$$

The price index evolves based on the following:

$$p_t^{1-\epsilon_f} = \theta_f (\pi_{t-1}^{\chi_f})^{1-\epsilon_f} p_{t-1}^{1-\epsilon_f} + (1-\theta_f) p_t^{*1-\epsilon_f} \tag{24}$$

Equation (24) implies that

$$1 = \theta_f \left[\frac{\pi_t^{\chi_f}}{\pi_{t+1}}\right]^{-\epsilon_f} + (1-\theta_f)\pi_t^{*1-\epsilon_f} \tag{25}$$

The Government

Fiscal sector. Expenditures on government consumption and investment and payment for bond issuances and transfers should be matched by tax collections.

$$\frac{B_{t+1}}{P_{t+1}} = G_t^c + G_t^I + \frac{B_t}{P_t}\frac{r_t}{\Pi_t} + TR_t - \left(\tau_t^c P_t C_t + \tau_t^K r_t^k K_{t-1} + \left(\tau_t^l + \tau_t^{ss}\right) W_t L_t\right) \tag{26}$$

where

$$TR_t = (1-\omega)TR_t^R + \omega TR_t^{NR}$$

In terms of feasibility, we have

$$G_t^c + G_t^I + C_t + I_t = Y_t \tag{27}$$

where G_t^c and G_t^I represent government consumption and implemented government investment, respectively. Government capital evolves based on capital replacement rate and authorized spending process given by A_{t-N}, where denotes the period between granting budget authority and completing the project. As Leeper et al. (2010) mentioned, A_t can be interpreted as the flow of investment from the budget stock, which means that when a project is officially funded, it will not be built right away. Instead, it will take years before the project starts generating social benefits. Government's capital accumulation is thus given by the following process:

$$K_{t-1}^G = (1-\delta_G)K_{t-2}^C + A_{t-N} \tag{28}$$

where δ_G is the depreciation rate of public capital stock, A_{t-N+1} represents the authorized budget for government in period $t - N + 1$ and is the authorized government investment or the stock of public investment (Leeper et al.,2010, p. 1003).

The authorized budget process is given by $A_t = \rho_A A_{t-1} + \mu_t^A, \mu_t^A \sim N(0,1)$. To account for the inefficiency caused by price dispersion, we followed Fernandez-Villaverde (2010) in adjusting output.

$$Y_t = \frac{1}{v_t}\mathcal{A}_t {k_{jt-1}}^{\alpha} {l_{jt}}^{1-\alpha}(k_{t-1}^G)^{\alpha_G}$$

where $\int_0^1 \left(\frac{p_{jt}}{p_t}\right)^{-\epsilon_f} dj = v_t$

Following Leeper et al. (2010)and Dacuycuy (2016),public investments evolve based on the following dynamics:

$$G_t^I = \sum_{n=0}^{N-1} \phi_n A_{t-n} + \left(1-\varrho_{G^I}\right)\xi_t^{G^I} + \varrho_{G^I}\xi_{t-1}^{G^I} \tag{29}$$

where $\xi_t^{G^I} = \rho_{\xi,G^I}\xi_{t-1}^{G^I} + \epsilon_t^{\xi,G^I}$, ϱ_{G^I} represents the weight associated with pre-announcement effects, and the sequence of disbursement rates $\{\phi\}_{i=0}^{N-1}$ sum up to 1.[2] Based on the process, the budget is authorized at time $t = 0$ and completed at time $(N - 1)$.

As shown, the impact of authorized spending shocks depends on the values of the outlay or disbursement parameters ϕ_n. Given smaller values of the parameters for initial periods after project commencement, it is possible that impact multipliers start out smaller initially, followed by increasing impact as the time horizon become longer. Following the logic of Leeper et al. (2010), government investments increase even as the project is yet to be completed. The rate of increase depends largely on the disbursement parameters.

In the model, two shocks that may matter for government investment. One is initiated by sudden, unanticipated changes in implemented government investment $\xi_t^{G^I}$. The other one must do with authorized spending shocks μ_t^A, which may expedite the flow of investments to government capital. The dynamics emanating from the respective shocks are expected to differ from each other. Despite their expected dissimilarities, they may provide insights, thereby enabling us to understand which one yields better dynamics.

We offer two probable scenarios to the above base model. First, there is a possibility that disbursements may suddenly stop because of a rare legal setback that abrogates the basis of the project. This may mean that parameter values may be small and become zero after the initial period/s of commencement.

$$G_t^I = \phi_0 A_t + \phi_1 A_{t-1} + \sum_{n=2}^{N-1} 0.A_{t-n} + \left(1-\varrho_{G^I}\right)\xi_t^{G^I} + \varrho_{G^I}\xi_t^{G^I},\ \ \phi_1 > 0 \ where \frac{\phi_1}{\sum_{n=0}^{N-1}\phi_n} < 1;\ \phi_0 = \phi_2 = \cdots = \phi_{N-1} = 0 \tag{30}$$

The effect will be transmitted to output because authorized spending affects the stock of public capital, which is used in the firm's production. Since other variables like private consumption depend on output, it means that a permanent stop to disbursement flow will affect them as well. Because automatic stabilizers are built-in fiscal tools, a dramatic stop in disbursement flows would also reduce government consumption.

