Assessing the Effects of Fiscal Policy in Japan with Estimated and Calibrated DSGE Models*

Takuji Fueki†, Ichiro Fukunaga‡, and Masashi Saito§

October 13, 2010

Abstract

In this paper, we assess the effects of fiscal policy in Japan using two dynamic stochastic general equilibrium (DSGE) models. One is a medium-scale DSGE model of Japan’s economy estimated using Bayesian techniques. The other is the IMF’s large-scale “Global Integrated Monetary and Fiscal (GIMF)” model (Kumhof, et al., 2010) calibrated to Japan’s and other countries’ data.

Keywords: Fiscal Policy; Dynamic Stochastic General Equilibrium Model; Global Integrated Monetary and Fiscal Model
JEL classification: E30; E60

*Very preliminary and incomplete draft prepared for 2010 Central Bank Macroeconomic Modeling Workshop. Views expressed in this paper are those of the authors and do not reflect those of the Bank of Japan.
†Research and Statistics Department, Bank of Japan.
‡Head of Macro Modeling, Research and Statistics Department, Bank of Japan. Corresponding author. E-mail: ichirou.fukunaga@boj.or.jp
§Research and Statistics Department, Bank of Japan.
1 Introduction

Many developed countries have recently launched aggressive fiscal stimulus packages to tackle with the global financial crisis. Japan is not an exception, but it had already deployed large-scale fiscal stimulus long before this crisis. In the late 1990s, when domestic financial crisis hit Japan’s economy, fiscal and monetary policy measures were aggressively pursued. The short-term nominal interest rate reached the zero lower bound, and large government budget deficits boosted public debt. Accordingly, in the recent crisis, the Japanese fiscal and monetary authorities faced the following questions: How effective are fiscal stimulus measures given the already high level of public debt and near-zero interest rate? How different are policy responses to global financial crisis from those to domestic financial crisis?

To answer these questions, we use two dynamic stochastic general equilibrium (DSGE) models. One is a medium-scale DSGE model of Japan’s economy estimated using Bayesian techniques. The other is the IMF’s large-scale “Global Integrated Monetary and Fiscal (GIMF)” model (Kumhof, et al., 2010) calibrated to Japan’s and other countries’ data. The latter is an open economy model that can consider the international spillover of fiscal policy effects and the effects of exchange rate movements. Moreover, it has many realistic features such as overlapping generations households, the financial accelerator mechanism for the non-financial corporate sector, etc.

Many recent studies have used DSGE models to analyze the effects of fiscal stimulus packages. The main benefit of using structural models is the large amount of identifying information that allows us to trace the transmission mechanisms of various fiscal policy measures. Coenen et al. (2010) compare seven structural models that have been heavily used in policymaking institutions, and show that there is substantial agreement across models on the sizes of fiscal multipliers and that the sources of differences across them are fairly straightforward to identify. Cogan et al. (2009) compare a standard estimated new Keynesian DSGE model with a practically used old Keynesian models, and show that the fiscal multipliers are very different between those models due to differences in underlying theories. Some
other studies including Corsetti, et al. (2009) and Christiano, et al. (2009) show that several key features of the model structures and the fiscal shock processes affect the sizes of fiscal multipliers.

Following these recent studies, we compare the two different types of DSGE models and examine how and why these models generate different results under various conditions and situations. In particular, motivated by the current state of Japan’s economy, we focus on the level of government debt and the degree of monetary policy responsiveness (e.g. the monetary authority’s accommodation of the government spending and the zero lower bound of the policy interest rate) as key factors that could affect the effectiveness of fiscal policy. Moreover, unlike previous studies, we examine the responsiveness of fiscal policy rules to domestic and foreign shocks as well as the effectiveness of fiscal shocks.

Our main results are summarized as follows. First, the fiscal spending multipliers are very small (near zero) in both models, when we assume a fiscal policy rule that targets a surplus-to-output ratio by adjusting labor income tax rate. Second, the fiscal spending multiplier becomes smaller when the government tries to reduce the debt more quickly. When a government spending shock occurs, the government’s policy stance for fiscal consolidation does not conflict with its stance for business-cycle stabilization, which means the government who considers business-cycle stabilization as well as fiscal consolidation counteracts its spending shock. When a non-fiscal shock hits the economy, however, the government’s policy stance for fiscal consolidation and business-cycle stabilization may conflict with each other. Third, the fiscal spending multiplier becomes larger when the policy interest rate does not change and the monetary authority accommodates higher government spending. Meanwhile, the effectiveness of endogenous adjustment of fiscal instruments (labor income tax rate in our models) depends on the types of shocks and the structure of the economy, and is generally not so much different between the cases of variable and constant interest rate.

In the remainder of the paper, the results from our estimated DSGE model are shown in Section 2, and those from the calibrated GIMF model are shown in Section 3. Section 4 concludes.
2 Results from Estimated DSGE Model

In this section, we assess the effects of fiscal policy using a Bayesian-estimated DSGE model of Japan’s economy. First we overview the model and then show the impulse responses to fiscal policy shocks and other types of shocks. The details of the model specification are described in Appendix. The estimated and calibrated parameter values are summarized in Table 1.

