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The Cost of Omitting the Credit Channel in DSGE Models: A Policy Mix Approach

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The Cost of Omitting the Credit Channel in DSGE Models: A Policy Mix Approach†

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Abstract:

This paper examines whether the omission of the credit channel from policy models used by both monetary and fiscal policymakers would lead to a noticeably "bad" policy outcome through model simulation. First, we simulate a financial crisis in which the financial market friction grows and the risk premium becomes more volatile. Next, both monetary and fiscal policymakers readjust their policy to stabilize the economy using an approximating DSGE model that does not feature the credit channel. We show that while the model misspecification does not affect much how policymakers perceive the crisis, the newly adopted policy based on the approximating model would cause further destabilization of the economy. We also show that the destabilization of the economy could be prevented if the fiscal policymaker is equipped with the correctly-specified credit channel model and chooses its new policy while taking into account the decision-making of the monetary policymaker. Finally, under the scenario that the correctly-specified model is unknown, we show that the destabilization of the economy could still be prevented if both policymakers can apply judgement to unreasonable parameter estimates during the crisis period. In sum, prediction of policy outcomes and cautiousness in interpreting estimation results can help in mitigating the credit channel misspecification.

Keywords: DSGE model, Lucas Critique, Bayesian estimation, Financial Accelerator model, monetary policy, fiscal policy, policy mix

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1 Introduction

Lucas (1976) argued that any macroeconomic model should be structural so that the hypothetical policy shift does not trigger any spurious shift in model parameters. Soon the analytical tool now known as the Dynamic Stochastic General Equilibrium (DSGE) model was developed and has become the workhorse for analyzing the aggregate economy among academics. Unlike previous generations of models, the behavioral equations of the DSGE model were in principle derived from an optimizing principle, and were further pinned down by time-invariant parameters describing preferences and technology of agents. More recently, many macroeconomists working in the public sector started to use the DSGE model in their forecasting (or projection) and policy analysis, embracing it as a practical solution to overcome the Lucas' critique.[1]

The financial crisis in 2008 brought in new criticism to then-existing DSGE models for their casual treatment of the "credit channel", which we broadly define as the transmission process of policy through the supply of loanable funds.[2] After the crisis many policy institutions formally incorporated credit channels into their policy models.[3] Recently, Cai *et al.* (2019) examined different vintages of the DSGE model used by the Federal Reserve Bank of New York (SWFF++) and found that the version that incorporates financial friction performs well in terms of forecasting.

[1] According to Yagihashi (2020), there are 82 institution-affiliated DSGE policy models that accompany formal documentation in the form of academic research papers, institutional discussion papers, or policy notes. Of these models, 54 are developed by central banks, 16 by national government, and 12 by international organizations.

[2] Prior to the financial crisis, the treatment of the credit channel within the policy institution was *ad hoc*. For example, Harrison *et al*. (2005) describe that in the macroeconometric model used by Bank of England (BEQM), the credit channel is represented by several non-structural auxiliary equations which "proxies for short-run effects such as credit constraints, house price effects, confidence and accelerator effects". Similar approaches were taken for other models that were used in International Monetary Fund, Federal Reserve, and European Central Bank prior to the financial crisis. See also Bayoumi *et al*. (2004), Christoffel *et al*. (2008), Coenen *et al.* (2008), and Erceg *et al.* (2006).

[3] These institutions include Federal Reserve Board, Federal Reserve Bank of New York, European Central Bank, the Bundesbank, Sveriges Riksbank, Bank of Finland, Bank of Canada, and Spanish Ministry of Economic and Finance.

Other studies also argued that the presence of the credit channel matters in the context of policymaking.[4]

The credit channel DSGE models used by many policy institutions typically do not feature the fiscal policymaker. This is not surprising because these models are mainly used by central banks whose mandate is the monetary policy. However, the fiscal policymaker can affect the financial market by changing the tax rate on capital, which could influence how the economy stabilizes after the financial crisis and hence the effectiveness of monetary policy. If we do not explicitly consider the possible model misspecification of the fiscal policymaker, we might misjudge the importance of the credit channel in DSGE models.

This paper aims to examine the cost of omitting the credit channel from DSGE models by taking a "policy mix approach", i.e., assuming that *both* the monetary and fiscal policymakers play a role in stabilizing the economy. The key question is whether the change in policy conducted by both policymakers during the financial crisis would lead to a noticeably "bad" policy outcome, had they used a simpler "approximating model" (AM thereafter) that does not feature the credit channel. We break this question down into three parts. First, we want to know whether the policymakers, equipped with the AM, would hold a vastly different view of the economy from what has actually happened in the "data-generating model" (DGM thereafter). Second, we check whether the policy changes, simultaneously conducted by the monetary and fiscal policymakers, would lead to a further destabilization of the economy. Third, we examine whether handing the correctly-specified model over to one of the two policymakers would be sufficient to prevent the destabilization caused by the credit channel misspecification, and what policymakers could do to mitigate the consequences if they do not know the "true" data generating process.

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[4] See for example, Kolasa and Rubaszek (2014) and Yagihashi (2018). For comprehensive overview on this topic, also see Christiano *et al.* (2018).

Our method utilizes the idea of model entropy (i.e., Kullback-Leibler information criterion) as in Cogley and Yagihashi (2010) and Yagihashi (2018). First, we simulate a financial crisis in which the exogenous risk premium shock becomes more volatile and the endogenous financial propagation mechanism strengthens due to the growing financial market friction. Second, both the monetary and fiscal policymakers independently readjust their policy to minimize the social welfare loss by using an approximating DSGE model that does not feature the credit channel.

To focus on the core issues, we introduce four assumptions that greatly simplify the analysis. First, we use a medium-scale DSGE model that embeds the financial accelerator model of Bernanke, Gertler, and Gilchrist (1999, hereafter BGG) as the core credit channel mechanism. This choice is motivated by BGG's wide use among policy institutions.[5] Second, a financial crisis is simulated by employing two sets of model parameters that characterize the "pre-crisis" and "crisis" periods. Third, the common goal of the monetary and fiscal policymakers is to minimize the quadratic loss function *a la* Woodford (2003), which involves stabilization of the interest rate.[6] Fourth, the policy shift is described as a one-time change in the reaction coefficients of the feedback rules regarding the risk-free interest rate, capital tax rate, and labor tax rate.

The main findings are as follows. First, we find that the policymakers would not see the economy much differently from what happened in the DGM before and after the crisis: changes in the pseudo-true values estimated via the AM are mostly contained within an economically plausible range, while the forecast error variance decomposition in the AM does not suggest that

[5]In 2008, Federal Reserve governor Mishkin stated that the financial accelerator mechanism describes well the macroeconomic risk that the monetary policymaker faces (Mishkin, 2008). The features of the BGG model are incorporated in many DSGE policy models. Examples include BoC-GEM-FIN model (Bank of Canada), Global Integrated Monetary and Fiscal model (International Monetary Fund), MEGA-D (Central Reserve Bank of Peru), PESSOA (Banco de Portugal), RAMSES2 model (Sveriges Riksbank), R.E.M. 2.0 (National Bank of Romania), SWFF++ model (Federal Reserve Bank of New York).

[6] This means that the fiscal institution can potentially aid monetary policymaker in stabilizing the economy (and vice versa) without facing any conflict that may arise from having a different policy objective. This assumption necessarily implies that a) the fiscal policymaker cares as much about the interest rate stabilization as the monetary policymaker does, and b) any additional role of the fiscal policy beyond the short-term economic stabilization is ignored. While it is interesting to consider the case of conflicting objectives among two branches of the government, addressing this issue goes well beyond the scope of this paper.

the model is doing a poor job. Second, we show that the new policy obtained using the AM would result in further destabilization of the economy. The destabilization occurs even if the policymakers use the unbiased parameter values in designing the policy shift. Third, we show that providing one policymaker with the correctly-specified DGM is not sufficient to avoid destabilization of the economy. To stabilize the model economy, we need to a) equip the fiscal policymaker with the correctly-specified DGM and b) let the fiscal policymaker predict the policy change of the monetary policymaker who uses the AM as a guide. Finally, under the scenario that both policymakers do not know the DGM, we show that the destabilization of the economy could still be prevented if both policymakers can use their judgement and partially ignore parameter estimates that seem unreasonable. Overall, we find that prediction of policy outcomes and cautiousness in interpreting estimation results can help in mitigating the credit channel misspecification.