Second, it is possible that the legal setback is temporary which implies that authorized spending or disbursements will flow for a period and then stop, pending the resolution of the legal issue in question. The high-resolution rate means that disbursement flows will then resume until the completion of the project.

$$G_t^I = \phi_0 A_t + \phi_1 A_{t-1} + \sum_{n=2}^{k} 0.A_{t-n} + \sum_{n=k+1}^{N-1} \phi_n A_{t-n} + (1-\varrho_{G^I})\xi_t^{G^I} + \varrho_{G^I}\xi_t^{G^I}, \phi_0 > 0; \phi_1 > 0; \phi_n > 0;\ \phi_0 + \phi_1 + \sum_{n=k+1}^{N-1} \phi_n = 1 \quad (31)$$

Finally, we integrated automatic stabilization policies following Leeper et al. (2010)and Coenen et al. (2013). The main characterization is the following: $\hat{s}_{t-s}^B$ is the ratio of government debt to output s periods ago. Had it been contemporaneous with the fiscal instrument, it would mean that fiscal adjustments, in reaction to debt expansions, would occur one period after spending spikes. However,this may be counterproductive and infeasible considering the lags of government expenditures.

As noted in Leeper et al. (2010), Fernandez-Villaverde (2010b), and Coenen et al. (2013), fiscal adjustments to debt expansions are minimal in the short-run. This means that the degree of variability of a fiscal variable relative to changes in public debt is limited. To facilitate stabilization policies, tax rates will eventually adjust upwards. The process for labor earnings tax is given by the following:

$$\tau_t^l = \rho_{\tau^l}\tau_{t-1}^l + \gamma_{\tau^l} s_{t-s}^B + (1-\varrho_{\tau^l})\xi_t^{\tau^l} + \varrho_{\tau^l}\xi_t^{\tau^l} \quad (32)$$

where $s_{t-s}^B = \frac{B_{t-s}}{Y_{t-s}}$.

Processes for consumption and capital taxes are represented by processes (33) and (34), respectively.

$$\tau_t^c = \rho_{\tau^c}\tau_{t-1}^c + \gamma_{\tau^c} s_{t-s}^B + \xi_t^{\tau^c} \quad (33)$$

$$\tau_t^k = \rho_{\tau^k}\tau_{t-1}^k + \gamma_{\tau^K} s_{t-s}^B + \xi_t^{\tau^k} \quad (34)$$

Finally, government spending needs to be reined in to generate surplus needed to stabilize the budget.

$$G_t^c = \rho_G \tau_{t-1}^G + \gamma_G s_{t-s}^B + (1-\varrho_G)\xi_t^G + \varrho_G \xi_t^G, \quad (35)$$

ϱ_{TR}, ϱ_{τ^l}, and ϱ_G represent weights associated with pre-announcement effects.

We now introduce processes for transfers that go to Ricardian and Non-Ricardian households. As noted in Leeper et al. (2010) and Coenen et al. (2013), transfers must be reduced in reaction to an increase in debt–output ratio. While Coenen et al. (2013)specified a transfer distribution rule, it is also plausible that transfers to non-Ricardian households increase with output and may be affected by authorized budget shocks that are not available to Ricardian households. They may also benefit from increased transfers even when the economy is growing.

Let ξ_t^{TR} represents discretionary fiscal policy on transfers to Ricardian households. The process is given by

$$TR_t^R = \rho_{TR}^R TR_{t-1}^R - \gamma_{TR}^R s_{t-s}^B + (1-\varrho_{TR}^R)\xi_t^{TR} + \varrho_{TR}^R \xi_t^{TR} \quad (36)$$

On the other hand, transfer to non-Ricardian households is specified as follows:

$$TR_t^{NR} = \rho_{TR}^{NR} TR_{t-1}^{NR} + \gamma_{TR}^{NR} s_{t-s}^B + (1-\varrho_{TR}^{NR})A_t^{NR} + \varrho_{TR}^{NR} A_{t-1}^{NR} \quad (37)$$

where A_t^{NR} is a process representing authorized budget specifically for non-Ricardian households.

Monetary sector. Like Fernandez-Villaverde (2010), the nominal interest rate, is specified using a simple Taylor rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\gamma_R} \left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\Pi(1-\gamma_R)} \epsilon_t^M \quad (38)$$

where is the inflation rate, and are the steady state values of interest and inflation rates, respectively, and represents an autoregressive monetary policy shock.