2.1 Model Overview

Our estimated model is a variant of the Medium-scale Japanese Economic Model (M-JEM), which has been developed at Research and Statistics Department, Bank of Japan (Fueki et al., 2010). It shares many similar features with recent New Keynesian DSGE models in the literature and those practically used in central banks, especially the Federal Reserve Board’s Estimated, Dynamic, Optimization-based (EDO) model (Edge, Kiley, and Laforte, 2007; Chung, Kiley, and Laforte, 2010). The M-JEM is a two-sector growth model that takes into account growth rate shocks including investment-goods sector specific technological progress. The two-sector production structure reflects the trends in relative prices and categories of real expenditure apparent in the Japanese data. Meanwhile, the M-JEM does not explicitly consider foreign countries and assumes that the export demand follows an exogenous stochastic process.

We add some features to the M-JEM for the analyses of fiscal policy. First, we introduce liquidity-constrained households who do not have access to asset markets and are forced to consume their after-tax income in every period. Due to the existence of this type of households (“rule-of-thumb” households) in addition to the households who optimize consumption plan subject to intertemporal budget constraints, fiscal policies including transfers have real effects.\(^1\) Second, we assume a simple fiscal policy rule for ensuring a non-explosive debt-to-output ratio and for specifying fiscal policy stances.

\(^1\) The rule-of-thumb households are introduced in many DSGE models for the analysis of fiscal policy, as in Gali et al. (2007).
Following the GIMF that will be compared with this model in the next section, we specify the fiscal policy as a targeting rule for the surplus-to-output ratio.\textsuperscript{2} The government budget constraint relates the surplus in period $t$ to the evolution of the debt level.

$$\frac{B_t}{R_t} = B_{t-1} - S_t,$$

where $B_t$ is the real government debt, $R_t$ is the real interest rate, and $S_t$ is the real government surplus. Then the fiscal policy rule is specified as follows.

$$\frac{S_t}{X_t} = s^* + \alpha_1(b_t - b^*) + \alpha_2\tilde{X}_t,$$

(1)

where $X_t$ is the real GDP, $s^*$ is the target surplus-to-GDP ratio, $b^*$ is the target debt-to-GDP ratio, and $\tilde{X}_t$ is the output gap. Apart from the surplus targeting, this rule incorporates two policy-feedback mechanisms: fiscal consolidation and business-cycle stabilization. The second term of the right-hand side in the rule (1) implies that setting $\alpha_1 > 0$ ensures faster convergence of debt at the expense of more volatile government surpluses. The parameter $\alpha_1$ represents the policy stance for this sense of “fiscal consolidation,” although the rule (1) automatically ensures a non-explosive debt-to-GDP ratio even with $\alpha_1 = 0$. Meanwhile, the third term of the right-hand side in (1) implies that setting $\alpha_2 > 0$ allows the government to run a temporary fiscal deficit (or below-target fiscal surplus) when the economic activity falls below the normal level (the output gap is negative). The parameter $\alpha_2$ represents the policy stance for “business cycle stabilization.” Given the policy rule (1), the government can use various policy instruments such as tax, transfer, and spending, to control the surplus. In what follows, however, we assume that the government adjusts only the labor income tax rate to control the surplus.

\textsuperscript{2}Various kinds of policy rules are assumed in DSGE models for the analysis of fiscal policy. Leeper et al. (2010) estimates a DSGE model that incorporates various specifications of fiscal policy rules.
2.2 Fiscal Policy Effects

Using this model, we first assess the effects of an unanticipated increase in government consumption. The government simultaneously raises the labor income tax rate to control the surplus following the policy rule (1). How much the tax rate is raised depends on the government’s policy stances.

Figure 1 shows the impulse responses to a positive shock to the government consumption that follows an AR(1) process and gradually diminishes as shown in panel (7). All variables are percent deviations from their baseline levels. In response to the positive government consumption shock, the labor income tax rate increases as shown in panel (2). The three responses for each variable correspond to the following three policy stances: “no feedback” policy under which the government simply meets the target surplus-to-GDP ratio in each period without policy feedback mechanisms ($\alpha_1 = \alpha_2 = 0$ in the rule (1)), “stabilization” policy under which the government considers business-cycle stabilization ($\alpha_1 = 0$ and $\alpha_2 > 0$), and “stabilization and consolidation” policy under which the government considers both business-cycle stabilization and fiscal consolidation ($\alpha_1 > 0$ and $\alpha_2 > 0$). When the government considers business-cycle stabilization, it additionally raises the tax rate to dampen the boom caused by its spending increase. Moreover, when the government considers fiscal consolidation, it further raises the tax rate to reduce more quickly its debt accumulated by the spending increase. Therefore, when a shock to the government spending occurs, the government’s policy stances for business-cycle stabilization and fiscal consolidation do not conflict with each other.

