The Effects of Myopia on Fiscal Multipliers

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This paper investigates the impact of fiscal policy on economic stimulation within the context of agents who exhibit partial myopia, implying that households and firms are less forward-looking and attentive towards future events. This deviation from perfect rationality impacts the marginal propensity to consume, ultimately challenging the theory of Ricardian Equivalence. To address this, I emphasize the importance of introducing partially myopic agents into a medium-scale new Keynesian model that includes hand-to-mouth consumers. This inclusion has substantial effects on the determinacy of the model, where empirically founded values of hand-to-mouth consumers, reasonable degrees of myopia, and active monetary policy cannot all coexist. Thus, I estimate the model using Bayesian MCMC methods to fit U.S. time series data between 1984-2019 under both determinacy and indeterminacacy. Under determinacy, partially myopic agents may result in higher fiscal multipliers but significantly crowd out private investment. Furthermore, the estimated myopia parameter is 0.86, which is in alignment with Gabaix (2020). However, the data suggets a preference for an indeterminate solution characterized by low degrees of myopia and a passive monetary policy.

Fiscal policy has taken a more active role in stimulating the economy in recent times. Yet the theory of Ricardian equivalence suggests that individuals, anticipating future tax increases to finance government spending, will increase their savings to offset the expected tax burden, resulting in no expansionary effects on the macroeconomy[1]. This theory assumes that individuals are able to make rational decisions and "smooth" their consumption based on foresight of events happening at an indeterminate future date.

The bulk of empirical literature studying the stimulus effects of fiscal policy follow this line of assumption; the models include a representative household that optimize based on perfect rational expectations. Within this strand of literature, fiscal multiplier values range anywhere between 0.8 and 1.5, but values of 0.5 or 2.0 are deemed reasonable as well (Ramey, 2011). The difference in multiplier values found depend on the economic

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[1]See Barro (1989) for a detailed explanation.

environment[2], how the spending is financed[3], or the persistence of the spending[4].

A notable departure away from the representative agent model literature in fiscal policy is Gali et al. (2007), where they incorporate rule-of-thumb (referred to in this paper as hand-to-mouth) households that consume all of their income in each period and cannot smooth out consumption. Given that these households have a high marginal propensity to consume than the optimizing households, they find multipliers as high as 2.0 as Ricardian equivalence breaks down. In this paper, I also include hand-to-mouth households but calibrate the share of hand-to-mouth households to a empirically accurate value of 0.35 (Kaplan et al., 2014; Coenan & Straub, 2005).

This paper not only enriches the standard representative agent model with hand-to-mouth households, but considers the case of behavioral households and firms. Specifically, instead of relying on the strong assumption that optimizing agents form expectations rationally and have full attention of future events, I examine the case where agents are not perfectly rational. To model irrational agents, I use a ”cognitive discounting” parameter, myopia, à la Gabaix (2020). Thus, my research question studies how the inclusion of myopic agents who cannot perfectly optimize affects the economic outcomes of an increase in fiscal spending. In particular, I look at the effects of myopia on economic determinacy and estimate the values of myopia and fiscal multipliers in the US during the years of 1984 to 2019. To my knowledge, this is the only paper that studies the effects of of irrational agents on fiscal policy [5].

I find that with the addition of myopic agents, the regions of indeterminacy are much larger, thus necessitating an analysis of the effects of myopia under indeterminacy. Furthermore, government spending generally yields larger output multipliers with more myopic agents but at a huge cost of private investment. Finally, using US time-series data, I conduct a Bayesian MCMC estimation and conclude that the value of myopia is 0.86 under determinacy but results show that data prefers an indeterminate non-behavioral equilibrium with low cognitive discounting and active monetary policy.

The paper proceeds as follows. Section I describes the baseline New Keynesian model used in the paper. Section II presents the implications of the model including myopia on determinacy and highlights the ”determinacy trilemma”. Section III shows the effect of myopia on fiscal multipliers at multiple horizons and its interactions with the share of hand-to-mouth consumers. The paper also conducts a Bayesian estimation of an extended model; this is presented in section IV. Section V concludes.

[2]Multipliers are larger when nominal interest rates are close to or constrained at the zero lower bound (Christiano et al., 2018; Correia et al., 2013; Eggertsson 2010; Ramey & Zubairy, 2018; Woodford, 2011; Cogan et al., 2009; Miyamoto et al., 2018)

[3]Baxter & King (1993) find that financing temporary spending through distortionary taxes can generate a multiplier as low as -2.5, whereas financing through deficit spending or current taxes without distortionary taxes will have no differences in effect on the multiplier.

[4]Aiyagari et al. (1992) find that when the government spending is sufficiently persistent, the multiplier can exceed one

[5]Bianchi, et al. (forthcoming) looks at the effects of irrational agents on fiscal multipliers and tax policy but only at the zero lower bound.

I. Theoretical Model

We use a conventional New Keynesian model adopted from Gali et al. (2007), which consists of two types of households, a continuum of differentiated intermediate goods producing firms, a final good producing firm, a central bank that sets the monetary policy, and a fiscal entity that sets the fiscal policy. Our contribution to this model is the myopic parameter M, which will enter after we have log-linearized the model. Additionally, We include the monetary policy, preference, technology, and labor supply shocks.

A. Households

The economy consists of a continuum of households denoted by $j \in [0, 1]$, where a proportion $1 - \lambda$ are optimizing or Ricardian households (o), and the remaining proportion λ are rule-of-thumb households (r). Optimizing households have full access to the capital and asset markets and the rule-of-thumb households fully consume their current period income with no ownership of capital and assets. The distinction between the two types of households is important in this context since the effects of a fiscal stimulus may affect the behavior of rule-of-thumb households more. All households (A) share the same preferences represented by equation:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t^A(j) - \frac{N_t^A(j)^{1+\kappa}}{1+\kappa} \right] \tag{1}$$

where κ is the inverse of the Frisch labor supply elasticity. $C_t^A(j)$ is the consumption of the final good and $N_t^A(j)$ is the amount of labor supplied by household j.

Optimizing households. Optimizing households $j \in (0, 1-\lambda)$ maximize their utility subject to the following budget constraint and capital accumulation equation:

$$P_t(C_t^o + I_t^o) + R_t^{-1} B_{t+1}^o = W_t P_t N_t^o + R_t^k P_t K_t^o + B_t^o + D_t^o - P_t T_t^o \tag{2}$$

$$K_{t+1}^o = (1-\delta)K_t^o + \phi(\frac{I_t^o}{K_t^o})K_t^o. \tag{3}$$

In each period, the real consumption (C_t^o) and investment (I_t^o) expenditures, as well as the risk-less nominal government bond (B_t^o) paid out with the nominal gross interest rate R_t^{-1} must equal the total labor income $W_t P_t N_t^o$, capital holdings income $R_t^k P_t K_t^o$, risk-less bonds carried over from the previous period, dividends from firm ownership D_t^o, and lump sum taxes (or transfers) $P_t T_t^o$. Thus, P_t is used to denote the price level, W_t is the real wage, N_t^o is hours worked, and K_t^o is the capital holdings.

In the capital accumulation equation, the $\phi(\frac{I_t^o}{K_t^o})K_t^o$ is the capital adjustment costs, which establishes the change in capital generated by investment spending. Following Gali et al. (2007), I assume $\phi' > 0$, and $\phi'' \leq 0$, with $\phi'(\delta) = 1$, and $\phi(\delta) = \delta$.