To our knowledge, this paper is the first to study the consequences of credit channel misspecification in *both* monetary and fiscal policy. Previous papers have studied the same topic in the monetary policy context (e.g., Yagihashi, 2018). The key difference is that we incorporate a pair of stylized fiscal policy rules, which is becoming increasingly popular in the DSGE literature (Kliem and Kriwoluzky, 2014), into the otherwise standard medium-scale credit channel DSGE model. This paper is also related to the classic literature that examines monetary-fiscal policy coordination.[7] However, to our knowledge, there are no studies in this field that explicitly examine how model misspecification in one institution could affect the policymaking of the other and

[7] Using the framework of noncooperative games, Sargent and Wallace (1981) first demonstrated that whether the monetary policymaker or the fiscal policymaker gets to move first matters in terms of the final policy outcome. Other related studies include Leeper and Sims (1994), Davig and Leeper (2007), and Schmitt-Grohe and Uribe (2005, 2007).

whether policy outcomes would be any different if one institution is equipped with the correctly-specified model whereas the other is not.

Another contribution of this paper is to demonstrate the importance of the credit channel in fiscal policymaking, in particular the capital tax policy. There are only few studies that examine the importance of the credit channel in fiscal policy. On the theoretical front, Carton *et al*. (2017) use simulation to examine how the increase of the capital return tax impacts the model economy with BGG-type of financial friction. They show that the tax increase has a strong contractionary effect on the economy in the long-run by forcing firms to cut down on investment. On the empirical front, Bird *et al*. (2018) find some supporting evidence for the existence of the credit channel in fiscal policy by analyzing data from the 2004-2005 U.S. repatriation tax holiday. This paper adds to the literature by pointing out the importance of the credit channel for fiscal policymakers in the context of model misspecification.[8] Our paper emphasizes the effect of the capital tax policy during a financial crisis of the sort that we experienced in 2008-09.

The next section provides an overview of the simulation design. Third section describes the model. Fourth section presents the main result and discuss its policy implications. The last section concludes.

2 Simulation Design

We largely follow the approach of Yagihashi (2018) to study the cost of the credit channel misspecification: we generate artificial time series data using the data-generating model ("DGM") and design the policy shift according to the misspecified approximating model ("AM"). The key

[8] Note that there are DSGE models developed by policy institutions that incorporate the capital tax rate. However, most of them treat the capital tax rate as a constant parameter instead of a policy instrument (e.g., models developed by Bundesbank and Sveriges Riksbank).

difference from Yagihashi (2018) is that we incorporate two policymakers, monetary and fiscal, in this analysis.[9] The fiscal policymaker selects policy rule coefficients related to the capital and labor tax rate after the financial crisis erupts. The capital tax rate is closely tied to the user cost of capital in our model and therefore affect the volatility of the rate of return on capital. As such, the fiscal policymaker can influence how the economy stabilizes after the financial crisis through its policy shift and indirectly influence the effectiveness of the monetary policy.

2.1 Financial Crisis

We define three subsamples that trace the sequence of events that happened during the recent financial crisis of 2008-09. Each of the three subsamples are named as follows:

1. *Pre-crisis period*: the financial market condition and policy rules are set to the benchmark level,
2. *Crisis period*: the financial market condition deteriorates, while the policy rules remain unchanged from the pre-crisis period, and
3. *Policy shift period*: policy rules are reoptimized based on the estimated model parameters and the policy model.

We assume that the financial crisis and the policy shift occur instantly and the economy immediately converges to a new rational-expectations equilibrium after the events. Between the pre-crisis and the crisis period, there is a joint shift in the subset of model parameters that represents the deterioration of the financial market conditions. Policymakers do not observe the parameter shift directly because their policy models do not feature these model parameters, but they do observe the change in the moments of the economic variables (e.g., inflation, output, interest rate)

[9] More minor changes include making the welfare loss measure cover multiple period as opposed to current period only (Section 2.3) and adding non-Ricardian "hand-to-mouth" consumers in addition to the rational forward-looking consumers (Section 2.5).

caused by the parameter shift. Between the crisis and the policy shift period, policymakers reoptimize their policy rule coefficients so as to minimize the prespecified welfare loss function conditional on the re-estimated model parameters in the crisis period. We first explain how model parameters are estimated by the policymakers (Section 2.2) and then how the policy shift is designed (Section 2.3).

2.2 Parameter Estimation

First, DGM is used to generate the three sets of data corresponding to "pre-crisis", "crisis", and "policy shift" periods. Next, AM is used by both policymakers to estimate model parameters and choosing the optimized policy rule coefficients. The process of parameter estimation is equivalent to minimizing the distance metric known as the Kullback-Leibler Information Criterion (a.k.a. "*KLIC*")

$$\text{argmin}\, KLIC = \int \log \frac{p_{DGM}(\mathbf{Y}|\boldsymbol{\theta}_{\boldsymbol{DGM}};\boldsymbol{\phi})}{p_{AM}(\mathbf{Y}|\boldsymbol{\theta}_{\boldsymbol{AM}};\boldsymbol{\phi})}\, p_{DGM}(\mathbf{Y}|\boldsymbol{\theta}_{\boldsymbol{DGM}};\boldsymbol{\phi})d\mathbf{Y}, \tag{1}$$

where $p(\mathbf{Y}|\boldsymbol{\theta};\boldsymbol{\phi})$ is the likelihood function, $\mathbf{Y}$ is a vector of variables common across models, $\boldsymbol{\theta}$ is a vector of estimated model parameters, and $\boldsymbol{\phi}$ is a vector of policy parameters, which we treat as "known" to policymakers and leave out of estimation.

When the fiscal policymaker estimates the values of $\boldsymbol{\theta}_{\boldsymbol{AM}}$ using Equation (1), the resulting estimates $\boldsymbol{\theta}^*_{\boldsymbol{AM}}$ converge in probability to what is known as the "pseudo-true" values. Due to model misspecification pseudo-true values necessarily differ from the "true" parameter values used in DGM. Thus our policymakers use the asymptotically-biased parameters in designing the policy shift. To ensure that $\boldsymbol{\theta}^*_{\boldsymbol{AM}}$ reaches the pseudo-true values, we generate time series equivalent of

3200 quarters (800 years) for each of the three sample periods.[10] We then estimate the posterior parameter mode using the maximum likelihood method in combination with Bayesian priors.[11] Observables are output, inflation, nominal interest rate, investment, consumption, labor, wage rate, which are standard in the literature of Bayesian estimation of medium-scale DSGE models.

2.3 Policy Shift

In this model, there exist two types of policymakers, namely the monetary and fiscal policymakers. We assume that both policymakers share a common goal of minimizing the quadratic loss function, which takes the following functional form

$$\min_{\phi} WL_t = E\left\{\sum_{t=0}^{15} \beta^t L_t\right\}, \tag{2}$$

$$L_t = \Gamma_t' \Psi \Gamma_t = \left[\hat{\Pi}_t, \hat{X}_t, \hat{R}_t\right] \begin{bmatrix} 1 & 0 & 0 \\ 0 & \lambda_X & 0 \\ 0 & 0 & \lambda_R \end{bmatrix} \begin{bmatrix} \hat{\Pi}_t \\ \hat{X}_t \\ \hat{R}_t \end{bmatrix}, \tag{3}$$

where $\Pi_t \equiv P_t / P_{t-1}$ is inflation, X is output, R is the interest rate, and the hat on top of each variable denotes deviation from the steady state. The idea of incorporating the interest rate stabilization as part of the quadratic loss function follows Woodford (2003): parameters λ_X and λ_R denote the relative importance of output and interest rate stabilization, respectively. We set the period that covers the period welfare loss to 16 quarters (4 years). This implies that the policymakers care about economic stabilization in both short and medium terms.

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[10] In practice, we generated 3,520 quarterly time series and treated the first 320 quarters as "burn-in". This procedure is to ensure that our sample is not affected by the initial round of shocks that are randomly picked. The adequate length of the sample period is determined by observing the behavior of the standard error of the parameter estimates. While in principle these should approach zero in limit, the speed of convergence is not uniform across parameters. Before picking our sample length, we experimented with different values of T to check how sensitive the parameter estimates are for different sample length.