In response to the positive government consumption shock, real gross domestic product (GDP, panel (1)) increases if the government raises the labor income tax rate to the extent that the surplus-to-GDP ratio meets the target (“no feedback” policy). Since the tax increase dampens the demand for private consumption (panel (3)), the increase in GDP caused by the unanticipated increase in government consumption is very small. The spending multiplier, defined as the ratio of the change in GDP to the size of the government consumption shock, is 0.05 in the first year after the shock. If the
government considers business-cycle stabilization and fiscal consolidation, it additionally raises the tax rate and then real GDP could decrease and the spending multipliers could be negative. Table 2(1) shows the spending multipliers under “no feedback” policy and “stabilization” policy with our chosen parameter values. Meanwhile, under any policy stances shown in Figure 1, private investment for capital (panel (4)) increases to produce consumption goods for which the government’s demand increases. Inflation (panel (5)) accelerates and policy interest rate (panel (6)) is raised very slightly.

Figure 2 shows the impulse responses to the same shock when the policy interest rate does not change for some reason (e.g. the monetary authority’s accommodation of the government spending and the zero lower bound of the policy interest rate). Since the interest rate is not raised, private investment increases more than in the case of variable interest rate shown in Figure 1. Accordingly, real GDP increases more, which means the spending multiplier is larger, in the case of constant interest rate under “no feedback” fiscal policy. This result is consistent with the previous studies, including Christiano, et al. (2009), that show that the spending multiplier becomes larger when the monetary authority accommodates higher government spending. Under “stabilization” or “stabilization and consolidation” policy, however, the government raises the labor income tax rate more than it does when the interest rate is variable, so that real GDP decreases as in the case of variable interest rate. Then the spending multipliers in the cases of variable and constant interest rate are not so much different under “stabilization” policy and “stabilization and consolidation” policy. Table 2(1) shows those spending multipliers in the two cases under “no feedback” policy and “stabilization” policy. Moreover, Table 2(2) shows “stabilization responsiveness” and “stabilization effectiveness.” The former is defined as the ratio of the difference in the response of labor income tax rate between under “no feedback” policy and under “stabilization” policy to the size of the government spending shock. The latter is defined as the ratio of the difference in the response of GDP between under “no feedback” policy and under “stabilization” policy to the difference in the response of labor income tax rate between under the two policy stances. The product of the stabilization responsiveness and the
stabilization effectiveness is equal to the difference in the spending multiplier between under “no feedback” policy and under “stabilization” policy. While the stabilization responsiveness is larger in the case of constant interest rate, the stabilization effectiveness is not so much different between the cases of variable and constant interest rate.

2.3 Domestic and Foreign Shocks

Next we assess the responsiveness of fiscal policy rules to non-fiscal shocks and their effectiveness on the economic activity. We focus on a negative productivity shock, which was an important factor related to Japan’s domestic financial crisis in the 1990s, and a negative foreign demand shock, which corresponds to the recent global financial crisis. We continue to assume that the government adjusts the labor income tax rate, when a shock hits the economy, to control the surplus following the policy rule (1).

Figure 3 shows the impulse responses to a negative economy-wide productivity growth shock that causes a permanent decrease in the level of TFP as shown in panel (7). Accordingly, real GDP decreases permanently from its baseline level. The government cuts the labor income tax rate even under “no feedback” policy because it will keep the target surplus-to-GDP ratio when the level of GDP decreases. Meanwhile, inflation accelerates and policy interest rate is raised very slightly.

Under “stabilization” policy, the government cuts the labor income tax rate even more than under “no feedback” policy, which softens the negative effect of the productivity growth shock on real GDP. Table 2(2) shows the stabilization responsiveness (1.52) and the stabilization effectiveness (-0.33) in response to the productivity shock. Under “stabilization and consolidation” policy, the government does not cut the labor income tax rate so much as under “stabilization” policy, for reducing the government debt more quickly. Therefore, in response to the productivity shock, the government’s policy stances for business-cycle stabilization and fiscal consolidation conflict with each other, unlike the cases in response to the government spending shock.

Figure 4 shows the impulse responses to the same shock when the policy
interest rate does not change. Since the interest rate is not raised, real GDP and especially private investment does not decrease so much as in the case of variable interest rate shown in Figure 3. It follows that the government does not need to cut the labor income tax rate so much as in the case of variable interest rate under “no feedback” policy and especially under “stabilization” policy. Table 2(2) shows that the stabilization responsiveness is much smaller and the stabilization effectiveness is also smaller in the case of constant interest rate than in the case of variable interest rate.