Probing the Links

The consideration of Ricardian and non-Ricardian households, and the incorporation of time to build processes and government investments subject to implementation delays provide an opportunity to understand New Keynesian mode l dynamics.

We determined the impact of shocks on the authorized budget via stochastic simulation, which indirectly affects government investments subject to implementation delays and sudden stops. Consistent with the objectives set forth in the paper, we focused on the dynamics of output, public investments, marginal costs, prices and wages, and their optimal counterparts, as well as price inflation and nominal interest rates. These dynamics will be conditioned on simple assumptions pertaining to disbursements.

To facilitate tractable comparisons, we considered four scenarios, one of which represents the base reference. The base scenario is one where there are no delays or sudden stops. This implies that government capital can be immediately increased through infusions in government investments. The second and third scenarios are associated with one quarter and eight quarter delays, respectively. Finally, the last scenario shows the impact of sudden stops in disbursement flows. In this case, it is assumed that project implementation will be stopped after the second quarter. Because the study will only focus on dynamic simulation impulse response, functions will not be bounded by confidence bands.[3]

Calibration Strategy

The model estimated is nonlinear, as there is no attempt to log-linearize the system of expectational equations.[4] Because this paper only involves simulations, we used a set of calibrated parameters values based on the literature. Two parameter sets were utilized. First, for the New Keynesian model bloc, we appealed to Fernandez-Villaverde (2010)and Fernandez-Villaverde and Ramirez (2006). Second, parameter values for fiscal policy bloc were taken from Leeper et al. (2010) and Dacuycuy (2016). In the Appendix, we presented a table that contains a list of the parameters and their values, and following the table is a description of each.

Like most DSGE studies, we set the discount factor to 0.998, which is consistent with an annual interest rate of 4%. Habit formation parameter is pegged at 0.97, which is quite high but allows the model to converge as in Fernandez-Villaverde (2010).[5] The parameter associated with the labor supply component, ψ, is set to 8.97. The capital income share in the production function is set to 0.21, which is quite low but reflects capital to output share in the Philippines. The inverse of the Frisch elasticity ξ is set to 1.17. The parameter in the adjustment function is pegged at 9.51. The depreciation rates for both public and private capital are pegged at 0.025. The risk aversion parameter $\sigma = 1$. Elasticities of substitution in output and consumption are given $\epsilon_f = 10$ by and $\epsilon_h = 10$.

The probabilities θ_f and θ_w are set to 0.82 and 0.68, respectively. Indexation parameters χ_f and χ_h are given by 0.63 and 0.68, respectively. Parameters in the Taylor rule $\gamma_R = 0.77$, $\gamma_\Pi = 1.29$ and $\overline{\Pi} = 1$.

Productivity of public capital is evaluated using the following values: 0.05, 0.1, and 0.20. For the spending rates, the following sequence was used for a project that requires eight quarters to complete: $\{\phi_t\}_{t=0}^{8} = \left\{0, \frac{2}{8}, \frac{1}{8}, \frac{1}{8}, \frac{1}{8}, \frac{1}{8}, \frac{1}{8}, \frac{1}{8}\right\}$. For sudden stops, we have $\{\phi_t\}_{t=0}^{8} = \left\{0, \frac{1}{8}, 0,0,0,0,0,0\right\}$. Based on Leeper et al. (2010), the first entry in the sequence of disbursement parameters is set to zero because this usually corresponds to the planning period. For our purposes, we adopted a base scenario wherein there are no delays and public capital build-up is immediate.

For the parameters associated with shock processes and preference structures, refer to information provided in the appendix.

Output and Public Investments

As an important result, we briefly interpreted the impact of authorized budget shocks on output and public investments. Similar to results in Bhattarai and Trzeciakiewicz (2017), Leeper et al. (2010), and Dacuycuy (2016), we found that such shocks are expansionary (see Figure 1). This is expected since public capital enters a firm's production functions. With no delays, output readily responds to increases in public investments. With a 1-quarter delay in the implementation of projects, output increases sustainably, thereby allowing the economy to achieve higher levels of output. The least preferred scenario is associated with sudden disbursement stops. Outputs tagnates and grows slowly compared with other scenarios where projects are completed. Relative to other trajectories, there is no chance for output under a sudden stop to catch-up.

As shown in Figure 2, authorized budget shocks quickly increase public investments when the duration of implementation delays is minimal. As expected, disbursement sudden stops lead to low public investments. Such patterns are consistent with Leeper et al. (2010).

Prices and Wages

As noted in the model, public capital enters the firm's production function. It is also embodied in the firm's marginal costs. When authorized budget shocks occur, output increases since both marginal products of capital and labor will increase. With the increase, wages and rental rates both rise, which result in an increase in marginal costs.