[11] The approach of Bayesian estimation is standard and closely follows An and Schorfheide (2007). We use Chris Sim's optimization routine to obtain the posterior mode of each parameter. Bayesian priors introduce curvature into the likelihood function and facilitate computation.

The monetary policymaker in our model chooses the risk-free nominal interest rate R_t through the Taylor-type feedback rule,

$$R_t = R_{t-1}^{\rho_R}\left[(\,\Pi_t\,)^{\phi_\Pi}(X_t)^{\phi_X}\left(\frac{X_t}{X_{t-1}}\right)^{\phi_{\Delta X}}\right]^{1-\rho_R} \exp(S_{m,t}), \tag{4}$$

where $S_{m,t}$ is the monetary policy shock that follows the AR(1) process,

$$S_{m,t} = (\,S_{m,t-1})^{\rho_m}\exp\,(\,e_{m,t}), \tag{5}$$

with $e_{m,t} \sim N(0, \sigma_m^2)$. We treat ρ_R as the time-invariant preference parameter that represents the monetary policymaker's general tendency to move the policy rates cautiously. The policy coefficients that the monetary policymaker can choose are $\boldsymbol{\phi_m} = [\phi_\Pi, \phi_X, \phi_{\Delta X}]$.

The fiscal policymaker chooses the capital and labor tax rate τ_t^k, τ_t^w through a pair of feedback rules similar to that of the monetary policymaker,

$$\tau_t^k = \tau_{t-1}^{\rho_k}\left[(X_t)^{\phi_{kX}}\left(\frac{X_t}{X_{t-1}}\right)^{\phi_{\Delta kX}}(\,B_{t-1}\,)^{\phi_{kB}}\right]^{1-\rho_k}, \tag{6}$$

$$\tau_t^w = \tau_{t-1}^{\rho_w}\left[(X_t)^{\phi_{wX}}\left(\frac{X_t}{X_{t-1}}\right)^{\phi_{\Delta wX}}(\,B_{t-1}\,)^{\phi_{wB}}\right]^{1-\rho_w}, \tag{7}$$

where B is the amount of government bond. The policy rule parameters involving output (ϕ_{kX}, ϕ_{wX}) represent the automatic stabilizing component (e.g., see Coenen *et al.*, 2013), while those involving output growth $(\phi_{\Delta kX}, \phi_{\Delta wX})$ represent the responsiveness of the tax rate during the business cycle. The policy rule parameter on the government bond (ϕ_{kB}, ϕ_{wB}) represents how quickly the fiscal policymaker wants its projected budget balance to adjust towards its long-run target of debt-to-output ratio. As with the monetary policy rule's case, ρ_k, ρ_w are treated as (time-invariant) preference parameters.[12] Thus, the fiscal policymaker reoptimizes $\boldsymbol{\phi_f} = [\phi_{kX}, \phi_{\Delta kX}, \phi_{kB}, \phi_{wX}, \phi_{\Delta wX}, \phi_{wB}]$ during the crisis.

We assume that both institutions are granted operational independence when designing and conducting the policy shift. As such, when reoptimizing the policy coefficients, the policy coefficients of the other institutions are treated as exogenous constraints as with other model equations and parameters. In our baseline analysis, we assume that each policymaker naively believes that the other institution keeps its policy the same as the pre-crisis period. We call this "no prediction case" to distinguish with another "predicted outcome case", in which the policy institution equipped with the "true" DGM forms a prediction of the response of the other institution equipped with the AM.

2.4 Financial Accelerator Mechanism

We follow BGG in modeling the financial accelerator mechanism, motivated by its wide use among policy institutions.[13] The key feature of the financial accelerator mechanism, which also distinguishes our DGM from the AM, is that there is imperfection in the financial market that results in a time-varying risk premium between the return on capital (R^k) and the risk-free interest rate. A risk-neutral financial intermediary collects funds from the representative household and lends them out to individual entrepreneurs. Entrepreneurs are subject to a random idiosyncratic productivity shock, and they would be forced to declare bankruptcy when they are hit by a large adverse shock. The optimal contract between the financial intermediary and the entrepreneurs

[12] The two parameters ρ_k, ρ_w are somewhat more difficult to interpret economically compared to ρ_R, because tax rate smoothing is not empirically supported (a permanent tax change would accompany a ρ that is one). Here, we follow the specification that is popular in the fiscal policy literature, (e.g., Kliem and Kriwotzky, 2014).
[13] Other credit channel models that are popular among policy institutions are Gertler and Karadi (2011) and Gerali *et al*. (2010). See Yagihashi (2020) for further details.

requires that the entrepreneurs maximize their profit conditional on the financial intermediary's participation (i.e., nonnegative profit). Solving the contract problem results in an expression for the supply of loanable funds

$$\frac{E_t R_{t+1}^k}{R_{t+1}} = E_t \left[\frac{Q_t \bar{K}_t}{N_{t+1}}\right]^{\nu}, \tag{8}$$

where Q is the price of capital ("Tobin's q"), $\bar{K}$ is the quantity of (installed) capital, N_{t+1} is the entrepreneur's net worth available at the beginning of period $t+1$. The term $Q_t\bar{K}_t/N_{t+1}$ thus represents the leverage ratio of the entrepreneur and the risk premium $E_t R_{t+1}^k/R_{t+1}$ are expressed as a function of the leverage ratio. The parameter ν is the financial market friction, which shows (the elasticity of) how strongly the risk premium responds to the leverage ratio. When $\nu = 0$, the risk premium (in gross terms) becomes one at all times and our AM becomes isomorphic to the DGM.

Entrepreneurs use the loanable funds to buy capital from producers of physical capital and rent the capital out to intermediate goods producers. The expected gross return from capital investment can be expressed as

$$E_t R_{t+1}^k = E_t \left[\frac{MPK_{t+1} + (1-\delta)Q_{t+1}}{Q_t}\right] \exp(S_{rp,t}), \tag{9}$$

where MPK_{t+1} is the (gross) marginal product of capital and δ is the depreciation rate. The risk premium shock $S_{rp,t}$ follows the AR(1) process

$$S_{rp,t} = \left(S_{rp,t-1}\right)^{\rho_{rp}} \exp\left(e_{rp,t}\right), \tag{10}$$

where $e_{rp,t} \sim N(0, \sigma_{rp}^2)$. This shock is introduced to capture the large swing in the risk premium that occurred during the recent financial crisis.[14]

[14] We note that in the DSGE literature, the expression of the risk premium shock is sometimes reserved for different types of shocks. For example, the risk premium shock could mean the wedge that perturbates the marginal rate of substitution between

In the AM, e_{rp} is set to zero at all times and $\nu = 0$ due to the lack of financial market friction. Thus, the demand for loanable funds equation simplifies to

$$R_{t+1} = E_t \left[\frac{MPK_{t+1} + (1-\delta)Q_{t+1}}{Q_t}\right], \quad (11)$$

and the supply of loanable funds is simply the consumption Euler equation derived from the households' optimization problem.

2.5 The Remaining Parts of the Model

Both the DGM and AM mostly share the same model structure as the conventional medium-scale New Keynesian DSGE model populated by Smets and Wouters (2003) and Christiano *et al*. (2005).[15] Here we highlight the differences with these workhorse models.

First, our DGM and AM feature a marginal efficiency of investment (MEI) shock as described in Justiniano *et al*. (2010, hereafter JPT). More specifically, our law of motion for capital is defined as follows,

$$\overline{K}_t = (1-\delta)\overline{K}_{t-1} + \mu_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t,$$

where S represents the adjustment cost of capital that satisfies $S = S' = 0$ and $S'' > 0$ in the steady state. The MEI shock μ_t is modeled as,

$$\mu_t = (\mu_{t-1})^{\rho_\mu}\exp(e_{\mu,t}),$$

with $e_{\mu,t} \sim N(0, \sigma_\mu^2)$. According to Justiniano *et al*. (2011), this shock "proxies for more fundamental disturbances to the functioning of the financial sector". Thus, introducing this shock

consumption across different period within the consumption Euler equation (in this paper we name this type of shock as the preference shock). Alternatively, the risk premium shock could mean the wedge that enters the uncovered interest rate parity condition.