Figure 5 shows the impulse responses to a negative foreign demand shock that follows an AR(1) process and causes a temporary decline in net export (rather than gross export) as shown in panel (7). Since the M-JEM is a closed economy model and assumes that export goods are all produced by (fast-growing) investment goods sector, the foreign demand shock has similar features to a government investment shock. In response to the negative foreign demand shock, real GDP declines while domestic private investment increases because the domestic relative price of investment goods to consumption goods declines. Inflation accelerates and policy interest rate is raised very slightly. Under “stabilization” policy, the government cuts the labor income tax rate, which softens the negative effect of the shock on real GDP. Table 2(2) shows the stabilization responsiveness (0.02) and the stabilization effectiveness (-0.28) in response to the foreign demand shock. Compared with the cases in response to the productivity shock, the stabilization responsiveness is much smaller because the negative effect of the foreign demand shock on real GDP is much smaller than that of the productivity shock. The stabilization effectiveness is also smaller because the labor income tax cut boosts only consumption in response to the foreign demand shock while it boosts both consumption and investment in response to the productivity shock. Meanwhile, as in the cases in response to the productivity shock, the government does not cut the labor income tax rate under “stabilization and consolidation” policy so much as under “stabilization” policy.

Figure 6 shows the impulse responses to the same shock when the policy interest rate does not change. Since the interest rate is not raised, real GDP does not decrease so much as in the case of variable interest rate shown in
Figure 5. Compared with the cases in response to the productivity shock, however, the difference in the response of real GDP between the cases of variable and constant interest rate is much smaller. Table 2(2) shows that the stabilization responsiveness is not so much different between the two cases in response to the foreign demand shock. It also shows that the stabilization effectiveness is slightly smaller in the case of constant interest rate than in the case of variable interest rate.

3 Results from Calibrated GIMF Model

We also use the IMF’s large-scale “Global Integrated Monetary and Fiscal (GIMF)” model (Kumhof, et al., 2010) to assess the effects of fiscal policy in Japan. Although the GIMF is not estimated, it has several important features that are not considered in our estimated model (M-JEM) in Section 2. Most of all, the GIMF is an open economy model that can consider the international spillover of fiscal policy effects and the effects of exchange rate movements. Moreover, the GIMF considers overlapping generations households as well as liquidity constrained households, the financial accelerator mechanism for the non-financial corporate sector, etc. In this section, we first briefly overview the GIMF and then show the impulse responses to fiscal policy shocks and other types of shocks. The details of the model specification are described in Kumhof, et al. (2010).

3.1 Model Overview

The version of the GIMF we use in this paper is the 5-block version, consisting of the United States, the Euro Area, Japan, emerging Asia, and other countries. All parameters except gross population growth and gross technology growth differ across blocks. Some parameter values for Japan are calibrated by referring to our estimated model (M-JEM).

The fiscal policy specifications of the GIMF are very rich, which is one of its main features. However, for simplicity and comparison purposes, we use the same policy rule (1) as that introduced in our estimated model. Moreover,
as in Section 2, we continue to assume that the government adjusts the labor income tax rate to control the surplus following the policy rule (1), although the GIMF contains a rich set of fiscal policy instruments including lump-sum tax and transfers, redistribution between agents, and public investment and consumption spending. Meanwhile, we keep the GIMF’s assumption that there are overlapping generations households as well as liquidity constrained households, which makes the effects of fiscal policy more realistic.

The GIMF we use in this paper is an annual rather than quarterly model. In what follow, we compare the GIMF’s annual impulse responses with the M-JEM’s quarterly impulse responses shown in Section 2.

3.2 Fiscal Policy Effects

Using the GIMF, we first assess the effects of an unanticipated increase in government consumption, as in Section 2.

Figure 7 shows the impulse responses to a positive shock to the government consumption that follows an AR(1) process and gradually diminishes as shown in panel (7). The size of the shock is comparable to the corresponding quarterly AR(1) process of the M-JEM shown in Figure 1 and 2. In response to this shock, real GDP increases from the baseline level but only for two years after the shock. The government raises the labor income tax rate following the policy rule, which dampens the demand for private consumption persistently. Moreover, unlike in the M-JEM (Figure 1), export and private investment also decreases persistently. Meanwhile, inflation accelerates and policy interest rate is raised, which leads to real appreciation of the domestic currency (not shown in the figure). Table 2(1) shows the spending multiplier in the first two years. Compared with the M-JEM, the first-year multiplier is larger but the second-year multiplier is smaller.

Under “stabilization” policy, the government raises the labor income tax rate more than under “no feedback policy,” but only for two years. The stabilization responsiveness and the stabilization effectiveness shown in Table 2(2) are much smaller than the corresponding cases with the M-JEM. Under “stabilization and consolidation” policy, however, the government raises the
labor income tax rate even more, which almost halves the first-year spending multiplier. The responsiveness and effectiveness of the government’s policy stance for fiscal consolidation seems much larger than with the M-JEM.

Figure 8 shows the impulse responses to the same shock when the policy interest rate does not change. Since the interest rate is not raised, private investment increases and export does not decrease so much and so persistently as in the case of variable interest rate. Accordingly, real GDP increases more persistently and the spending multiplier is larger than in the case of variable interest rate. As shown in Table 2(1), this result is obtained both under “no feedback” policy and under “stabilization” policy, which is consistent with the previous studies that show that the spending multiplier becomes larger when the monetary authority accommodates higher government spending. Meanwhile, Table 2(2) shows that, as with the M-JEM, the stabilization effectiveness is not so much different between the cases of variable and constant interest rate, although the stabilization responsiveness is larger in the case of constant interest rate.