Wages are set by two different labor market structures: there is a competitive labor market where each household chooses the hours worked given the market wage and an economy-wide union that sets wages in a centralized manner so that firms choose hours supplied instead of the households. In the case of the competitive labor market, the labor supply of optimizing households must follow:

$$W_t = C_t^o (N_t^o)^{\varphi} \zeta_t. \tag{4}$$

ζ_t is the labor supply shock that follows the AR(1) process:

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \varepsilon_\zeta. \tag{5}$$

A thorough description of the case where the union sets wages can be found in Gali et al. (2007), since it does not follow the same condition as in (4).

After log-linearization of the equations describing the optimizing consumers, I have:

$$c_t^o = mE_t c_{t+1} - (r_t - E_t \pi_{t+1}) + \chi_t. \tag{6}$$

Here, $m \in [0, 1]$ is the myopia parameter that represents cognitive discounting for optimizing households. When $m = 1$, agents are fully rational and the model reverts back to the baseline model in Gali et al. (2007). With myopia, m is strictly less than one, so that innovations to the economy in the future get heavily discounted. In this case, Ricardian equivalence no longer holds even for optimizing agents. This should mean that any changes in the economy, such as changes in fiscal policy, would have a bigger impact when they happen in the present. For the mathematically derivation of this log-linearized equation, please refer to Gabaix (2020).

Rule-of-thumb households. Since rule-of-thumb households can only consume the labor income they receive net of taxes, they face the budget constraint:

$$P_t C_t^r = W_t P_t N_t^r - P_t T_t^r. \tag{7}$$

Similar to the optimizing households, rule-of-thumb households also follows two labor market structures. In the case of when the wage is set by the union, I suggest referring to the Appendix in Gali et al. (2007) for a detailed description. The case of the competitive labor market must satisfy the condition:

$$W_t = C_t^r (N_t^r)^{\varphi} \zeta_t. \tag{8}$$

Notice that there is no myopia parameter for rule-of-thumb households since they consume all of their income in each period.

Aggregation. The aggregated consumption and hours supplied by all households are:

$$C_t^A \equiv \lambda C_t^r + (1 - \lambda) C_t^o \tag{9}$$

and

$$N_t^A \equiv \lambda N_t^r + (1-\lambda) N_t^o. \tag{10}$$

Since investment and capital stock is only determined by the proportion of optimizing households, the total investment and capital stock is written as:

$$I_t \equiv (1-\lambda) I_t^o \tag{11}$$

and

$$K_t \equiv (1-\lambda) K_t^o. \tag{12}$$

B. Firms

The production sector is made up of monopolistically competitive firms that produce differentiated intermediate goods and a representative firm that uses these intermediate goods to produce a single final good.

The intermediate good firm (i) produces a differentiated good $Y_t(i)$ with the Cobb-Douglas production technology:

$$Y_t(i) = A_t(i) K_t(i)^{\alpha} N_t(i)^{1-\alpha}. \tag{13}$$

$K_t(i)$ and $N_t(i)$ denote the capital and labor services hired by firm i, and $A_t(i)$ is the total factor productivity. The total factor productivity shock follows the AR(1) process:

$$A_t = \rho_a A_{t-1} + \varepsilon_t^A. \tag{14}$$

The intermediate goods firm takes wage and rental costs of capital as given and adjusts prices according to the Calvo pricing mechanism.

The perfectly competitive firm that produces the final good follows the constant returns production function:

$$Y_t = \left[\int_0^1 X_t(i)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} di \right]^{\frac{\varepsilon_p}{\varepsilon_p - 1}}. \tag{15}$$

Here, $\varepsilon_p > 1$ and $X_t(i)$ represents the amount of intermediate good i used as inputs. Given the prices for intermediate goods $P_t(i)$ and the price of the final good P_t, the final goods producer's demand function for intermediate inputs is given by

$$X_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon_p} Y_t. \tag{16}$$

Finally, the final goods firm also faces the zero-profit condition

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon_p} dj \right)^{\frac{1}{1-\varepsilon_p}}. \tag{17}$$

Firms can also be myopic, and similar to optimizing consumers, the myopia parameter m enters in the log-linearized equation as:

$$\pi_t = m\beta E_t \pi_{t+1} - \frac{(1-\beta\theta)(1-\theta)}{\theta} \mu_t^p. \tag{18}$$

C. Monetary Policy

The central bank sets the nominal interest rate $r_t \equiv R_t - 1$ every period following the interest rate rule

$$r_t = \phi_\pi \pi_t + MP_t, \tag{19}$$

with MP_t being monetary policy shock process that follows:

$$MP_t = \rho_{mp} MP_{t-1} + \varepsilon_t^{MP} \tag{20}$$

As mentioned in Gali et al. (2007), the interest rate rule here satisfies the Taylor principle if and only if $\phi_\pi > 1$, which is also necessary and sufficient to guarantee the uniqueness of equilibrium in the absence of rule-of-thumb consumers.

D. Fiscal Policy

The government is subject to the budget constraint:

$$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t, \tag{21}$$

where aggregate taxes are calculated from the sum of taxes received from optimizing households and rule-of-thumb households such that $T_t \equiv \lambda T_t^r + (1-\lambda) T_t^o$. By defining $g_t \equiv (G_t - G)/Y$, $t_t \equiv (T_t - T)/Y$, and $b_t \equiv ((B_t/P_{t-1}) - (B/P))/Y$, I can assume a fiscal policy rule as

$$t_t = \phi_b b_t + \phi_g g_t, \tag{22}$$

where ϕ_b and ϕ_g are greater than zero.

Government spending follows an AR(1) process:

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g, \tag{23}$$

where $0 < \rho_g < 1$ is the persistence parameter and ε_t^g is the i.i.d government spending shock with constant variance σ_ε^2.

E. *Market Clearing*

Factor and good markets clear when the following conditions are met for all periods t:

$$N_t = \int_0^1 N_t(i)di, \qquad Y_t(i) = X_t(i) \quad \text{for all} \quad i, \tag{24}$$

$$K_t = \int_0^1 K_t(i)di, \qquad Y_t = C_t + I_t + G_t. \tag{25}$$

Please refer to the Appendix for the log-linearized equations and Gali et al.'s (2007) for a more detailed presentation of the model.