Figure 3 shows the various responses of prices and wages to authorized budget shocks. First,

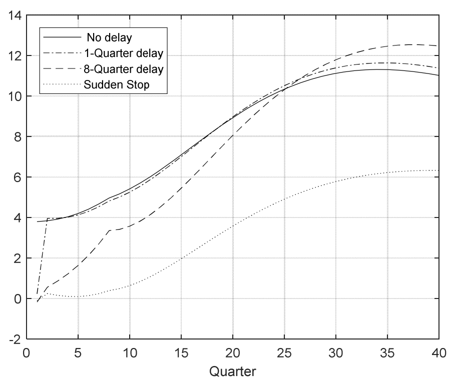


Figure 1 .Impact of authorized budget shocks on output.

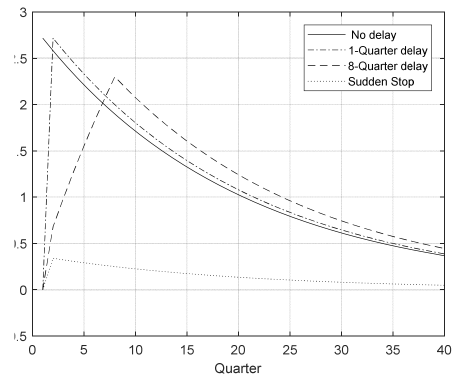
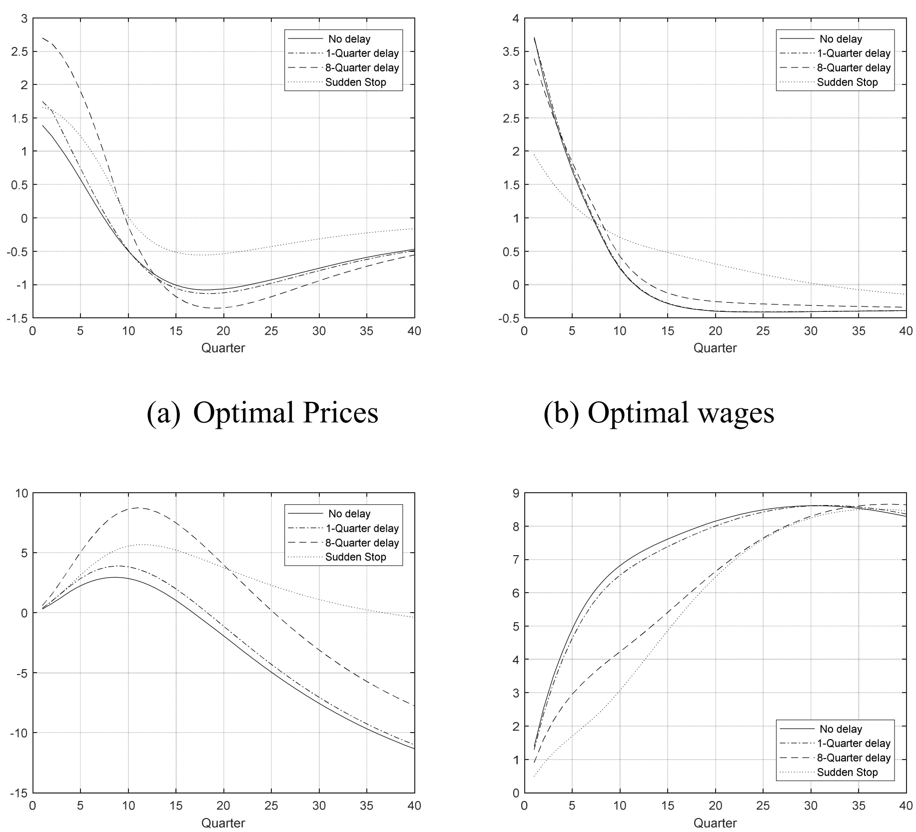


Figure 2. Effects of authorized budget shocks on public investment.



(a) Optimal Prices (b) Optimal wages

(c) Prices (d) Wages

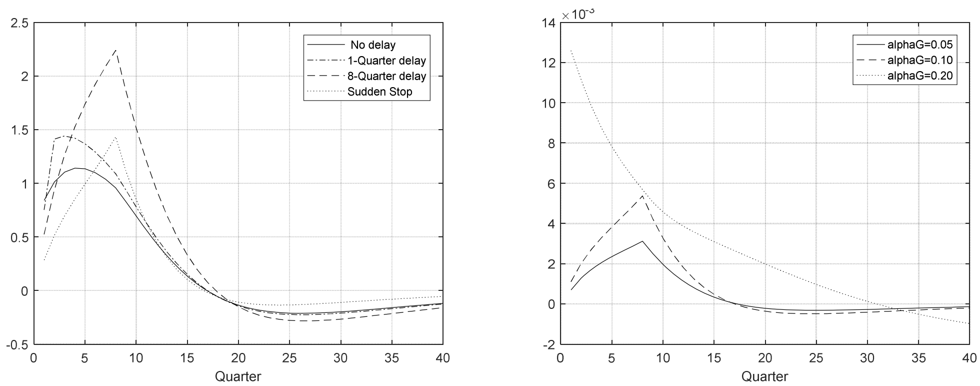
Figure 3. Response of prices and wages to authorized budget shocks.