### 3.3 Domestic and Foreign Shocks

Next we assess the responsiveness of fiscal policy rules to non-fiscal shocks and their effectiveness on the economic activity. As in Section 2, we focus on a negative productivity shock and a negative foreign demand shock, but these shocks in the GIMF are substantially different from those in the M-JEM.

Figure 9 shows the impulse responses to a negative productivity shock that causes a temporary decrease (rather than a permanent decrease as with the M-JEM) in the level of TFP as shown in panel (7). In response to this shock, real GDP, consumption, investment, and export decrease persistently from their baseline level. The government raises the labor income tax rate under “no feedback” policy for compensating the decrease in the tax base. Meanwhile, inflation accelerates and policy interest rate is raised slightly. Under “stabilization” policy, the government cuts the labor income tax rate, which softens the negative effect of the productivity shock on real GDP. Under “stabilization and consolidation” policy, however, the government does
not cut the labor income tax rate so much as under “stabilization” policy, for reducing the government debt more quickly.

Figure 10 shows the impulse responses to the same shock when the policy interest rate does not change. Since the interest rate is not raised, real GDP does not decrease so much as in the case of variable interest rate shown in Figure 9. It follows that the government does not need to cut the labor income tax rate so much as in the case of variable interest rate under “stabilization” policy. Table 2(2) shows that the stabilization responsiveness is smaller in the case of constant interest rate than in the case of variable interest rate. Meanwhile, the stabilization effectiveness is not so much different between the cases of variable and constant interest rate.

Figure 11 shows the impulse responses to a negative foreign demand shock, which is a combination of the shocks to consumption and investment demand in the U.S. and the Euro Area. It causes temporary declines in foreign GDP and in gross export as shown in panel (7) and (8), respectively. In response to this shock, unlike with the M-JEM, consumption and investment decrease, inflation rate falls, and policy interest rate is reduced. The government raises the labor income tax rate under “no feedback” policy for compensating the decrease in the tax base. Under “stabilization” policy, the government cuts the labor income tax rate, which softens the negative effect of the productivity shock on real GDP. Under “stabilization and consolidation” policy, however, the government does not cut the labor income tax rate so much as under “stabilization” policy, for reducing the government debt more quickly.

Figure 12 shows the impulse responses to the same shock when the policy interest rate does not change (possibly under the zero lower bound). Since the interest rate is not reduced, real GDP decrease more than in the case of variable interest rate shown in Figure 11. Table 2(2) shows that the stabilization responsiveness is larger than in the case of variable interest rate. Meanwhile, the stabilization effectiveness is not no much different (slightly smaller) from the case of variable interest rate.
3.4 Further Analyses with GIMF

Currently we are considering how sensitive is the effectiveness of fiscal policy to domestic structural parameters (e.g. population aging) and the policy stances of foreign countries. Those analyses could be conducted using the GIMF.

4 Concluding Remarks

(To be written.)
Appendix: Estimated DSGE Model

In this Appendix, we provide a brief description of our estimated model, which our analyses in Section 2 are based on. More details including the equilibrium conditions, stationary equilibrium conditions, and log-linearized system are provided in Fueki et al. (2010).

Final goods producers

Final goods producers in the slow-growing sector (sector $c$) produce the consumption goods $X^c$, and those in the fast-growing sector (sector $k$) produce the investment goods $X^k$. They face the competitive market and produce the final goods, $X^s$, $s \in \{c, k\}$, combining a continuum of $s$ sector-specific intermediate goods, $X^s(j)$, $j \in [0, 1]$, according to the following Dixit-Stiglitz type technology:

$$X^s_t = \left( \int_0^1 X^s_t(j)^{\frac{\alpha^s_{t-1}}{\alpha^s_{t-1}}} \right)^{\frac{\Theta^x,s_t}{\Theta^s_{t-1}}}, \quad s = \{c, k\}$$

(2)

where $\Theta^x,s_t$ is the elasticity of substitution between the differentiated intermediate goods input. Letting $\theta^x,s_t \equiv \ln \Theta^x,s_t - \ln \Theta^s_{t-1}$, we assume that $\theta^x,s_t$ follows an ARMA(1,1) process.

$$\theta^x,s_t = \rho^{\theta^x,s} \theta^x,s_{t-1} + \epsilon^x,s_t + \rho^{\theta^x,s,ma} \epsilon^x,s_{t-1}$$

(3)

where $\epsilon^x,s_t \sim i.i.d. N(0, (\sigma^{\theta^x,s})^2)$. This stochastic elasticity of substitution introduces transitory markup shocks into the pricing decisions of intermediate goods producers. Subject to the above aggregation technology, a final goods producer in each sector chooses the optimal level of each intermediate goods to minimize the cost to purchase them taking their prices as given.