II. Determinacy Analysis

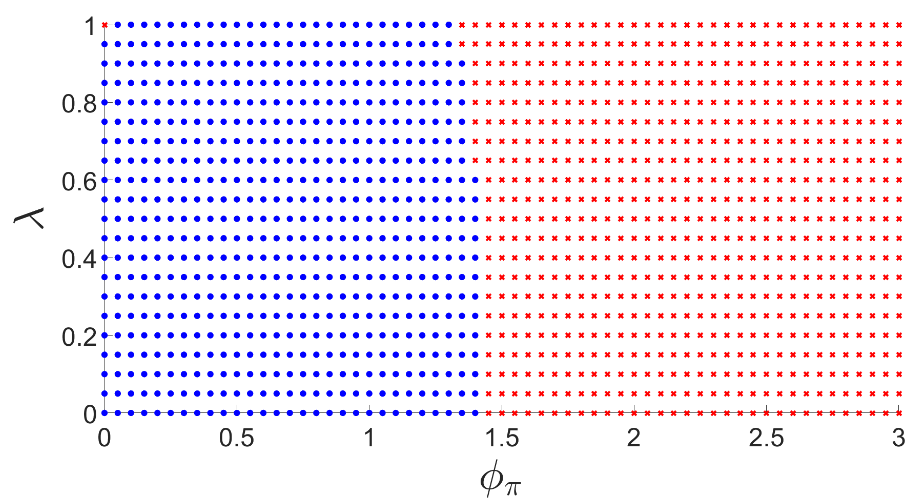

FIGURE 1. DETERMINACY REGION: ϕ_π V. λ, $M = 0.85$

This section documents the implications of including the degree of myopia in the analysis of determinacy. We show three pairwise determinacy plots for the degree of myopia (M), share of HTM agents (λ), and response of monetary policy to inflation (ϕ_π) in the style popularized by Bullard and Mitra (2002) and similarly shown in GLV2007.

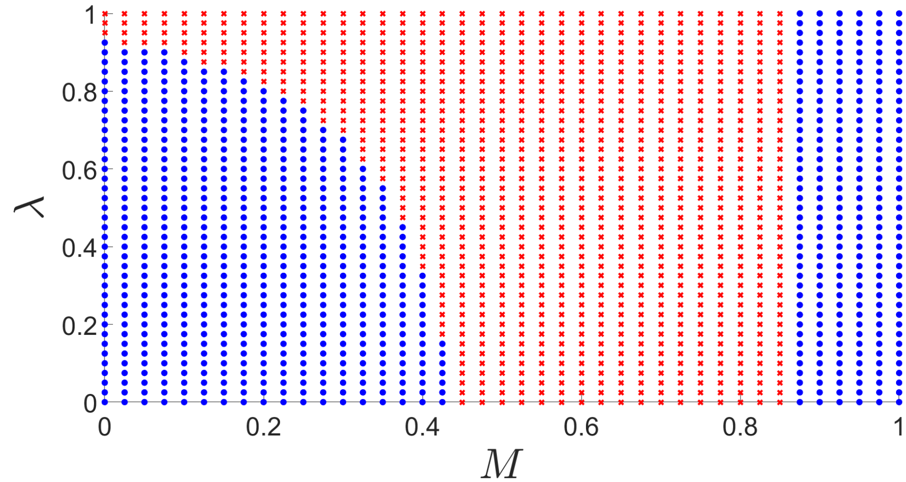

FIGURE 2. DETERMINACY REGION: M V. λ, $\phi_\pi = 1.5$

Unlike GLV2007, the results are presented for the version of the model that includes imperfect labor markets which increases the regions of indeterminacy altogether although the overall implications remain similar under both perfectly and imperfectly competitive labor markets. In all graphs, regions of indeterminacy are demarcated by red dots. Blue-dotted regions represent parameter combinations that lead to model determinacy. Similar to GLV (2007), model determinacy is established via a numerical method utilizing the *gensys* tool from Sims (2002). Given the multitude of model equations, it is difficult to analytically compute explicit algebraic determinacy conditions such as the Taylor Principle computed in Bullard and Mitra (2002). The key finding from this analysis is the presence of a *determinacy trilemma*: reasonable values (for the U.S. macroeconomy) for M, λ, and ϕ_π cannot simultaneously co-exist while having a determinate model solution. One of these three must be calibrated to a value that sharply differs from existing literature for the model to be determinate.

Figure 1 shows the pairwise effect of λ and ϕ_π with M calibrated at its value of 0.85 from Gabaix (2020). As mentioned in the introduction, roughly $1/3$ of the U.S. population is HTM. Notice from the graph that for λ values around 33%, FED response to inflation must actually be relatively *passive* for model determinacy; this in stark contrast to the Taylor Principle where $\phi_\pi > 1$ ensures determinacy. Values marginally over one are still determinate but any deviation towards stronger inflation responses may trigger indeterminacy. Estimates of ϕ_π are usually significantly higher than unity; for instance Smets and Wouters (2007) estimate an inflation response of 2.04 for the U.S. economy. The conviction that inflation responses are well above one is so strong that most empirical literature in macroeconomics that utilize Bayesian methods to estimate inflation responses usually utilize a prior mean of 1.5 for ϕ_π. Under Smets and Wouters (2007),

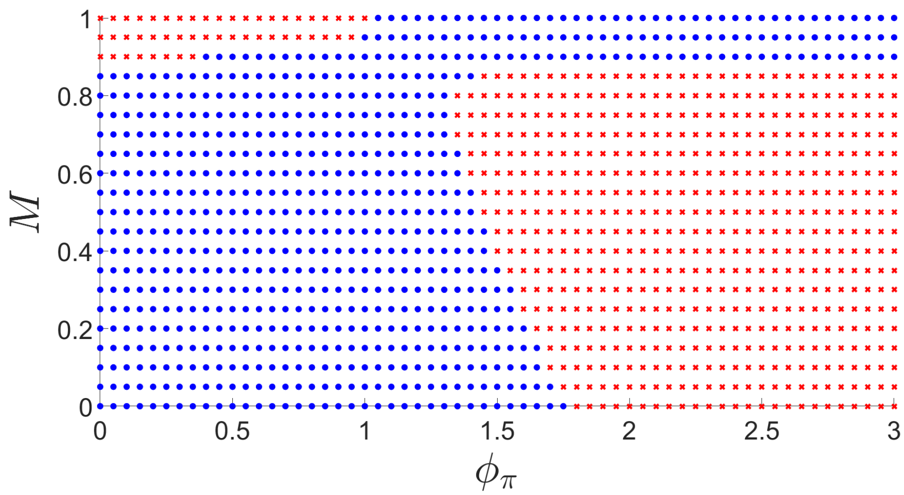

FIGURE 3. DETERMINACY REGION: ϕ_π V. M, $\lambda = 0.35$

both prior and posterior means for ϕ_π would result in indeterminacy if M is calibrated at 0.85.

Figure 2 shows the pairwise effect of λ and M with ϕ_π calibrated to 1.5. Again, within the context of the U.S. with a roughly 33% HTM ratio, only strong (< 0.40) or weak (> 0.85) degrees of myopia are able to achieve determinacy. Note that for values between these two points, the region that corresponds with reasonable values for cognitive discounting as described in Gabaix (2020), the model is indeterminate. A likely explanation is that for strong degrees of myopia, optimizing agents tend to mimic HTM agents, effectively increasing the share of rule-of-thumb consumers. As this share increases, active monetary policy begins to help rather than hurt model determinacy as shown in the prior graph.

Finally, Figure 3 shows the pairwise effect of ϕ_π and M, with λ calibrated to a value of 0.35 to accurately capture the share of U.S. consumers that are HTM. Once again, the determinacy dilemma is presented where strong responses of monetary policy to inflation can only lead to determinate outcomes only when the optimizing agents barely exhibit any cognitive discounting or a high degree of discounting. For values of M around 0.85, the FED should either be passive or barely active ($\phi_\pi < 1.3$). As the degree of myopia increases (i.e. M decreases) the monetary authority can correspondingly react more aggressively to inflation but still in a manner that is more restricted than indicated by prior macro literature.