wages invariably rise. As noted by Bhattarai and Trzeciakiewicz (2017), wages rise more strongly because the impact of such shocks is to increase the marginal product of labor and capital. In our model, wages do rise, and the highest initial jump is associated with minimal delays. This is expected since the output is expected to increase more rapidly when implementation delays are short-lived. In the literature, this resembles the response of wages to increases in fiscal consumption spending. The most inferior wage temporal profile is associated with sudden disbursement stops.

Second, optimal prices do respond positively to implementation delays because firms which can reoptimize every period take this into account. The longer the period of project completion, the higher will be the initial price jump. However, optimal prices under sudden stops move relatively more sluggishly towards the steady state. This is understandable considering the tepid reaction of marginal costs in the case of disbursement sudden stops. This temporal behavior appears replicated by the price trajectory.

Marginal Costs

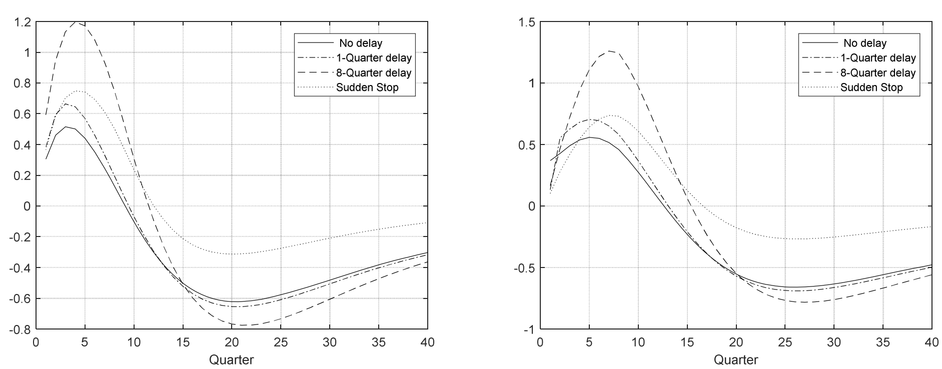
As shown in Figure 4, marginal costs invariably rise with the duration of implementation delays. While this is true for the case of an 8-quarter delay, it is also noteworthy that projects that are not



(a) Marginal costs

(b) Marginal costs and government efficiency (sudden stops)

Figure 4. Response of marginal costs to authorized budget shocks.



(a) price inflation

(b) Nominal interest rate

Figure 5. Response of price inflation and interest rate to authorized budget shocks.

subject to sudden stops appear to converge to the same marginal cost trajectory after 20 quarters. The marginal cost associated with sudden stops becomes much higher after 20 quarters. Because of sudden stops to disbursements, the inferior temporal profile of marginal costs simply reflects the slow growth of public capital. Thus, there should be a strong incentive for the government to reduce the length of delays or avoid sudden stops.

We also varied the government efficiency parameter under sudden stops. As noted in Leeper et al. (2010), this is difficult to pin down, so we use alternative values ranging from 0.05 to 0.20. If government spending is deemed more efficient, marginal costs will be highest and more persistent when there are sudden stops.

Price Inflation and Interest Rate

Finally, as shown in Figure 5, the positive impact of implementation delays on marginal costs and optimal prices will cause inflation to rise. Faster inflation is associated with longer delays. When there are no delays, price inflation follows a low trajectory. Predictably, the monetary authority will respond to the increase in inflation by hiking interest rates. Expectedly, a low trajectory for the interest rate is consistent with no delays.

Discussion

This theoretical note focuses on key factors that may affect public capital-related firm's pricing decisions, which may have material implications for fiscal and monetary policy. As part of the paper's objective, we have provided a dynamic framework to account for and analyze the macroeconomic effects of implementation delays. The obvious limitations are the exogenous nature of disbursement sudden stops, the use of calibrated parameters not specific to the Philippines, and the assumption of a representative project.

What we want to discuss are some practical implications of the research that deal with institutional arrangements, sources of bottlenecks, and post-investment surge implications. To strengthen arguments that have been already known, we refer to historical experiences associated with massive investment episodes as analyzed by Warner (2014).

The literature offers one unmistakable piece of advice for government planners—choose high impact projects well. It is noteworthy that the current administration has focused on 75 high impact projects all over the Philippines, most of which will be completed on or before 2022. This is a deviation from the emphasis on small projects funded through congressional budget allocations, which may fail to complement the social benefits attributable to other major projects. The invigorated push towards robust infrastructure spending is now heavily underway in the Philippines, but implementation delays are still evident. Reducing implementation delays is important because, as highlighted in Ganelli and Tervala (2016), government investments have sizable welfare effects that are not usually the object of statistical measurement. Both argued that public investments should also be interpreted in terms of their welfare effects, as output multipliers may be misleading.