[15] Much of the details of the model is provided in the appendix of Yagihashi (2018).

to our model could potentially help the policymakers in identifying the occurrence of the financial crisis.

Second, we introduce non-Ricardian "hand-to-mouth" households as in Gali *et al*. (2007) and Forni *et al*. (2009). The non-Ricardian households have restricted access to the financial market and thereby cannot adjust their consumption/saving easily in response to the crisis. Aggregate variables of the entire household sector is defined as the linear combination of the corresponding variables for each type of household (o for optimizers, and r for restricted) as follows,

$$C_t = \omega_R C_t^r + (1 - \omega_R) C_t^o,$$

$$L_t = \omega_R L_t^r + (1 - \omega_R) L_t^o,$$

$$D_t = (1 - \omega_R) D_t^o,$$

$$B_t = (1 - \omega_R) B_t^o,$$

where C_t is consumption, L_t is labor, D_t is saving, and the parameter ω_R is the share of non-Ricardian households, which we estimate in later analysis. This modeling strategy is highly popular among policy institutions because it generates a strong fiscal multiplier effect.[16]

Finally, since we incorporate capital and labor tax rates in our model, relevant equations will be slightly modified. With regard to the capital tax rate, the "net" marginal product of capital that pins down the value of physical capital is now defined as

$$MPK_{net,t} = \left[\left(1 - \tau_t^k\right) MPK_t\right] u_t - P_t a(u_t),$$

[16] According to the detailed policy model analysis in Yagihashi (2020), majority of the policy institutions adopt Gali *et al*-type "hand-to-mouth" households to make households act in a non-Ricardian manner. Few institutions adopt the "perpetual youth" structure or apply high future discount rate for borrower-type households.

where MPK_t is the (gross) marginal product of capital derived from the cost minimization problem, P_t is the price level, and $a(u_t)$ is the real cost of capital utilization per unit of physical capital. The budget constraint of the both types of households are

$$C_t^o + \frac{D_t^o}{P_t} + \frac{B_t^o}{P_t} = \frac{R_{t-1}}{\Pi_t}\left(\frac{D_{t-1}^o}{P_t} + \frac{B_t^o}{P_t}\right) + (1-\tau_t^w)\frac{W_t(k)L_t^o(k)}{P_t},$$

$$C_t^r = (1-\tau_t^w)\frac{W_t(k)L_t^r(k)}{P_t},$$

where $W_t(k)$ is the wage rate for worker *k*.

2.6 Parameters

The parameters values are initialized based on past research. These are reported in Tables 1 to 4 and explained below.

Table 1 summarizes the parameter values estimated by policymakers with the help of Bayesian priors. Most of the *prior* mean is set equal to the *posterior* mean estimates obtained by JPT.[17] These parameter values are also used in generating data. This means that any deviation of the point estimates from the data-generating values arise solely from model misspecification and not from how the prior mean is set. Likewise, prior standard deviation is set equal to the posterior standard deviation of JPT. Finally, the distributions of the priors also follow those in JPT.[18]

Table 2 summarizes the values of the common parameters across DGM and AM, which are not estimated due to identification issues. Again, most of them follow JPT's values. The fiscal policy reaction coefficients (ρ_k, ρ_w) and policy weight parameters (λ_X, λ_R) that do not appear in JPT are borrowed from Kliem and Kriwoluzky (2014) and Woodford (2003).

[17] JPT estimated parameter values using the pre-crisis U.S. data from 1954Q3 to 2004Q4. The values are largely consistent with the literature. The parameter value for the share of non-Ricardian households is obtained from Gali *et al*. (2007).
[18] In principle, parameters that are strictly positive follow the gamma distribution. Those constrained between 0 and 1 follow the beta distribution. The standard deviations of the shock processes follow the inverse-gamma distribution.

Table 3 summarizes the parameter values that appear only in the DGM. We prepare two sets of values, which correspond to the pre-crisis and the crisis period. The uncertainty about borrowers' investment project σ_{FA} and bankruptcy cost λ_R are calibrated so that the implied changes of bankruptcy rate, risk premium, and leverage ratio roughly match those observed during the recent financial crisis.[19] For the survival probability of lenders γ and borrowers' spending share of output $\bar{C}^e/\bar{X}$, we assume the values remain unchanged across periods.[20] For the size of the risk premium shock σ_{rp}, we experiment with different values and check how the result of the forecast error variance decomposition of the key endogenous variables (inflation, output, interest rate, risk premium) changes before settling to current values.

Table 4 reports the initial set of policy rule parameters $\boldsymbol{\phi_m}$ and $\boldsymbol{\phi_f}$. They are chosen so that they *jointly* minimize the quadratic loss function in Equation (2). Several points are worth noting. First, the Taylor rule parameter for inflation satisfies the famous Taylor principle ($\phi_\Pi > 1$). Second, output elasticities of tax rates are positive, meaning that the fiscal policy is countercyclical. Finally, bond elasticities of tax rates are positive, which implies long-run sustainability of the fiscal policy.

2.7 Equilibrium and Summary Statistics

The rational expectations equilibrium is obtained in three steps. First, we solve for the model's deterministic steady state. Second, the model equations are log-linearized around the steady state and stacked into a system of linear expectational difference equations. Lastly, the system is solved to find the approximate equilibrium law of motion.

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[19] The targeted values are as follows: (1) the implied annualized business failure rate is 3.42% in the pre-crisis period and 5.64% in the crisis period, (2) the annual risk premium is calibrated to be 100 basis points in the pre-crisis period and 150 basis points in the crisis period, and (3) the leverage ratio declines from 5 in the pre-crisis period to 4 in the crisis period. Based on the chosen values, the elasticity of the risk spread with respect to the leverage ratio becomes 0.0126 in the pre-crisis period and 0.0175 in the crisis period. For more on value choices, see Yagihashi (2018).
[20] The values are taken from BGG.

To confirm how the above model replicates the financial crisis in our simulation, we conduct a stochastic simulation in which all economic shocks are activated at once. We generate two sets of data, one corresponds to the pre-crisis period and the other for the crisis period. Table 5 reports the standard deviations of the ten pre-selected variables in each subsample. The standard deviations of all variables rise across subsamples, most notably the capital-related variables. The increase occurs as a result of the increase in the financial market friction and the larger volatility of the risk premium shock. The increased volatility of the marginal product of capital, the return on capital, and the risk spread is related to the increased volatility of the risk-free interest rate (+15%), which further causes the increase in the welfare loss (+47.3%).

Table 6 shows the 10-period ahead forecast error variance decomposition in the DGM for selected variables. To save space, we only report the result of the crisis period and the change from the pre-crisis period in the parenthesis. During the crisis period, the demand shock plays a larger role for the key variables compared with the pre-crisis period (+2.6% points for the variance of inflation, +1.7% points for output, and +4.1% points for interest rate). This primarily comes from the heightened role of the risk premium shock. We also see a *reduced* role of the MEI shock on key variables, which partially offsets the positive contribution of the risk premium shock within the demand shock category.

3 Results

3.1 Changes in Pseudo-True Parameters and Variance Decomposition

We first report how the estimated pseudo-true values for the model parameters ($\boldsymbol{\theta}^{*}_{\boldsymbol{AM}}$ described in Section 2.1) change from the pre-crisis to the crisis period using the AM. Table 7 shows the result for the subset of parameters. First, among the 23 model parameters estimated, six of them deviated from the pre-crisis values by more than 10% in absolute terms, which are investment adjustment cost (-44.3%), size of MEI shock (-28.6%), persistence of MEI shock (+19.1%), persistence of monetary policy shock (-15.1%), price indexation (+16.6%), and wage indexation (+10.9%). The first four belong to the demand block of the model, while the last two belongs to the supply block of the model. The most surprising outcome is that the size of the MEI shock is falling (rather than rising) in the eyes of the policymakers. Since the volatility in key model variables is rising as seen in Table 5, policymakers are likely to anticipate the size of the demand shocks to rise. Turning to other model parameters, most of the changes in the pseudo-true values estimated via the AM are within an economically plausible range. In that regard, there is not enough evidence suggesting the AM performs poorly as a policy model.