Thus, we have demonstrated the existence of a ”determinacy trilemma”, where active monetary policy and empirically founded values of HTM and myopia cannot all coexist. However, the more important takeaway from this section is that adding myopia increases the regions of indeterminacy significantly when compared to the baseline Bullard and

Mitra (2002) and GLV2007 determinacy analysis. Consequently, an estimation of the model under indeterminacy is necessary present a full picture of the parameter values.

Parameter	Value	Details
β	0.99	Discount rate
δ	0.025	Depreciation rate
α	0.33	Effective share of capital
λ	0.35	Fraction of HTM agents
θ	0.75	Calvo pricing
φ	0.2	Inverse Frisch elasticity of labor supply
η	1	Elasticity of investment adjustment
ϕ_π	1.5	MP inflation weight
ϕ_g	0.1	FP govt. spending weight
ϕ_b	0.33	FP debt weight
γ_c	0.6	Consumption share
γ_i	0.2	Investment share

TABLE 1—CALIBRATED PARAMETERS

III. Fiscal Multipliers

For the nuanced empirical analysis pertaining to fiscal multipliers presented in this section as well as the estimation analysis in the following section, the paper utilizes a model that includes several other common frictions and shocks in addition to the features of the base model presented in section I. This is to ensure that the analysis presented here may be comparable to benchmark structural models such as Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). To test the importance of myopia on fiscal policy, it is important to first include sources of persistence that are common to most empirical DSGE macro models so that the results are not spuriously attributed to myopia instead of some other source of persistence of friction. The model is expanded to include the following additional features:

- Habit formation
- Wage stickiness (instead of the imperfect labor market)
- Price indexation
- Wage indexation
- Variable capital utilization
- Backward-looking Taylor Rule

The model also has several other AR(1) shocks:

- Monetary policy
- Preference
- Price markup
- Wage markup
- Investment-specific technology

Since these features are standard in the macro literature, we will not discuss them in greater detail here. The full set of log-linearized equilibrium conditions for this version of the model may be found in Appendix A.

In this section, we analyze the effect of myopia on the fiscal multiplier. As mentioned in the introduction, in traditional models of the macroeconomy where all agents optimize their future consumption paths with perfect foresight, government stimulus is ineffective as per Ricardian equivalence. The original Gali et. al. (2007) paper included HTM agents who violated Ricardian equivalence as they simply consumed all earned income with no ability to offset the stimulus by saving. In this section we investigate if relaxing the assumptions of perfect foresight and rationality on the part of optimizing agents via cognitive discounting can lead to further increases in the effectiveness of fiscal stimulus.

Figure 4 plots the fiscal multipliers for the 1-quarter and 4-quarter (1-year) impacts for output (YM_1 and YM_4). The results closely match the multiplier analysis from Gali et. al. (2007) except that myopia is able to further raise the YM_1 and YM_4 for the U.S. share of HTM consumers ($\lambda \approx 0.35$). At this value for λ, the multiplier increases with the degree of myopia. As optimizing agents become increasingly myopic, they value current consumption to a greater degree than future consumption via savings (essentially acting more like HTM consumers); this allows them to increasingly violate Ricardian equivalence. Interestingly, the effect of myopia does not remain the same for all levels of λ. At a HTM share of approximately 0.85 and 0.80 for YM_1 and YM_4, respectively, the effect of myopia *inverts* as increased cognitive discounting *decreases* YM_1 and YM_4. The interactions of several variables in this sophisticated model results in a non-linear relationship between λ, M, and the multiplier.

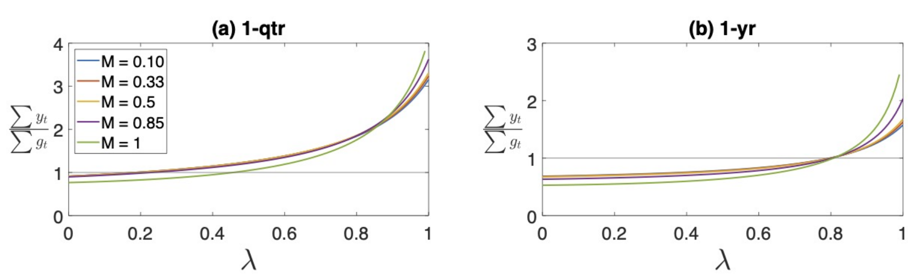

FIGURE 4. FISCAL MULTIPLIERS FOR OUTPUT, SHORT RUN

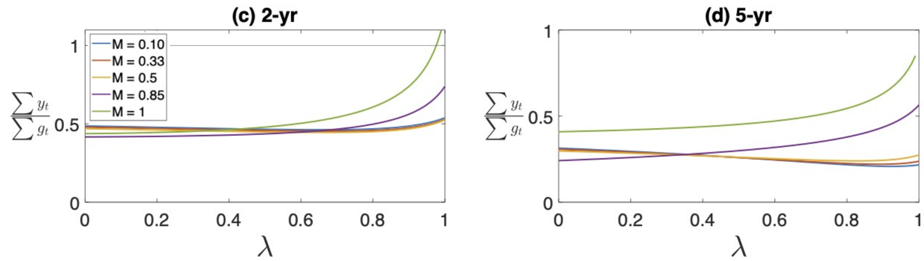

FIGURE 5. FISCAL MULTIPLIERS FOR OUTPUT, LONG RUN

Figure 5 plots the fiscal multipliers for 8 and 20 quarters (two and five years) after impact for output (YM_8 and YM_20). As can be seen, output multipliers diminish at longer horizons and only extremely high values of λ can push the multiplier above 1 in YM_8. The excess increases in output in the short-run are now paid off in the longer horizons with no myopia leading to highest YM at distant horizons. At the 5-yr horizon the results are stark; YM_{20} is significantly larger under no myopia as compared to high degrees of discounting.

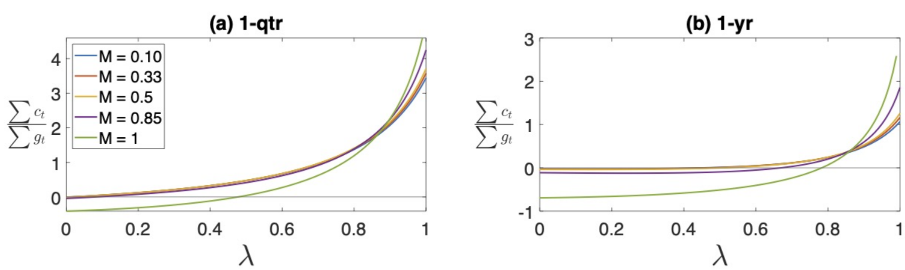

FIGURE 6. FISCAL MULTIPLIERS FOR CONSUMPTION, SHORT RUN

Figure 6 shows that CM_1 and CM_4 follows in a similar manner to output and is almost always positive. Generally, the degree of myopia does not seem to have a large effect on the multiplier as much as the presence of multiplier. When λ is below 0.85, any degree of myopia raises the multiplier of consumption higher than the baseline model with no myopia. At the 1-year horizon, private consumption is crowded out for most values of λ unless there is myopia. Both CM_8 and CM_{20} are below zero as agents have been over-consuming in the immediate aftermath of stimulus and must now revert to reducing consumption. However, private consumption is crowded-out to a significantly lesser extent when agents are highly myopic.