Intermediate goods producers

Intermediate goods producers in both sectors face the monopolistically competitive market and produce the sector-specific intermediate goods $X^s(j)$, $s \in \{c, k\}$ with the following production function.
\[ X_t^s(j) = [K_t^{u,s}(j)]^\alpha [AZ_t^m AZ_t^k L_t^{x,s}(j)]^{1-\alpha} \]  

where \( K_t^{u,s}(j) \) and \( L_t^{x,s}(j) \) are the effective capital input and the labor input of a firm \( j \), respectively. Letting \( U_t^s \) be the capital utilization rate in sector \( s \), the effective capital input is written as \( K_t^{u,s}(j) \equiv K_t^s(j) \times U_t^s(j) \). Further, the labor input of a firm \( j \) is the continuum of the differentiated labor input; \( L_t^{x,s}(j) = \int_1^0 [L_t^{x,s}(i,j)]^{(\Theta_t^s-1)/\Theta_t^s} d\Theta_t^s/((\Theta_t^s-1)) \) where \( \Theta_t^s \) is the elasticity of substitution and \( \theta_t^s(\equiv \ln \Theta_t^s - \ln \Theta_t^s) \) follows an ARMA(1,1) process. This stochastic elasticity of substitution introduces transitory wage markup shocks into households’ labor supply decisions.

\( AZ_t^m \) is the economy-wide technology shock and \( AZ_t^k \) is the fast-growing (investment goods producing) sector specific technology shock. In order to reduce the number of shocks in the model, we presume that the slow-growing (consumption goods producing) sector does not have the sector-specific shock; \( AZ_t^c = 1 \). We assume that each of the technology shocks contains two separate stochastic components, one \((A_t^n)\) is stationary in levels and the other \((Z_t^n)\) is stationary in growth rates, where \( n \in \{m, k\} \).

\[
\ln AZ_t^n = \ln A_t^n + \ln Z_t^n, \\
\ln A_t^n = A_s + \epsilon_t^{a,n}, \\
\ln Z_t^n - \ln Z_{t-1}^n = \ln \Gamma_t^{z,n} = \ln(\Gamma_s^{z,n} \times \exp[\gamma_t^{z,n}]) = \ln \Gamma_s^{z,n} + \gamma_t^{z,n}, \\
\gamma_t^{z,n} = \rho_t^{z,n} \gamma_{t-1}^{z,n} + \epsilon_t^{z,n},
\]

where \( \epsilon_t^{a,n} \) and \( \epsilon_t^{a,n} \) are i.i.d. shock processes, \( A_s \) and \( \Gamma_s^{z,n} \) are the constant technology level and growth rate, respectively. (Hereafter, variables with subscript * represent the variables at steady state.)

An intermediate goods producer in sector \( s \in \{c, k\} \) maximizes the discounted future profit, taking as given the final goods producers’ demand schedule, \( X_t^s(j) = [P_t^s(j)/P_t^s]^{-k^{x,s}} X_t^s \), the marginal cost, \( MC_t^s(j) \), of a unit product, \( X_t^s(j) \), the aggregated price level of its sector, \( P_t^s = \{\int_0^1 [P_t^s(j)]^{(\Theta_t^s-1)/\Theta_t^s} d\Theta_t^s\}^{\Theta_t^s/(\Theta_t^s-1)} \), and households’ valuation of a unit nominal income in each period, \( \Lambda_t^c/P_t \), where \( \Lambda_t^c \) is the marginal utility of consumption.
\[ E_0 \sum_{t=0}^{\infty} \beta^t \frac{\Lambda_t^c}{P_t^c} \left\{ P_t^s(j)X_t^s(j) - MC_t^s(j)X_t^s(j) \left[ R_t^cU_t^c(k)K_t^c(k) + R_t^kU_t^k(k)K_t^k(k) - P_t^sI_t(k) \right] \right\} \]

where \( \Pi^{p,s}_t \) represents the time-invariant trend inflation. Since the quadratic price adjustment cost is imposed on the deviation of the optimum price inflation from the past inflation, not only the price response to the marginal cost becomes sticky as in Rotemberg (1982) but the equilibrium inflation also becomes sticky.

**Capital stock owners**

Capital stock owners provide the capital service to the intermediate goods producers in both sectors, receive the rental cost of capital in exchange, and accumulate the investment goods. Each capital stock owner chooses investment expenditure, \( I_t \), the amount and utilization of capital in both sectors, \( K_t^c, U_t^c, K_t^k, \) and \( U_t^k \), to maximize its discounted profit,

\[ E_0 \sum_{t=0}^{\infty} \beta^t \frac{\Lambda_t^c}{P_t^c} \left[ R_t^cU_t^c(k)K_t^c(k) + R_t^kU_t^k(k)K_t^k(k) - P_t^sI_t(k) \right] \]

subject to the capital evolution process with quadratic investment adjustment cost and the costs from higher utilization rates,

\[ K_{t+1}(k) = (1 - \delta)K_t(k) + I_t(k) \]