Table 8 reports the forecast error decomposition result using the AM. The lack of the risk premium shock in the AM means that the demand shocks only consists of the MEI shock, the preference shock, the monetary policy shock, and the government spending shock. We observe that the contribution of the demand shock to inflation rises by 6.2% points, half of which are attributed to the rise of the preference shock (+3.5%). The preference shock also plays a larger role in explaining the overall volatility in output (+3.1%) and the interest rate (+6.2%). The increased contribution of the preference shock in explaining the volatility of key variables in the AM closely parallel with the increased contribution of the risk premium shock in explaining the volatility of key variables in the DGM (see Table 6). In the AM, the preference shock effectively serves as a "stand-in" for the risk premium shock, thereby preventing policymakers from understanding the true nature of model misspecification.[21]

[21] Our finding also corroborates with some of the research within the DSGE literature (e.g., Gali *et al*., 2012) that calls our preference shock as the risk premium shock.

In sum, we argue that the policymaker would not see the economy much differently from what happened in the DGM before and after the crisis. Hence, they would not see any problem to continue using the AM as their policy model.

3.2 Did the Policymakers Succeed in Stabilizing the Economy?

The next step is to examine whether policymakers can successfully stabilize the model economy despite using the misspecified model as a guide. Table 9 summarizes the result. The column labeled as "DGM outcome" reports the simulation outcome in which both policymakers *jointly* choose coefficients $\boldsymbol{\phi_m}$ and $\boldsymbol{\phi_f}$ so as to minimize the pre-specified quadratic welfare loss function while using the DGM as their policy model. We treat this as our benchmark in evaluating the other policy outcome.[22] We find that under the benchmark, the welfare loss decreases by 6.3% compared with the crisis period. This means that under the full-information disclosure setting, the policy shift results in economic stabilization as intended.

The column labeled as "AM outcome" reports the simulation outcome in which both policymakers use the misspecified model *and* shift their policy independently. The measured welfare loss is now 9.5% *higher* compared to the crisis period, meaning that the model economy has destabilized due to the policy shift. The welfare loss is 16.9% higher than what would have been achieved under the "DGM outcome".

To examine what exactly causes the destabilization of the model economy, we examine two more cases. The first case is when the policy model is misspecified, but the model parameters used in calculating the optimized policy coefficients are set to the DGM values ("case (a)"). The second

[22] Under this scenario, the newly chosen interest rate rule becomes slightly anti-inflationary (higher ϕ_{Π}) relative to the pre-crisis period, whereas the capital tax rate rule becomes less responsive to output and bond (lower ϕ_{kX}, $\phi_{\Delta kX}$, and ϕ_{kB}) relative to the pre-crisis period. The actual values of these policy coefficients are available upon request.

case is when the policy model is correctly specified but parameters are set to the biased estimates based on the AM ("case (b)"). Case (a) shows that the welfare loss becomes 26.4% higher compared with the crisis period, whereas case (b) shows that the welfare loss decreases by 3.1% relative to the crisis period. While in the latter case the loss is still higher than what would have been achieved under the DGM outcome, at least the policymakers are partially successful in stabilizing the economy.

In sum, we find that designing a policy shift using a misspecified policy model, as opposed to using the biased parameters, costs more in the case of credit channel misspecification. This corroborates with our earlier finding that parameter changes seem inconsequential from the policymaker's standpoint.

3.3 Who Should be More Aware of Model Misspecification?

As we mentioned in the introduction, most of the existing credit channel models used in practice are those developed by the central banks. Motivated by this observation, we now ask the following question: if either the monetary or the fiscal policy institution uses the DGM while the other continues to use the AM, would the above outcome improve? We examine this question under both "no prediction case" and "predicted outcome case" as described in Section 2.3. Table 10 shows the result.

First, we examine the case of "no prediction case". We find that the welfare loss increases by 0.2% relative to the crisis period when the fiscal policymaker uses the DGM (Table 10 column (1)), whereas the welfare loss increases by 6.2% when the monetary policymaker uses the DGM (Table 10 column (2)). Both outcomes have improved compared with the case in which both institutions use the AM as their policy model (-8.5% and -3.0%, respectively). Yet, in both cases the policy shift results in further destabilization of the model economy from the crisis period. This means that the cost of the credit channel misspecification is smaller but still present.

Next, we examine the case of "predicted outcome case", i.e. assume that the policy institution equipped with the DGM can predict how the other institution shifts its policy based on the AM. When the fiscal policymaker uses the DGM and the monetary policymaker uses the AM, the welfare loss *decreases* by 3.1% relative to the crisis period (column (3)). When the monetary policymaker uses the DGM and the fiscal policymaker uses the AM, the welfare loss increases slightly by 1.3% relative to the crisis period (column (4)). Both results improve upon the "no prediction case", which makes sense because the institution that uses the DGM knows exactly how the other institution would respond to the financial crisis and therefore it can design a better policy shift of its own. In conclusion, only when the fiscal policy is equipped with the DGM, the policy shift would stabilize the economy (Table 10, Column (3)).

In reality, it is common that the monetary policymaker uses DSGE models that feature financial market friction whereas the fiscal policymaker does not. Our result seems to suggest that misspecification in the credit channel is at least as important for the fiscal policymaker as it is for the monetary policymaker. The result also indicates that when shifting a policy during a financial crisis, forming a prediction regarding to what the other institution does can be quite beneficial.

4 The Role of Judgement

In practice, policymakers rarely take the model outcome at face value because they are aware of the fact that DSGE models are approximation to the complicated reality. As such, policymakers would first check whether model outcomes are indeed consistent with his/her own knowledge about the state of the economy and apply further judgment if deemed necessary.[23]

In this section we examine whether applying judgement to the result of the parameter estimates could be beneficial for the policy outcome under the credit channel misspecification. In Section 3.1, we found that six model parameters showed large changes during the crisis (10% and over), which did not actually occur in the data-generating process. Here, we specifically focus on those related to the MEI shock, which is often interpreted as a proxy for the financial market (Justiniano *et al.*, 2011). According to our earlier estimation, both the size and persistence of the MEI shock changed notably during the crisis (-28.6%, +19.1%, respectively). Furthermore, the observed *decrease* of the size of the MEI shock is counterintuitive, given that the risk premium shock has increased in our simulation. While Equation (1) tells us that all parameter changes are simply an artifact arising from the KLIC optimization and therefore have no structural interpretation, policymakers who are not aware of the mechanism may be confused by the seemingly inconsistent outcome between the observed increase in the volatility of the financial market variables and the reduced size of the MEI shock. One practical solution is to partially ignore the estimation outcome regarding the MEI shock.

4.1 Judgement Exercised by Both Policymakers

Parallel to Section 3, we start our analysis by assuming that both policymakers use the AM as their policy model. Furthermore, we assume that *both* policymakers can simultaneously adopt the same combination of parameter values for the size and persistence of the MEI shock that fall

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[23] For example, Bank of England has its own pre-specified procedure ("misspecification algorithm") in which bank staff examine possible ways that their policy model (COMPASS) may mislead them in forming an official forecast (Burgess *et al.*, 2013). An alternative approach is to introduce a minimax-type robust control approach to the policymaking process, e.g., "slant" the model outcome such that the policymaker is best prepared for the worse outcome that could possibly arise from the policy model (Hansen and Sargent, 2008).

within the pre-crisis and crisis period estimates. Figure 1 presents the contour map of the welfare loss in which the size of the shock is on the vertical axis and persistence is on the horizontal axis. The dot in the lower-right corner represents the combination of the estimates for the pre-crisis period ($100\sigma_{\mu} = 10.29$ and $\rho_{\mu} = 0.68$), whereas the dot in the upper-left corner shows those for the crisis period ($100\sigma_{\mu} = 7.35$ and $\rho_{\mu} = 0.81$).

We find that if both policymakers stick to the original estimates (lower-right corner), the welfare loss would be as high as 3.752. This is much worse than the loss in the crisis period (3.039) and 13% higher than the welfare loss when the estimates during the crisis period were used in designing the policy shift (3.327). Within this contour map, the lowest loss is achieved when policymakers adopt the new estimates for the persistence of MEI shock but *mostly* ignore the change in the size of the MEI shock (2.967). The loss associated with this judgment is 2% lower than the crisis period and thus implies economic stabilization through policy shift.