The higher multipliers from output and consumption with myopia in the short run is not without consequence. For investment multipliers, higher myopia is accompanied

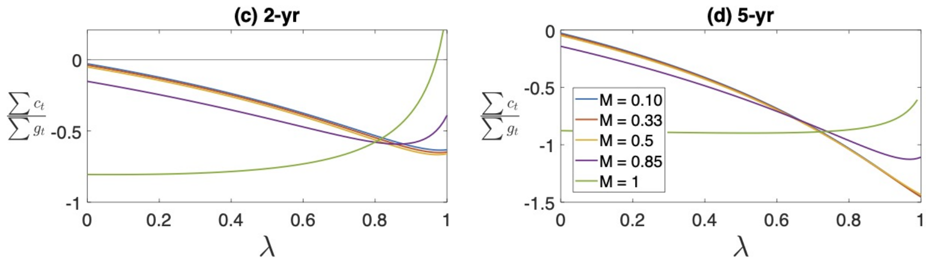

FIGURE 7. FISCAL MULTIPLIERS FOR CONSUMPTION, LONG RUN

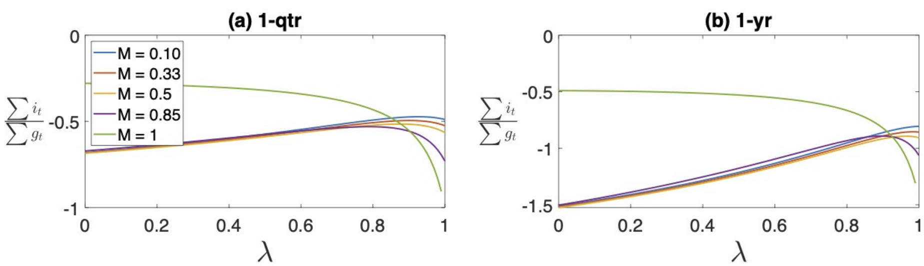

FIGURE 8. FISCAL MULTIPLIERS FOR INVESTMENT, SHORT RUN

by a stronger crowding-out effect, as can be seen in 8. At $\lambda = 0.35$, IM_1 is around -0.36 without myopia but falls drastically to -0.65 for $M = 0.85$. These results clearly indicate that fiscal stimulus is much more effective at impact for U.S. consumers, keeping output multipliers higher than 1 without significantly crowding-out private consumption. However, the investment sector suffers a significantly sharper decline than suggested in Gali et. al. (2007). As with the immediate quarter, IM_4 stays well below zero and the crowding-out effect is even stronger than IM_1. Any degree of myopia severely exacerbates this phenomenon; the results are similar for M ranging from 0.10 to 0.85. Only under the absence of myopia entirely is IM_4 higher as agents trade-off increases government spending with decreases in both consumption and investment.

Figure 9 plots the fiscal multipliers for two and five years after impact for investment (IM_5 and IM_{20}). Short-run trends for investment continue into the longer horizons with massive crowding-out at virtually every level of myopia. Only in the case of no myopia does the model exhibit IM_8 and IM_{20} that are above -1. For the U.S. HTM share of 0.35 with the Gabaix (2020) value of $M = 0.85$, crowding-out is very large with $IM_8 \approx -1.8$ and $IM_{20} \approx -2$.

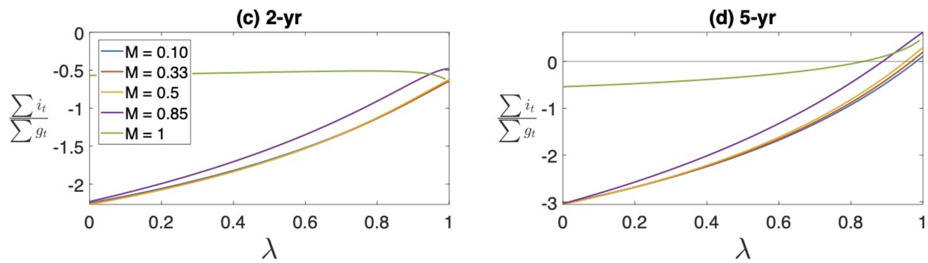

FIGURE 9. FISCAL MULTIPLIERS FOR INVESTMENT, LONG RUN

IV. Bayesian Estimation

A. Data and Methodology

The extended model presented in section A is estimated via Bayesian MCMC techniques[6] to fit data for six quarterly macroeconomic U.S. time series: log difference of real GDP, log difference of consumption, log difference of investment, log difference of wages, log difference of labor supply, inflation (log difference of GDP deflator), and the federal funds rate. Data on these variables were obtained fromt he Bureau of Economic Analysis. Additionally, as discussed in the introduction, prior empirical approaches in this area of study have largely ignored expectations data. Since the primary innovation of this paper is the inclusion of a parameter that discounts expectations, it is important to include expectations data in the data series that is to be fitted. Data on expectations of inflation were collected from the Michigan Survey of Consumers for the 1-year horizon.

The final dataset spans Q1 1984 through Q4 2019: roughly corresponding to the start of the post-Volcker monetary era and proceeding until the start of the COVID-19 pandemic; this period also roughly corresponds to the modern U.S. macroeconomy with active monetary policy. The measurement equation used in the estimation procedure for the standard non-expectations macro data is given by:

$$OBS_t = \begin{bmatrix} dlY_t \\ dlC_t \\ dlI_t \\ dlW_t \\ dlN_t \\ dlP_t \\ FFR_t \end{bmatrix} = \begin{bmatrix} \bar{\chi} \\ \bar{\chi} \\ \bar{\chi} \\ \bar{\chi} \\ \bar{\chi} \\ \bar{\pi} \\ \bar{r} \end{bmatrix} + \begin{bmatrix} \log Y_t/Y_{t-1} \\ \log C_t/C_{t-1} \\ \log I_t/I_{t-1} \\ \log W_t/W_{t-1} \\ logN_t - N_{t-1} \\ \log P_t/P_{t-1} \\ r_t \end{bmatrix} \tag{26}$$

where dl represents 100 times the log difference, $\bar{\chi}$ is the quarterly trend growth rate

[6]See An and Schorfheide (2007), Fernández-Villaverde (2010), and Herbst and Schorfheide (2015) for an overview of Bayesian MCMC estimation methods pertaining to DSGE models.

common to Y_t, C_t, I_t and W_t, $\bar{\pi}$ is the steady-state quarterly inflation rate, and $\bar{r}$ is the steady-state quarterly interest rate.

Parameter	Value	Details
β	0.99	Discount rate
δ	0.025	Depreciation rate
α	0.33	Effective share of capital
μ_p	1.20	Steady state price markup
γ_z	0.75	Capital utilization share
γ_c	0.6	Consumption share
γ_i	0.2	Investment share

TABLE 2—CALIBRATED PARAMETERS: BAYESIAN ESTIMATION

Some structural parameters are calibrated; these parameters are presented in Table 2. The remaining parameters are estimated using a standard Bayesian MCMC procedure. First, the mode of the posterior distribution is estimated by maximizing the log of the posterior function; the posterior is computed as the product of the prior information of non-calibrated parameters and the likelihood of the data described above. The priors for the selected parameters are set based on standard choices in the empirical macro literature and may be found in Tables B5 and 4. Secondly, a Metropolis-Hastings computational algorithm comprising two MCMC chains and enough draws to achieve convergence is utilized to map a complete posterior distribution for all estimated parameters. Note that all estimated parameters are identified from the data. The estimated posterior means are used to compute IRFs to the various shocks within the model. The results from these analyses are presented in the following section.