Recent growth trends in the Philippines may seem to defy Warner's (2014) historical lessons that growth appears to taper off after massive investment episodes. Year-on-year growth rates for 2017 indicate that the Philippines grew at a fast pace of 6.5%, the fastest growth among ASEAN countries.

While it may be true that growth is spurred by sources other than public investments, public investments are undeniably one of the main drivers of growth. Capital formation grew at 30% in in the second quarter of 2017 compared with 8.7% the previous year. Growth in final government consumption also grew at 13.5%, indicative of greater government involvement in key programs.

Per official announcements, the government aims to increase spending on infrastructure from 5.32% of GDP in 2017 to more than 7% in 2022. The Philippines' budget department has also instituted several budget reforms that seek to reduce the incidence of questionable disbursement practices, improve project identification leading to a streamlined list of welfare-enhancing projects, and formulate better work schedule through planning.

There are several interpretations that we can present based on influential parameters. First, government efficiency is critical in facilitating better dynamics in prices, output, and wages. A clear case in point is the recent inflationary episode experienced by the Philippines during the second half of 2018. The inflation spike triggered concerns because it coincided with the implementation of the new tax system, which mandated the increase in excise taxes for several intermediate and final goods. Because the rice prices have soared, attention was focused on the agricultural sector. While there were a lot of initiatives that have attempted to improve productivity-boosting projects in agriculture, many projects remain delayed. For instance, if farm-to-market roads improve productivity, then non-completion may mean higher costs, and such costs may not seep into rice prices. As expected, the Bangko Sentral ng Pilipinas hiked the interest rates to stem rising prices.[6]

Moreover, a high government efficiency parameter can reduce the marginal costs of firms if they do decide to factor in public capital into their production processes. When government efficiency is high, this means that output in the private sector will also be high.

Second, delays can come from various sources, not necessarily interpreted as a symptom of reversible government plans but more of side effects coming from poor foresight. Delays are expected given that the scale of government projects are much larger than before. Right-of-way concerns continue to delay the effective implementation of big infrastructure projects.

If the object of fiscal policy is to sustain wage increases, projects must be completed on time. While no major projects can be completed within a quarter, surely an unreasonable assumption, completing a project within its scheduled period is way better than not completing it. This underscores the importance of undertaking unbiased project studies to establish feasibility, societal value, and financial soundness. Though the paper did not dwell on the financial effects of implementation delays, it is rather clear that contractual stipulations may obligate the government to pay for penalties for abrogated projects. This may again introduce undue burden.

Third, delays do have economic costs and the length of delays may affect future growth. In the short run, changes in output and labor supply will be minimal and private investments are expected to fall significantly. If agents do form expectations that government projects will be completed in the future, then the negative wealth effect associated with government expenditures will be mitigated, leading to lower reductions in labor supply. This is so because positive wealth effect may dominate the negative wealth effect associated with government consumption. One major lesson for fiscal authorities is for them to acknowledge the systemic impact of implementation delays on prices and wages, especially for projects like infrastructure. This is what Warner (2014) was referring to. Planners need to understand the implications of the projects beyond project completion.

Delays are expected and, in most cases, imminent due to existing institutional arrangements. For instance, past budget practices encouraged stakeholders to propose budgets even if the project is several quarters away from being readily implemented due to right-of-way litigations and negotiations. It also highlights the importance of legal questions that may be resolved by the judiciary itself. Questions on appropriability of properties, right-of-way concerns, and bidding irregularities are just some of the issues that are tackled in proper fora but do have the potential to delay the implementation of projects. Because of the scale of major projects, a special court whose task is to speedily act on legal complaints to reduce implementation delays.

While not factored in formally, we may assume that firms have perfect foresight in that they know that there is pending legislation for the increase in government investments but are not aware that sudden disbursement stops may occur. This already has as noted in the recent Philippine experience on disbursement acceleration program (DAP). The only problem is when firms form expectations about project completion and effectively condition their plans on the planning and implementation horizons associated with big government projects.

Fourth, planning that goes beyond the temporal mandate of current administrations should be made. One plausible source of the delay comes from the exercise of administrative review or oversight of projects that were approved by the previous administration. There should be a law which binds future administrations to a set of verifiable project properties that will serve as the basis for the review. Project parameters, such as costs and benefits, should be made clear and bases for approval should be transparent.

Finally, the framework also provides a way to analyze potential effects emanating from financing fiscal deficits associated with public debt. The paper used automatic stabilizers. The reason for this is that sustainability is important to preserve the gains from government investments in longer time horizons. This is where it becomes important to have strongly productive government capital because weakly productive ones may trigger contractionary episodes in the long run.