The key finding from this exercise is that policymakers' judgement of parameter changes seem to matter greatly in terms of subsequent policy outcome. If judgement is exercised carefully, it can help policymakers in stabilizing the economy and overcome the credit channel misspecification.

4.2 Judgement Exercised by *One* Policymaker

In this subsection, we repeat the above exercise by first assuming that only the monetary policymaker uses the misspecified AM while the fiscal policymaker uses the DGM.[24] Figure 2 shows the resulting contour map. We notice that the contour map looks much simpler in structure compared to Figure 1. Also, the loss is not much different whether the crisis estimates or the pre-

[24] We assume that the fiscal policymaker uses the DGM and optimize their policy independently (i.e. no prediction of monetary policy shift).

crisis ones (3.045 as opposed to 3.078) are used. The loss would further reduce if the monetary policymaker uses the new estimate for the size of the MEI shock while ignoring the persistence of the MEI shock. The associated loss (2.963) is very similar to the case when both policymakers use the AM and apply judgement (2.967, see Figure 1).

Next, we examine the case in which the fiscal policymaker uses the AM and the monetary policymaker uses the DGM. Figure 3 shows the result. Comparing with Figure 2, the loss varies more markedly depending on whether the fiscal policymaker uses the crisis period estimates (4.101) or stick with the pre-crisis estimates (3.226) when choosing the new policy. The loss is minimized when the fiscal policymaker sticks to the old estimate for the size of the MEI shock while adopting the new estimate for the persistence of the MEI shock. The associated loss (2.852) is almost identical to the loss realized when both policymakers use the DGM as the policy model (2.847, see Table 9).

In sum, we find that judgment regarding to the MEI shock parameters have different policy implications for each policymaker. The monetary policymaker's judgment about the MEI shock estimates had only minor impact on policy outcome as long as the fiscal policymaker used the DGM. In contrast, the fiscal policymaker's judgement about the MEI shock, when the monetary policymaker uses the DGM, had a larger impact on policy outcome. This finding seems to point to the importance of using the correctly-specified credit channel model for fiscal policymaking, consistent with earlier findings in Section 3.3.

5 Conclusion

This paper examined the cost of policymaking in DSGE models when model misspecification occurs in the credit channel for both the monetary and fiscal policymakers. The financial accelerator model of Bernanke *et al.* (1999) was chosen as the data generating model and the simpler approximating model without the financial market friction and the risk premium shock was used as the policy model. We simulated a financial crisis that involved changes in the degree of financial market friction and a more volatile risk premium. Following the crisis, both monetary and fiscal policymakers estimated model parameters and shifted their policy accordingly to combat the crisis using the approximating model.

Our main findings are as follows. First, while the model misspecification does not affect much on how policymakers perceives the crisis, the newly adopted policy based on the approximating model would cause further destabilization of the economy. Second, the destabilization of the economy could be prevented if the fiscal policymaker is equipped with the correctly-specified DSGE model and chooses its new policy while taking into account decision of the monetary policymaker. Third, we find that the destabilization of the economy could be prevented if both policymakers can partially ignore the increase in the size of the marginal efficiency of investment shock that is observed in the approximating model during the crisis period.

While previous literature has studied DSGE model misspecification with the credit channel, none of them has examined policy implications while explicitly considering the interaction between monetary and fiscal policymakers. The novelty of our finding is that model misspecification seems to be more important for the fiscal policymaker than it is for the monetary policymaker. This finding goes against the common practice that most of the credit channel DSGE models are used by central banks but not by fiscal policy institutions. Our paper suggests that fiscal policymakers should consider using a DSGE model that incorporates the credit channel.

The limit of this paper is that we adopted a very simplified optimization process in policymaking. One possible extension is to experiment with different policy objectives. For example, if we were to introduce term structure of the interest rate into our model, we could include stabilization of the long-term interest rate in policymaking, which is more relevant for public debt management. Another extension is to add government spending rules such as those used by the European Commission (Albonico *et al*., 2017). We leave them for future research to explore.

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Table 1: Estimated Parameters in the New Keynesian Approximating Model

	Prior Mean	Prior St.Dev.	Distri-bution
Preference and Technology Parameters			
Consumption habit h	0.78	0.04	Beta
Inverse Frisch elasticity φ	3.79	0.76	Gamma
Elast. Of capital utilization χ	5.30	1.01	Gamma
Investment adjustment cost S''	2.85	0.54	Gamma
Calvo prices ξ_p	0.84	0.02	Beta
Price indexation ι_p	0.24	0.08	Beta
Calvo wages ξ_w	0.70	0.05	Beta
Wage indexation ι_w	0.11	0.03	Beta
Share of non-Ricardian household ω_{NR}	0.50	0.10	Beta
Shock-related Parameters			
Persistence of monetary policy shock ρ_{mp}	0.14	0.06	Beta
Persistence of technology shock ρ_A	0.95	0.01	Beta
Persistence of government spending shock ρ_G	0.95	0.01	Beta
Persistence of MEI shock ρ_μ	0.72	0.04	Beta
Persistence of price markup shock ρ_p	0.94	0.02	Beta
Persistence of wage markup shock ρ_w	0.95	0.01	Beta
Persistence of preference shock ρ_b	0.67	0.04	Beta
Size of monetary policy shock $100\sigma_{mp}$	0.22	inf	Inv-Gamma
Size of technology shock $100\sigma_A$	0.88	inf	Inv-Gamma
Size of government spending shock $100\sigma_G$	0.35	inf	Inv-Gamma
Size of MEI shock $100\sigma_\mu$	6.03	inf	Inv-Gamma
Size of price markup shock $100\sigma_{p^*}$	0.14	inf	Inv-Gamma
Size of wage markup shock $100\sigma_{w^*}$	0.20	inf	Inv-Gamma
Size of preference shock $100\sigma_{b^*}$	0.04	inf	Inv-Gamma

Note: The MEI shock refers to the marginal efficiency of the investment shock. The prior mean in the second column is set equal to the parameter values that are used for data generation. All model parameters are based on quarterly frequency.

Table 2: Calibrated Parameters Common to the DGM and AM

	Value	Source
Discount factor β	0.9904	JPT
Capital share α	0.17	JPT
SS price markup Λ_p^{ss}	0.23	JPT
SS wage markup Λ_w^{ss}	0.15	JPT
MA parameter of price markup shock θ_p	0.77	JPT
MA parameter of wage markup shock θ_w	0.91	JPT
SS work hours (in log) $logL_{ss}$	0.38	JPT
Government spending share of output $\bar{G}/\bar{X}$	0.21	JPT
Depreciation rate δ	0.025	JPT
Monetary policy: smoothing ρ_R	0.82	JPT
Capital tax policy: smoothing ρ_k	0.8162	KK
SS capital tax rate $\bar{\tau}^k$	0.3572	KK
Labor tax policy: smoothing ρ_w	0.8577	KK
SS labor tax rate $\bar{\tau}^w$	0.2343	KK
Policy weight: output λ_X	0.048	Woodford (2003)
Policy weight: interest rate λ_R	0.236	Woodford (2003)

Note: DGM refers to the data generating model and AM refers to the approximating model. For the size of the risk premium shock, we prepare two values that correspond to the pre-crisis period and the crisis period. In the "Source" column, JPT stands for Justiniano *et al*. (2010) and KK stands for Kliem and Kriwoluzky (2014). All parameters are in quarterly frequency.

Table 3: Calibrated Parameters in the DGM

	Pre-crisis	Crisis
Uncertainty about borrowers' investment project σ_{FA}	0.093	0.129
Bankruptcy cost λ_R	0.039	0.043
Elasticity of the risk spread w.r.t. leverage ratio ν	0.0126	0.0175
Survival probability of lender γ	0.9724	0.9724
Borrower spending share of output $\bar{C}^e/\bar{X}$	0.01	0.01
Persistence of risk premium shock ρ_{rp}	0.50	0.50
Size of risk premium shock $100\sigma_{rp}$	0.20	1.00

Note: For the uncertainty about borrowers' investment project, bankruptcy cost, and elasticity of the risk spread with respect to the leverage ratio, we prepare two values that correspond to the pre-crisis and the crisis period. The survival probability of the lender is calibrated based on Bernanke *et al*. (1999), while other parameters are calibrated based on Yagihashi (2018). All parameters are in quarterly frequency.