B. Posterior Estimates

ESTIMATES UNDER DETERMINACY. — Table B5 shows the posterior estimates (means and 90% credible intervals) for the structural parameters of the model. We begin the results discussion with the key parameters of this model under determinacy. With λ fixed at 0.35, the posterior mean for M is 0.86, which is in line with Gabaix's suggested value of 0.85. This value implies that agents in the economy are half as attentive towards events one year in the future as compared to today. The data also prefers an extremely high monetary response to inflation with χ_π estimated to be 2.75. Referencing to Figure 3, we see that this solution lingers on the border of determinacy and indeterminacy.

Contrary to Milani (2017), mechanical sources of persistence uphold their importance in fitting the sluggishness of macro variables, even in the presence of behavioral features. For the rest of this discussion, we will highlight any cases where there is significant disagreement between our parameter estimates and those of Smets and Wouters (2007) ("SW2007") as that provides a valuable benchmark for comparison. If a SW2007 value

Parameter	Description	Prior	Posterior Means	
			Determinacy	Indeterminacy
φ	Inverse Frisch elas.	**N**(4.00, 1.50)	6.84	2.72
h	Habit formation	**B**(0.70, 0.10)	0.60	0.31
θ_p	Calvo prices	**B**(0.50, 0.10)	0.70	0.71
θ_w	Calvo wages	**B**(0.50, 0.10)	0.55	0.48
ι_p	Price indexation	**B**(0.50, 0.15)	0.44	0.09
ι_w	Wage indexation	**B**(0.50, 0.15)	0.39	0.97
σ_l	Labor supply elas.	**N**(2.00, 0.75)	2.01	1.59
ψ	Capital util. elas.	**B**(0.50, 0.15)	0.56	0.88
α	Capital share	**N**(0.30, 0.05)	0.28	0.22
M	Myopia	**B**(0.85, 0.10)	0.86	0.97
χ_π	MP inflation	**N**(1.50, 0.25)	2.75	0.19
χ_y	MP output	**N**(0.12, 0.05)	0.04	0.11
ϕ_g	FP govt. spending	**N**(0.10, 0.05)	0.02	0.13
ϕ_b	FP debt	**N**(0.33, 0.10)	0.41	0.41
y^*	Trend	**N**(0.40, 0.10)	0.81	0.59
π^*	Trend	**N**(0.60, 0.10)	0.40	0.59
i^*	Trend	**N**(0.75, 0.10)	0.71	0.55
	Marginal likelihood		-1266.2	-1021.6

TABLE 3—POSTERIOR ESTIMATES: STRUCTURAL PARAMETERS WITH $\lambda = 0.35$

is not provided, it is because our estimates are similar. Habit formation (h) is moderate at 0.60 which is within the range of standard studies. The parameter for sticky wages (θ_w) is 0.55, lower than SW2007 (0.73). This suggests that the data favors a higher degree of sluggishness in price adjustments instead of wage adjustments. Price indexation (ι_p) and wage indexation (ι_w) have posterior means of 0.44 and 0.39 respectively, indicating a higher $iota_p$ but a lower $iota_w$ compared to their SW2007 counterparts: 0.22 and 0.59. Price stickiness and price indexation are both more important than wage stickiness and wage indexation in fitting the data under this model.

Next we discuss the estimates of standard macro parameters. There is a wide range of estimated values for the inverse Frisch elasticity (φ); our estimated mean is 6.84 which is higher than the SW2007 value of 5.74. The Fed response to output (χ_y) is expectedly low at 0.04. The trend coefficients, y^*, π^*, and i^*, are along expected values at 0.81, 0.40, and 0.71 respectively. Inflation and interest rate trends are lower than SW2007, which intuitively corroborates the low interest rate, low inflation period following the sample used in SW2007.

Table 4 shows the posterior estimates of the shock processes. Preference shocks have a high degree of persistence and deviation of 0.80 and 0.92, respectively. Both markup shocks, wage and price, have high persistence (similar to SW2007) of 0.96 and 0.99 but price markup shocks have a low deviation of 0.15. Wage markups are persistent and large with a deviation of 0.70. Technology shocks are very persistent with an AR parameter value of 0.97, again similar to its value from SW2007; it has a moderate deviation with a value of 0.53. Government spending shocks are highly persistent (0.98), which is in line with SW2007 (0.97). It is also volatile with a deviation of 0.45. Investment-

Parameter	Description	Prior	Posterior	
			Determinacy	Indeterminacy
Persistence				
ρ_χ	Preference	**B**(0.50, 0.20)	0.80	0.93
ρ_w	Wage markup	**B**(0.50, 0.20)	0.96	0.98
ρ_p	Price markup	**B**(0.50, 0.20)	0.99	0.98
ρ_a	Technology	**B**(0.50, 0.20)	0.97	1.00
ρ_g	Govt. Spending	**B**(0.50, 0.20)	0.98	0.95
ρ_i	Investment specific	**B**(0.50, 0.20)	0.61	0.95
ρ_r	Monetary Policy	**B**(0.50, 0.20)	0.85	0.98
Deviation				
σ_χ	Preference	Γ^{-1}(0.30, 1.00)	0.92	0.21
σ_w	Wage markup	Γ^{-1}(0.30, 1.00)	0.70	0.77
σ_p	Price markup	Γ^{-1}(0.30, 1.00)	0.15	0.19
σ_a	Technology	Γ^{-1}(0.30, 1.00)	0.53	0.47
σ_g	Govt. Spending	Γ^{-1}(0.30, 1.00)	0.45	0.44
σ_i	Investment specific	Γ^{-1}(0.30, 1.00)	0.84	0.35
σ_r	Monetary Policy	Γ^{-1}(0.30, 1.00)	0.15	0.14

TABLE 4—POSTERIOR ESTIMATES: SHOCK PROCESSES WITH $\lambda = 0.35$

specific shocks are moderately persistent (0.61) and highly volatile (0.84). Monetary policy exhibits a high degree of smoothing with an AR coefficient of 0.85 but is mildly volatile with a 0.15 mean deviation.

ESTIMATION UNDER INDETERMINACY. — Here, I focus on the estimation results under indeterminacy that differ from the results under determinacy. Most notably, the posterior mean for M is 0.97, indicating that under indeterminacy, agents exhibit very low degrees of myopia. Furthermore, the data now prefers a very passive monetary response to inflation where $\chi_\pi = 0.19$. Fiscal policy coefficients (ϕ_g and ϕ_b) estimates now stay closer to their prior means at 0.13 and 0.41 respectively.

Although price stickiness and wage stickiness remain fairly in line with the values under determinacy (0.71 and 0.48), it is interesting to note that values for price and wage indexation have drastically changed. With $\iota_p = 0.09$ and $\iota_w = 0.97$, the data under indeterminacy strongly prefers wage indexation over price indexation in fitting the data.

As for the posterior estimates of the shock processes, results show that shocks are generally more persistent under indeterminacy. Investment-specific shocks are now highly persistent (0.95) but not as volatile (0.35). Similarly, preferences shocks are also slightly more persistent (0.93) and much less volatile (0.21) compared to the case under determinacy.