Concluding Remarks

Based on simulation results, implementation delays and sudden disbursement stops do condition the dynamic impact of authorized budget shocks. We focused on this to motivate the plausibility that the monetary authority will react to other sources of shocks. Simulation evidence shows that implementation delays affect the pricing policies of firms. It was shown that price inflation jumps and in response, the monetary authority hikes the nominal interest rate. Moreover, the model can explain why disbursement performance does matter for output growth and efficient fiscal response. For the Philippines, sluggish growth in 2010 was caused by low disbursement rates and the prescribed remedy, notwithstanding legal ramifications, was to shift savings to more efficient projects.

Model dynamics show that this is not the only distortion associated with government investment delays. If public investment's completion lags, firms whose production functions depend on public capital will have higher marginal costs, which may lead to inflation as the optimal response of firms is to increase markups. Thus, another channel through which inefficiencies affect the conduct of monetary policy can be plausibly established.

Endnotes

[1] We are grateful to the anonymous referee for his excellent comments and suggestions. Thanks are also due to the administrators of De La Salle University for logistical and financial support, as well as to the speakers and participants of the 2nd De La Salle University – National Institute for Development Administration (DLSU – NIDA) Macroeconomics Workshop held on May 28, 2018 in De La Salle University. All remaining errors are, of course, our responsibility.

[2] Agents tend to have prior information that a major fiscal policy initiative may be implemented in the future. This kind of advanced information may condition responses to fiscal policy shocks.

[3] As the model uses calibrated values, its primary contribution is to understand, in a simulation setting, the positive aspects of the theoretical model. A further refinement is to calibrate the parameters based on Philippine data.

[4] We used the code NK_baseline.mod,which was written by Benjamin Bonn and Johanne Pfeifer and is a part of Dynare Reference Manual developed by Adjemian et al (2018) to implement in Matlab the nonlinear version of Fernandez-Villaverde's (2010a) DSGE model.

[5] For instance, the calibrated value of the habit formation parameter is just 0.5, based on the study written by McNelis, Glindro, Co, and Dakila (2009)

[6] We extend gratitude to a reviewer of this paper for this particular example.

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APPENDIX

Parameter	**Description**	**Value**
Preference structure		
β	Discount factor	0.99
hc	Habit persistence parameter	0.97
σ	Inverse of the relative risk aversion	1
ξ	Inverse Frisch elasticity	2.0
θ	Share of Non – Ricardian Households in Total consumption	0.5
ω	Share of Non – Ricardian Households in Transfers	0.5
δ_g,δ_p	Depreciation rate for both public and private capital	0.025
α	Share of capital in output	0.21
α^G	Efficiency parameter for government capital in production function	0.1
Announcement effects		
ϱ_{G^I}	Government investments	0.5
ϱ_G	Government consumption	0.5
ϱ_{τ^l}	Earnings tax	0.5
Sensitivity to debt		
γ_{τ^l}	Earnings tax	0.0015
γ_{τ^k}	Capital tax	0.0015
γ_c	Consumption tax	0.0015
γ_{TR}	Transfer	0.0015
γ_G	Government consumption	-0.0015
Persistence		
ρ_{τ^l}	Earnings tax	0.95
$\rho_{TR}^R, \rho_{TR}^{NR}$	Transfers	0.95
ρ_{τ^k}	Capital tax	0.95
ρ_{τ^c}	Consumption tax	0.95
ρ_G	Government spending	0.95
ρ_A	Authorized government budget	0.95
ρ_{ξ,G^I}	Government investments	0.95

Definitions and Notations

Preference Structure

Discount factor, β: This determines how a representative agent values future relative to present consumption. The higher the value of this parameter is, the higher is the valuation of future relative to present consumption. In the literature, its commonly represented by the parameter β, and remains as one of the parameters that is calibrated. Our parameter value is pegged at 0.99, which implies a 4% nominal interest rate.

Habit persistence parameter, h: It controls the influence emanating from lagged private or government consumption on the utility of a representative individual. The parameter is associated with superficial habits, which is a kind of habit that forms around a consumption aggregate. In the paper, its calibrated value is 0.97.

Inverse of the relative risk aversion, σ: It is a key parameter of the constant relative risk aversion utility function. We follow the literature by using 1.

Inverse of the Frisch labor supply elasticity, ξ^{-1}: The Frisch labor supply elasticity (ξ) measures the degree of responsiveness of labor supply to percentage changes in wages. We follow Fernandez-Villaverde (2010a) by setting its inverse to 1.17.

Share of non-Ricardian households to total consumption, θ: Non-Ricardian households are those who cannot optimally determine their consumption. The share represents the proportion of total consumption attributable to non-Ricardian households. The parameter is set to 0.3.