Table 4: Initial Policy Coefficients Calculated Under the DGM

	Values
Monetary Policy Rule Parameters	
Monetary policy.: inflation ϕ_{Π}	5.75
Monetary policy.: output ϕ_X	23.62
Monetary policy.: output $\phi_{\Delta X}$	74.19
Fiscal Policy Rule Parameters	
Capital tax policy: output ϕ_{kX}	392.94
Capital tax policy: output $\phi_{\Delta kX}$	48.82
Capital tax policy: output ϕ_{kB}	0.38
Labor tax policy: output ϕ_{wX}	953.32
Labor tax policy: output $\phi_{\Delta wX}$	86.86
Labor tax policy: output ϕ_{wB}	0.05

Note: The policy parameters are obtained from the data generated by the DGM and calculated using the same model so as to minimize the quadratic welfare loss function in Equation (2) subject to model equations.

Table 5: Standard Deviations of the Generated Variables Under the DGM

	Pre-crisis	Crisis	Change
Inflation Π	0.316	0.324	+3%
Output X	0.042	0.043	+3%
Interest rate R	1.032	1.187	+15%
Investment I	34.055	40.023	+18%
Capital K	8.811	12.056	+37%
Marginal product of capital MPK	10.352	13.157	+27%
Return on capital R^k	4.321	5.869	+36%
Risk spread spr	1.009	1.522	+51%
Labor L	4.365	4.675	+7%
Wage W	3.083	3.562	+16%
Welfare loss	2.063	3.039	+47.3%

Note: Standard deviations and welfare losses are obtained based on observations in the DGM.

Table 6: Share of the 10-period Ahead Forecast Error Variance Explained by Structural Shocks: DGM Case

	(1) Demand shocks	MEI	Risk prem.	Preference	Policy	(2) Supply shocks
Inflation Π	12.7%	5.2%	3.5%	1.4%	2.6%	87.3%
	(+2.6%)	(-0.6%)	(+3.4%)	(-0.1%)	(-0.1%)	(-2.6%)
Output X	52.1%	30.4%	4.4%	4.7%	12.5%	47.9%
	(+1.7%)	(-1.8%)	(+4.3%)	(-0.2%)	(-0.5%)	(-1.7%)
Interest rate R	73.9%	38.2%	16.9%	5.6%	13.1%	26.1%
	(+4.1%)	(-8.9%)	(+16.3%)	(-1.0%)	(-2.3%)	(-4.1%)

Note: The result is based on the 10-period ahead forecast error variance decomposition, measured during the crisis period. Policy parameters are set to baseline (pre-crisis) values. Demand shocks consist of the MEI shock, the risk premium shock, the preference shock, and two policy shocks (monetary plus government spending). Supply shocks consist of technology shock, price markup shock, and wage markup shock.

Table 7: Change of Pseudo-true Values from Pre-Crisis to Crisis Period

Parameters	Changes
Change of 10% or more in absolute value	
Inv. adjustment cost S''	- 44.3%, from 6.91 to 3.85
Size of MEI shock $100\sigma_\mu$	- 28.6%, from 10.29 to 7.35
Persistence of MEI shock ρ_μ	+19.1%, from 0.68 to 0.81
Price Indexation ι_p	+16.6%, from 0.15 to 0.18
Persistence of m-policy shock ρ_{mp}	- 15.1%, from 0.14 to 0.12
Wage indexation ι_p	+10.9%, from 0.12 to 0.13
Change of more than 5% and less than 10% in absolute value	
Persistence of preference shock ρ_b	+7.5%, from 0.69 to 0.74
Inverse Frisch elasticity φ	- 6.0%, from 3.59 to 3.38

Note: The table is produced based on Appendix Tables A.2 and A.3. Change are in terms of pseudo-true values between pre-crisis and crisis period.

Table 8: Share of Variance Explained by Structural Shocks During the Crisis Period: AM Case

	(1) Demand shocks	MEI	Preference	Policy	(2) Supply shocks
Inflation Π	20.0%	13.4%	5.1%	1.4%	80.0%
	(+6.2%)	(+3.5%)	(+3.5%)	(-0.7%)	(-6.2%)
Output *X*	52.0%	34.1%	8.4%	9.5%	48.0%
	(-1.0%)	(-2.0%)	(+3.1%)	(-2.0%)	(+1.0%)
Interest rate *R*	79.7%	57.8%	12.4%	9.5%	20.3%
	(+3.3%)	(+0.7%)	(+6.2%)	(-3.6%)	(-3.3%)

Note: The result is based on the 10-period ahead forecast error variance decomposition. Policy parameters are set to baseline (pre-crisis) values. Demand shocks consist of the MEI shock, the risk premium shock, the monetary policy shock, the government spending shock, and the preference shock. Supply shocks consist of the technology shock, the price markup shock, and the wage markup shock.

Table 9: The Effect of Policy Shift When Both Policy Institutions Use the Same Policy Model

	(1) DGM outcome	(2) AM outcome	Case (a)	Case (b)
(1) Model	DGM	AM	AM	DGM
(2) Parameters	DGM	AM	DGM	AM
Welfare loss *WL*	2.847	3.327	3.841	2.945
(relative to crisis period)	(-6.3%)	(+9.5%)	(+26.4%)	(-3.1%)
(relative to DGM outcome)	(0.0%)	(+16.9%)	(+34.9%)	(+3.4%)

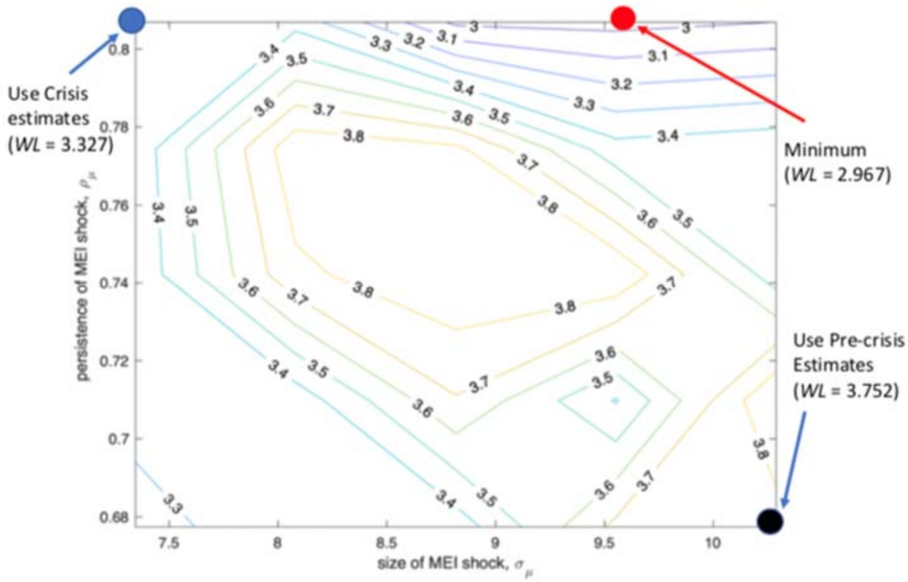
Note: Column (1) shows the case in which both policy institutions use the DGM as their policy model and jointly shift the policy coefficients so as to minimize the welfare loss. Column (2) shows the case in which both policy institutions use the AM as their policy model while adopting the estimated pseudo-true values as the model parameter. Case (a) is when both institutions use the AM as their policy model while adopting the true parameter values when designing the policy shift. Case (b) is when both institutions use the DGM as their policy model while adopting the estimated pseudo-true values for the model parameters.