\[ - \frac{100 \cdot \chi}{2} \left[ \frac{I_t(k)A_t^\varphi - I_{t-1}(k)\Gamma_i^{z,m}\Gamma_i^{z,k}}{K_t} \right]^2 K_t \]

\[ - \sum_{s=c,k} \kappa \left[ \left( Z^U U_t^s(k) \right)^{1+\psi} - 1 \right] K_t^s, \]

where \( K_t(k) = K_t^c(k) + K_t^k(k) \), \( \chi \) is the investment adjustment cost parameter, and \( A_t^\varphi \) is the investment adjustment cost shock of AR(1) that is unity at the steady state. The utilization cost in the capital evolution process presumes that high capital utilization leads to faster capital depreciation, as in
Greenwood, Hercowitz, and Huffman (1988) and Sugo and Ueda (2008). \( Z^U_t \) is a stochastic variation in the adjustment costs of capital utilization that is assumed to be common in both sectors and follows an AR(1) process.\(^3\)

### Households

Each household chooses its purchase of consumption goods, \( C_t \), its holdings of bonds, \( B_t \), its wages for both sectors, \( W^c_t \) and \( W^k_t \), and supply of labor consistent with each wage, \( L^c_t \) and \( L^k_t \), given the demand schedule for the differentiated labor supply, \( L^c_t(i) = (W^c_t(i)/W^c_t)^{-\Theta^c_t} L^c_t \) and \( L^k_t(i) = (W^k_t(i)/W^k_t)^{-\Theta^k_t} L^k_t \), to maximize the utility function,

\[
E_0 \sum_{t=0}^{\infty} \beta^t \Xi_t^{-\beta} \left\{ c^c \ln (C_t(i) - hC_{t-1}(i)) - c^l \left[ \frac{(L^c_t(i) + L^k_t(i)) / \Xi_t}{1 + \nu} \right]^{1+\nu} \right\} \tag{12}
\]

subject to its budget constraint,

\[
\frac{1}{R_t} B_{t+1}(i) = B_t(i) + \sum_{s=c,k} W^s_t(i) L^s_t(i) + \Omega_t(i) - P^c_t C_t(i)
\]

\[
- \sum_{s=c,k} \frac{100 \cdot \chi^w}{2} \left\{ \frac{W^s_t(i)}{L^s_t-1(i)} - \eta^w \Pi^w_t - (1 - \eta^w) \Pi^w_t \right\}^2 W^s_t L^s_t
\]

\[
- \frac{100 \cdot \chi^l}{2} \left( \frac{L^c_t}{L^c_t + L^k_t} W^c_t + \frac{L^k_t}{L^c_t + L^k_t} W^k_t \right)
\]

\[
\times \left( \frac{L^c_t(i)}{L^c_t(i)} - \eta^l L^c_t(i) - (1 - \eta^l) L^c_t(i) \right)^2 \frac{L^k_t}{L^c_t L^k_t} L_t \tag{13}
\]

In the utility function, \( \Xi_t^{-\beta} \) is the intertemporal preference shock, \( \Xi_t^l \) is the labor supply shock (intradepartamental preference shock), and \( h \) is the degree of the habit persistence of the household. We assume that the intertemporal preference shock follows an AR(1) process and the labor supply shock is non-stochastic (\( \Xi_t^l = 1 \)) as a benchmark case. In the budget constraint, \( \Omega_t \) is the household’s capital and profits income. The second line in the right hand side is the quadratic wage adjustment cost imposed on the deviation of the optimum wage growth from the past wage inflation. With this formulation,

\(^3\)We assume that \( \kappa = R_t/P^k_t \), which implies that utilization rate is unity at the steady state.
the wage inflation as well as the wage level becomes sticky. The third line in
the right hand side is the labor reallocation cost, which helps to mimic the
sectoral comovement of labor hours during business cycles.

**Real GDP growth and GDP deflator inflation**

Since the trend growth rate is different in each sector, we aggregate the
real GDP as a devisia index, following Whelan (2003) and Edge, Kiley, and
Laforte (2007). This devisia-index aggregation allows us to avoid the bias
of the deflator and also to mimic the SNA data which is compiled by the
chain-index aggregation. The growth rate of the real GDP is calculated as

\[
H_{t}^{dp} = \left[ \left( \frac{X_t^c}{X_{t-1}^c} \right)^{P_t^c \tilde{X}_t^c} \left( \frac{X_t^k}{X_{t-1}^k} \right)^{P_t^k \tilde{X}_t^k} \right]^{1/P_c^t \tilde{X}_t^c + P_k^t \tilde{X}_t^k},
\]

(14)

The inflation rate of the GDP deflator, \(\Pi_t^{p,dp}\), is implicitly defined by,

\[
\Pi_t^{p,dp} = \frac{P_t^{dp} X_t^{dp}}{P_{t-1}^{dp} X_{t-1}^{dp}} = \frac{P_t^c X_t^c + P_t^k X_t^k}{P_{t-1}^c X_{t-1}^c + P_{t-1}^k X_{t-1}^k}.
\]