Through comparing the values of the marginal likelihood between the estimation under determinacy and indeterminacy, it is evident the the data prefers the indeterminate solution far more. This indicates that between the period of Q1 1984 to Q4 2019, the US economy has trended towards a more indeterminate state.

V. Concluding Remarks

This paper includes cognitive discounting of expectations in a medium-scale monetary DSGE model of the macroeconomy that is typically used for fiscal policy analysis. Such deviation from rational expectations has drastic effects on the determinacy of the model, increasing the probability that the economy is indeterminate. Myopia also causes a larger deviation from the Ricardian equivalence equilibrium so that fiscal multipliers are larger at multiple horizons. However, the larger multipliers are accompanied by significantly larger crowding out of private investment. Additionally, the effects of myopia on fiscal multipliers are non-linear and reverse after crossing a particular threshold of the ratio of hand-to-mouth consumers. Finally, a Bayesian MCMC estimation reveals that under determinacy, agents in the economy are fairly myopic, with $M = 0.86$. However, the data indicates that the economy has been more indeterminate in the period that I have estimated.

This paper raises many more questions and research avenues that may be addressed in future iterations or other papers altogether. Myopia is just one potential form of behavioral bias, and a stylized one at that. It is also used in a reduced-form context. It may be interesting to apply other behavioral factors such as sentiment, anchoring, etc. and check if our results still hold.

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EXPANDED MODEL: LOG-LINEARIZED EQUATIONS

$$c_t^o = \frac{h}{1+h}c_{t-1}^o + \frac{1}{1+h}E_t c_{t+1}^o - \frac{1-h}{1+h}(r_t - E_t\pi_{t+1} + \nu_\chi) \tag{A1}$$

$$c_t^r = \frac{1-\alpha}{\mu_p\gamma_c}(w_t + n_t^r) - \gamma_c^{-1}t_t^r \tag{A2}$$

$$c_t = \lambda c_t^r + (1-\lambda)c_t^o \tag{A3}$$

$$n_t = \lambda n_t^r + (1-\lambda)n_t^o \tag{A4}$$

$$w_t = \frac{1}{1+\beta}w_{t-1} + \frac{\beta}{1+\beta}(E_t w_{t+1} + E_t\pi_{t+1}) - \frac{1+\beta\iota_w}{1+\beta}\pi_t \frac{\iota_w}{1+\beta}\pi_{t-1} - \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\beta}(\mu_t^w - \mu_t^{w,n}) \tag{A5}$$

$$\mu_t^w = w_t - (\lambda c_t^r + \frac{1-\lambda}{1-h}(c_t^o - hc_{t-1}^o) + \sigma_l n_t) \tag{A6}$$

$$i_t = \frac{1}{1+\beta}i_{t-1} + \frac{\beta}{1+\beta}E_t i_{t+1} + \frac{1}{\varphi(1+\beta)}q_t + \nu_t^i \tag{A7}$$

$$k_t = (1-\delta)k_{t-1} + \delta i_t + (\delta(1+\beta)\varphi)\nu_t^i \tag{A8}$$

$$z_t = \psi r_t^k \tag{A9}$$

$$q_t = \beta(1-\delta)E_t q_{t+1} + [1+\beta(1-\delta)]E_t r_{t+1}^k - (r_t - E_t\pi_{t+1} + \nu_\chi) \tag{A10}$$

$$\pi_t = \frac{\iota_p}{1+\iota_p\beta}\pi_{t-1} + \frac{\beta}{1+\iota_p\beta}E_t\pi_{t+1} - \frac{(1-\beta\theta_p)(1-\theta_p)}{(1+\iota_p\beta)\theta_p}(\mu_t^p - \mu_t^{p,n}) \tag{A11}$$

$$\mu_t^p = (y_t - n_t) - w_t \tag{A12}$$

$$r_t^k = c_t - z_t - k_{t-1} + (1+\sigma_l)n_t \tag{A13}$$

$$y_t = (1-\alpha)n_t + \alpha k_{t-1} + \alpha z_t + a_t \tag{A14}$$

$$y_t = \gamma_c c_t + \gamma_i i_t + \gamma_z z_t + g_t \tag{A15}$$

$$b_t = \beta^{-1}[b_{t_1} + g_t - t_t] \tag{A16}$$

$$t_t = \phi_b b_{t-1} + \phi_g g_t \tag{A17}$$

$$r_t = \rho_r r_{t-1} + (1-\rho_r)[\chi_\pi\pi_t + \chi_y y_t] + \varepsilon_t^r \tag{A18}$$

POSTERIOR ESTIMATES: VARYING SHARE OF HTM (λ)

Parameter	Description	Prior			Posterior		
		Dist.	Mean	Dev.	Mean	10%	90%
φ	Inverse Frisch elas.	Normal	4.00	1.50	5.34	5.22	5.48
h	Habit formation	Beta	0.70	0.10	0.74	0.73	0.74
θ_p	Calvo prices	Beta	0.50	0.10	0.94	0.93	0.94
θ_w	Calvo wages	Beta	0.50	0.10	0.69	0.68	0.70
ι_p	Price indexation	Beta	0.50	0.15	0.70	0.69	0.72
ι_w	Wage indexation	Beta	0.50	0.15	0.97	0.96	0.97
σ_l	Labor supply elas.	Normal	2.00	0.75	0.14	0.11	0.16
ψ	Capital util. elas.	Beta	0.50	0.15	0.60	0.59	0.60
α	Capital share	Normal	0.30	0.05	0.40	0.40	0.40
M	Myopia	Beta	0.85	0.10	0.93	0.93	0.94
χ_π	MP inflation	Normal	1.50	0.25	1.94	1.87	2.00
χ_y	MP output	Normal	0.12	0.05	0.11	0.11	0.11
ϕ_g	FP govt. spending	Normal	0.10	0.05	0.08	0.07	0.08
ϕ_b	FP debt	Normal	0.33	0.10	0.26	0.25	0.26
y^*	Trend	Normal	0.40	0.10	0.82	0.81	0.83
π^*	Trend	Normal	0.60	0.10	0.79	0.78	0.80
i^*	Trend	Normal	0.75	0.10	0.76	0.74	0.78

TABLE B1—POSTERIOR ESTIMATES: STRUCTURAL PARAMETERS UNDER DETERMINACY, $\lambda = 0.65$

Parameter	Description	Prior			Posterior		
		Dist.	Mean	Dev.	Mean	10%	90%
Persistence							
ρ_χ	Preference	Beta	0.50	0.20	0.83	0.83	0.84
ρ_w	Wage markup	Beta	0.50	0.20	0.69	0.68	0.70
ρ_p	Price markup	Beta	0.50	0.20	0.50	0.49	0.50
ρ_a	Technology	Beta	0.50	0.20	0.80	0.78	0.81
ρ_g	Govt. Spending	Beta	0.50	0.20	0.98	0.97	0.99
ρ_i	Investment specific	Beta	0.50	0.20	0.60	0.59	0.60
ρ_r	Monetary Policy	Beta	0.50	0.20	0.95	0.93	0.96
Deviation							
σ_χ	Preference	Γ^{-1}	0.30	1.00	0.57	0.53	0.61
σ_w	Wage markup	Γ^{-1}	0.30	1.00	1.60	1.53	1.66
σ_p	Price markup	Γ^{-1}	0.30	1.00	0.12	0.11	0.13
σ_a	Technology	Γ^{-1}	0.30	1.00	0.59	0.55	0.63
σ_g	Govt. Spending	Γ^{-1}	0.30	1.00	0.46	0.41	0.50
σ_i	Investment specific	Γ^{-1}	0.30	1.00	0.70	0.63	0.77
σ_r	Monetary Policy	Γ^{-1}	0.30	1.00	0.13	0.13	0.14