Share of non-Ricardian households in transfers, ω: Non-Ricardian households are those who cannot optimally determine their consumption. The share represents the proportion of total transfers attributable to non-Ricardian households. The parameter is set to 0.3.

Depreciation rate for both public and private capital, δ_g,δ_p: As noted in Leeper et al. (2010), depreciation rates are separately applied to public and private capital. We assign 0.025 to both depreciation rates.

Share of capital to output, α: It is a parameter that accounts for the value of output that goes to capital. The exponent of capital in the production function is usually interpreted as the share of output that goes to capital. We use 0.25.

Productivity of public capital, α^G: It is a parameter that is used to indicate the degree to which public capital contributes to firm productivity. We set the value to 0.2.

Announcement Effects

Accounting for announcement effects acknowledges fiscal foresight or the ability of agents to anticipate the impact of proposed fiscal policies. They are supposed to be represented by moving average processes that involve weighted current and lagged innovations, which are known proxies for information flows.

Announcement effect of government investments: The moving average representation $\left((1-\varrho_{G^I})\xi_t^{G^I}+\varrho_{G^I}\xi_{t-1}^{G^I})\right)$ is embedded in the process of government investments and controlled by the parameter $\varrho_{G^I}\in[0,1]$. For our purposes, we use 0.5, which means that current and lagged innovations are equally weighted.

Announcement effect of government consumption: The moving average representation is $\left((1-\varrho_G)\xi_t^G+\varrho_G\xi_t^G\right)$ embedded in the process of government investments and controlled by the parameter $\varrho_G\in[0,1]$. For our purposes, we use 0.5, which means that current and lagged innovations are equally weighted.

Announcement effect of earnings tax: The moving average representation $\left((1-\varrho_{\tau^l})\xi_t^{\tau^l}+\varrho_{\tau^l}\xi_t^{\tau^l}\right)$ is embedded in the process of government investments and controlled by the parameter $\varrho_{\tau^l}\in[0,1]$. For our purposes, we use 0.5, which means that current and lagged innovations are equally weighted.

Sensitivity to Debt

As shown by Fernandez-Villaverde (2010b), the degree of sensitivity to public debt is included to determine the responsiveness of tax policies and government expenditures to changes in the public debt. A low value of the parameter implies that in the short-run, variations in government tax or expenditure policy are limited.

Earnings tax: The value of the parameter is 0.0015, which means that the fiscal authority may increase the earnings tax rates minimally in response to an increase in public debt.

Capital tax: The value of the parameter is 0.0015, which means that the fiscal authority may increase the capital tax rate minimally in response to an increase in public debt.

Consumption tax: The value of the parameter is 0.0015, which means that the fiscal authority may increase consumption tax rates minimally in response to an increase in public debt.

Transfers to Ricardian households: The value of the parameter is -0.0001, which means that the fiscal authority may reduce transfers to optimizing households in response to an increase in public debt.

Transfers to non-Ricardian households: The value of the parameter is 0.0015, which means that the fiscal authority may increase transfers to non-optimizing households due to an increase in public debt.

Government consumption: The value of the parameter is 0.0015, which means that the fiscal authority may increase spending minimally in response to an increase in public debt. Note that for this parameter, we tried using -0.0015 but Dynare (year, p. x) returned the following message: "Blanchard Kahn conditions are not satisfied: no stable equilibrium."

Persistence

The persistence parameter is the coefficient of the lag value of a time series and is used to match the quarterly frequency. In a recursive setting, a high value connotes high persistence, indicating that shocks to continue to affect the variable for a relatively extended period.

Degree of persistence of earnings tax, ρ_{τ^l}: High degree of correlation between current and lagged earnings taxes is assumed. Value assigned to the persistence parameter is 0.95.

Degree of persistence of transfers to Ricardian households, ρ_{TR}^{R}: High degree of correlation between current and lagged transfers to Ricardian households is assumed. Value assigned to the persistence parameter is 0.95.

Degree of persistence of transfers to non-Ricardian households, ρ_{TR}^{NR}: High degree of correlation between current and lagged transfers to non-Ricardian households is assumed. Value assigned to the persistence parameter is 0.95.

Degree of persistence of Capital tax, ρ_{τ^k}: High degree of correlation between current and lagged capital taxes is assumed. Value assigned to the persistence parameter is 0.95.

Degree of persistence of government consumption, ρ_{τ^c}: High degree of correlation between current and lagged government consumption is assumed. Value assigned to the persistence parameter is 0.95.

Degree of persistence of authorized government budget, ρ_A: High degree of correlation between current and lagged authorized government budget is assumed. Value assigned to the persistence parameter is 0.95.

Degree of persistence of government investments, ρ_{τ^I}: High degree of correlation between current and lagged government investments is assumed. Value assigned to the persistence parameter is 0.95.