Table 10: The Effect of the Policy Shift When One Policy Institution Uses the AM and the Other Uses the DGM, with and without prediction

	(1)	(2)	(3)	(4)
(1) Monetary policymaker	AM	DGM	AM	DGM
(2) Fiscal policymaker	DGM	AM	DGM	AM
(3) Prediction of AM outcome	no	no	yes	yes
Welfare loss *WL*	3.045	3.226	2.943	3.079
(relative to crisis outcome)	(+0.2%)	(+6.2%)	(-3.1%)	(+1.3%)
(relative to both-AM outcome)	(-8.5%)	(-3.0%)	(-11.5%)	(-7.5%)
(relative to DGM outcome)	(+6.9%)	(+13.3%)	(+3.4%)	(+8.1%)

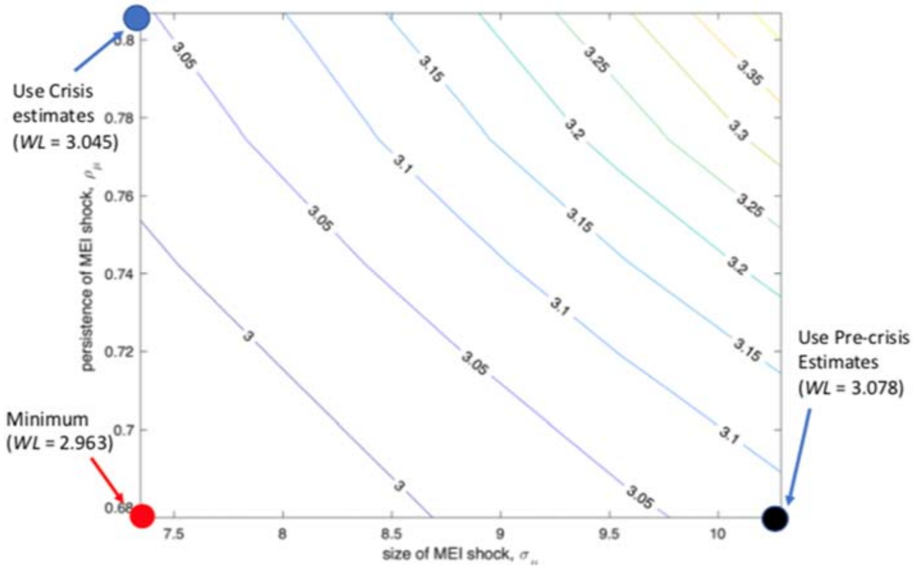
Note: Columns (1) and (2) show the cases in which one of the policy institutions uses the DGM as their policy model and shifts the policy while assuming that the other institution keeps the policy coefficients the same as in the pre-crisis period. Columns (3) and (4) repeat the same exercise, with the additional assumption that the policy institution that uses the DGM forms a prediction of the policy shift of the other institution that uses the AM when designing its own policy shift.

Figure 1 Contour Map of Welfare Loss: Both Institutions Distrust the Parameter Estimates



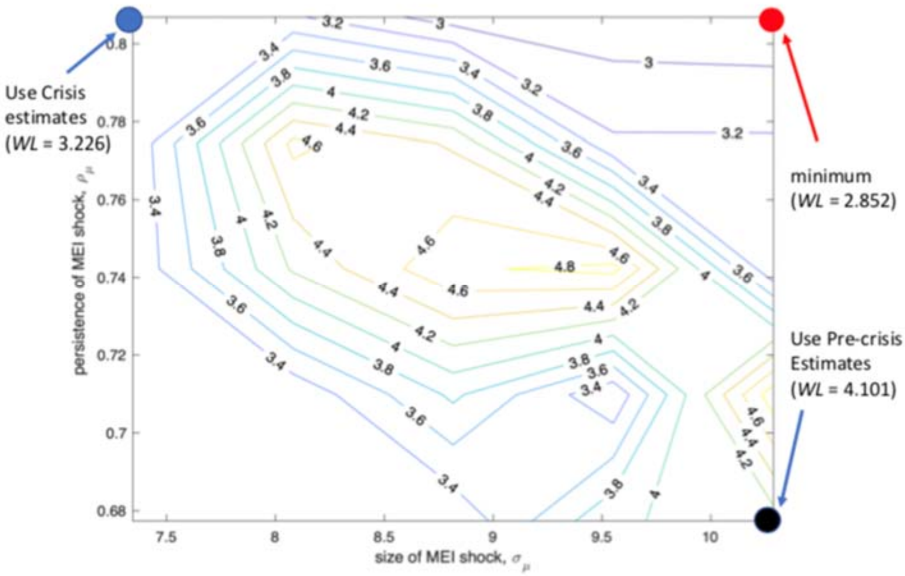
Note: Each line in the figure represents the level of welfare loss associated with the combination of parameter values for the size and persistence of the MEI shock adopted by the policymaker that uses the AM. The dot described as “minimum” represents the combination of parameter values that achieve the lowest welfare loss in the entire parameter space considered.

Figure 2 Contour Map of Welfare Loss: Monetary Policymaker Uses AM and Distrusts the Parameter Estimates, Fiscal Policymaker Uses DGM



Note: Each line in the figure represents the level of welfare loss associated with the combination of parameter values for the size and persistence of the MEI shock that is adopted by the policymaker that uses the AM. The dot described as "minimum" represents the combination of parameter values that achieve the lowest welfare loss in the entire parameter space considered.

Figure 3 Contour Map of Welfare Loss: Fiscal Policymaker Uses AM and Distrusts the Parameter Estimates, Monetary Policymaker Uses DGM



Note: Each line in the figure represents the level of welfare loss associated with the combination of parameter values for the size and persistence of the MEI shock that is adopted by the policymaker that uses the AM. The dot described as “minimum” represents the combination of parameter values that achieve the lowest welfare loss in the entire parameter space considered.

Appendix

Table A.1: Pseudo-true Values of Parameters Under Misspecified New Keynesian Approximating Model (AM)

(a) Preference/technology Parameters

	(1) Pre-crisis	(2) Crisis	Change
Consumption habit h	0.85 (0.01)	0.84 (0.01)	-1.0%
Inverse Frisch elasticity φ	3.59 (0.16)	3.38 (0.16)	-6.0%
Elast. Of capital utilization χ	5.56 (0.11)	5.68 (0.13)	+2.1%
Investment adjustment cost S''	6.91 (0.47)	3.85 (0.34)	-44.3%
Calvo prices ξ_p	0.85 (0.00)	0.84 (0.00)	-1.1%
Price indexation ι_p	0.15 (0.02)	0.18 (0.02)	+16.6%
Calvo wages ξ_w	0.72 (0.01)	0.74 (0.01)	+2.9%
Wage indexation ι_w	0.12 (0.02)	0.13 (0.03)	+10.9%
Share of non-Ricardian HH ω_{NR}	0.48 (0.01)	0.48 (0.01)	+1.4%

Table A.2: Pseudo-true Values of Parameters Under Misspecified New Keynesian Approximating Model (AM), *continued*

(b) Shock-related Parameters

	(1) Pre-crisis	(2) Crisis	Change
Persistence of monetary policy shock ρ_{mp}	0.14	0.12	-15.1%
	(0.02)	(0.02)	
Persistence of technology shock ρ_A	0.97	0.97	-0.4%
	(0.00)	(0.00)	
Persistence of government spending shock ρ_G	0.95	0.95	-0.5%
	(0.00)	(0.00)	
Persistence of MEI shock ρ_μ	0.68	0.81	+19.1%
	(0.01)	(0.01)	
Persistence of price markup shock ρ_p	0.99	0.98	-0.5%
	(0.00)	(0.00)	
Persistence of wage markup shock ρ_w	0.95	0.95	-0.3%
	(0.00)	(0.00)	
Persistence of preference shock ρ_b	0.69	0.74	+7.5%
	(0.01)	(0.01)	
Size of monetary policy shock $100\sigma_{mp}$	0.21	0.22	+3.9%
	(0.00)	(0.00)	
Size of technology shock $100\sigma_A$	0.95	0.97	+1.5%
	(0.01)	(0.01)	
Size of government spending shock $100\sigma_G$	0.35	0.34	-0.5%
	(0.00)	(0.00)	
Size of MEI shock $100\sigma_\mu$	10.29	7.35	-28.6%
	(0.61)	(0.38)	
Size of price markup shock $100\sigma_{p^*}$	0.12	0.12	+1.6%
	(0.00)	(0.00)	
Size of wage markup shock $100\sigma_{w^*}$	0.20	0.20	+2.0%
	(0.00)	(0.00)	
Size of preference shock $100\sigma_{b^*}$	0.04	0.03	-1.0%
	(0.00)	(0.00)	

Note: The estimates in each column are obtained from the data generated by the financial accelerator data generating model (DGM) and estimated using the New Keynesian approximating model (AM). Numbers in the parenthesis are standard errors. The MEI shock refers to the marginal efficiency of the investment shock.