TABLE B2—POSTERIOR ESTIMATES: SHOCK PROCESSES UNDER DETERMINACY, $\lambda = 0.65$

		Prior			Posterior		
Parameter	Description	Dist.	Mean	Dev.	Mean	10%	90%
φ	Inverse Frisch elas.	Normal	4.00	1.50	10.5	10.3	10.7
h	Habit formation	Beta	0.70	0.10	0.48	0.47	0.50
θ_p	Calvo prices	Beta	0.50	0.10	0.77	0.75	0.79
θ_w	Calvo wages	Beta	0.50	0.10	0.40	0.39	0.41
ι_p	Price indexation	Beta	0.50	0.15	0.49	0.45	0.52
ι_w	Wage indexation	Beta	0.50	0.15	0.83	0.81	0.85
σ_l	Labor supply elas.	Normal	2.00	0.75	0.40	0.35	0.44
ψ	Capital util. elas.	Beta	0.50	0.15	0.60	0.58	0.62
α	Capital share	Normal	0.30	0.05	0.23	0.23	0.24
M	Myopia	Beta	0.85	0.10	0.82	0.82	0.82
χ_π	MP inflation	Normal	1.50	0.25	0.00	0.00	0.00
χ_y	MP output	Normal	0.12	0.05	0.11	0.10	0.12
ϕ_g	FP govt. spending	Normal	0.10	0.05	0.08	0.07	0.08
ϕ_b	FP debt	Normal	0.33	0.10	0.11	0.11	0.12
y^*	Trend	Normal	0.40	0.10	0.71	0.70	0.71
π^*	Trend	Normal	0.60	0.10	0.30	0.28	0.31
i^*	Trend	Normal	0.75	0.10	0.46	0.44	0.48

TABLE B3—POSTERIOR ESTIMATES: STRUCTURAL PARAMETERS UNDER INDETERMINACY, $\lambda = 0.65$

		Prior			Posterior		
Parameter	Description	Dist.	Mean	Dev.	Mean	10%	90%
Persistence							
ρ_χ	Preference	Beta	0.50	0.20	0.93	0.90	0.96
ρ_w	Wage markup	Beta	0.50	0.20	0.85	0.83	0.87
ρ_p	Price markup	Beta	0.50	0.20	0.63	0.62	0.64
ρ_a	Technology	Beta	0.50	0.20	0.68	0.66	0.69
ρ_g	Govt. Spending	Beta	0.50	0.20	0.57	0.56	0.58
ρ_i	Investment specific	Beta	0.50	0.20	0.91	0.90	0.93
ρ_r	Monetary Policy	Beta	0.50	0.20	0.51	0.50	0.52
Deviation							
σ_χ	Preference	Γ^{-1}	0.30	1.00	0.58	0.52	0.63
σ_w	Wage markup	Γ^{-1}	0.30	1.00	2.31	2.27	2.37
σ_p	Price markup	Γ^{-1}	0.30	1.00	0.33	0.29	0.39
σ_a	Technology	Γ^{-1}	0.30	1.00	1.05	1.02	1.10
σ_g	Govt. Spending	Γ^{-1}	0.30	1.00	1.90	1.82	1.95
σ_i	Investment specific	Γ^{-1}	0.30	1.00	0.73	0.64	0.82
σ_r	Monetary Policy	Γ^{-1}	0.30	1.00	0.68	0.67	0.70

TABLE B4—POSTERIOR ESTIMATES: SHOCK PROCESSES UNDER INDETERMINACY, $\lambda = 0.65$

Parameter	Description	Prior			Posterior		
		Dist.	Mean	Dev.	Mean	10%	90%
φ	Inverse Frisch elas.	Normal	4.00	1.50	11.4	11.00	11.9
h	Habit formation	Beta	0.70	0.10	0.43	0.39	0.47
λ	Fraction HTM	Beta.	0.35	0.10	0.19	0.16	0.22
θ_p	Calvo prices	Beta	0.50	0.10	0.60	0.59	0.60
θ_w	Calvo wages	Beta	0.50	0.10	0.46	0.43	0.50
ι_p	Price indexation	Beta	0.50	0.15	0.82	0.76	0.88
ι_w	Wage indexation	Beta	0.50	0.15	0.35	0.27	0.41
σ_l	Labor supply elas.	Normal	2.00	0.75	2.77	2.53	3.00
ψ	Capital util. elas.	Beta	0.50	0.15	0.89	0.84	0.94
α	Capital share	Normal	0.30	0.05	0.17	0.13	0.19
M	Myopia	Beta	0.85	0.10	0.98	0.98	0.99
χ_π	MP inflation	Normal	1.50	0.25	4.07	3.81	4.27
χ_y	MP output	Normal	0.12	0.05	0.00	0.00	0.01
ϕ_g	FP govt. spending	Normal	0.10	0.05	0.15	0.11	0.17
ϕ_b	FP debt	Normal	0.33	0.10	0.12	0.07	0.18
y^*	Trend	Normal	0.40	0.10	0.53	0.50	0.56
π^*	Trend	Normal	0.60	0.10	0.45	0.42	0.49
i^*	Trend	Normal	0.75	0.10	0.16	0.07	0.28

TABLE B5—POSTERIOR ESTIMATES UNDER DETERMINACY: STRUCTURAL PARAMETERS

Parameter	Description	Prior			Posterior		
		Dist.	Mean	Dev.	Mean	10%	90%
Persistence							
ρ_χ	Preference	Beta	0.50	0.20	0.91	0.89	0.93
ρ_w	Wage markup	Beta	0.50	0.20	0.97	0.95	0.99
ρ_p	Price markup	Beta	0.50	0.20	0.97	0.96	0.97
ρ_a	Technology	Beta	0.50	0.20	1.00	1.00	1.00
ρ_g	Govt. Spending	Beta	0.50	0.20	1.00	0.99	1.00
ρ_i	Investment specific	Beta	0.50	0.20	0.46	0.43	0.49
ρ_r	Monetary Policy	Beta	0.50	0.20	0.90	0.89	0.91
Deviation							
σ_χ	Preference	Γ^{-1}	0.30	1.00	0.20	0.17	0.23
σ_w	Wage markup	Γ^{-1}	0.30	1.00	0.99	0.86	1.11
σ_p	Price markup	Γ^{-1}	0.30	1.00	0.25	0.23	0.26
σ_a	Technology	Γ^{-1}	0.30	1.00	0.50	0.46	0.54
σ_g	Govt. Spending	Γ^{-1}	0.30	1.00	0.46	0.43	0.48
σ_i	Investment specific	Γ^{-1}	0.30	1.00	0.55	0.52	0.59
σ_r	Monetary Policy	Γ^{-1}	0.30	1.00	0.15	0.13	0.16

TABLE B6—POSTERIOR ESTIMATES UNDER DETERMINACY: SHOCK PROCESSES