(15)

**Monetary authority**

Following Chung, Kiley, and Laforte (2010), we assume that the monetary
authority sets the short-term nominal interest rate following a Taylor type
feedback rule with interest rate smoothing.

\[
R_t = (R_{t-1})^{\phi^r} (\tilde{R}_{t})^{1-\phi^r} \exp (\epsilon^r_t)
\]

(16)

\[
\tilde{R}_t = R_{s} \left( \tilde{X}_t \right)^{\phi^h,dp} \left( \frac{\tilde{X}_t}{X_{t-1}} \right)^{\phi^{\Delta h,dp}} \left( \frac{\Pi_t^{p,dp} \phi^{\sigma,dp}}{\Pi_t^{dp,dp}} \right)
\]

(17)

where \(\phi^r\) is the degree of interest rate smoothing, \(\epsilon^r\) is the interest rate shock,
and \(\phi^{h,dp}, \phi^{\Delta h,dp}, \phi^{\sigma,dp}\) are the degrees of responsiveness in the policy
rule. \(\tilde{X}_t\) is the output gap, which is defined as the deviation of real GDP
from its level under flexible prices and wages.\(^4\)

\(^4\)The level of real GDP is defined as a devisia index, similarly to its growth rate (14).
Market clearing

Before closing the model, we assume that government expenditure and net export are produced by the slow-growing sector and fast-growing sector, respectively. Both of the external factors are stochastic and follow an AR(1) process as follows.

\[ G_t \equiv (\tilde{G}_t \times \Gamma_{t}^{xc}), \quad \ln \tilde{G}_t = \alpha^g \ln \tilde{G}_{t-1} + \epsilon_t^g \]  
\[ F_t \equiv (\tilde{F}_t \times \Gamma_{t}^{xk}), \quad \ln \tilde{F}_t = \alpha^f \ln \tilde{F}_{t-1} + \epsilon_t^f \]

At the symmetric equilibrium, each market clears.

\[ X^c_t = \int_0^1 C_t(i)di + G_t + \frac{100 \cdot \chi^w}{2} \left[ \Pi_t^{w,c} - \eta^w \Pi_{t-1}^{w,c} - (1 - \eta^w) \Pi^w_{*} \right]^2 W_t^c L_t^c \\
+ \frac{100 \cdot \chi^p}{2} \left[ \Pi_t^{p,c} - \eta^p \Pi_{t-1}^{p,c} - (1 - \eta^p) \Pi^p_{*} \right]^2 P_t^c X_t^c \\
+ \frac{100 \cdot \chi^l}{2} \left( \frac{L_t^c}{L_t^c + L_t^k} W_t^c + \frac{L_t^k}{L_t^c + L_t^k} W_t^k \right) \\
\times \left\{ \frac{L_t^c}{L_t^k} - \eta^l \frac{L_t^{c-1}}{L_t^{k-1}} - (1 - \eta^l) \frac{L_t^c}{L_t^k} \right\}^2 \frac{L_t^k}{L_t^c} L_t \]  
\[ X^k_t = \int_0^1 I_t(k)dk + F_t + \frac{100 \cdot \chi^w}{2} \left[ \Pi_t^{w,k} - \eta^w \Pi_{t-1}^{w,k} - (1 - \eta^w) \Pi^w_{*} \right]^2 W_t^k L_t^k \\
+ \frac{100 \cdot \chi^p}{2} \left[ \Pi_t^{p,k} - \eta^p \Pi_{t-1}^{p,k} - (1 - \eta^p) \Pi^p_{*} \right]^2 P_t^k X_t^k \]  
\[ L_t^s(i) = \int_0^1 L_t^s(i, j) dj \]  
\[ \int_0^1 U_t^s(k) K_t^s(k) dk = \int_0^1 K_t^{u,s}(j) dj \]

\( \forall i \in [0, 1] \) and for \( s = c, k \).
References


Table 1: Calibrated and Estimated Parameter Values

Calibrated Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.30</td>
<td>$\beta$</td>
<td>0.99</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.02</td>
<td>$\Theta_a^{l,c}$</td>
<td>6.00</td>
</tr>
<tr>
<td>$\Theta_a^{z,k}$</td>
<td>6.00</td>
<td>$\Theta_a^{l,l}$</td>
<td>6.00</td>
</tr>
<tr>
<td>$\Gamma_z^{z, m}$</td>
<td>1.002</td>
<td>$\Gamma_z^{l, k}$</td>
<td>1.004</td>
</tr>
<tr>
<td>$\phi^{z, gap}$</td>
<td>0.91</td>
<td>$\text{ROT}^{\text{share}}$</td>
<td>0.5</td>
</tr>
<tr>
<td>$d_{gap}$</td>
<td>0.9</td>
<td>$\rho^{l,debt}$</td>
<td>0.025</td>
</tr>
<tr>
<td>$\rho^z$</td>
<td>0.97</td>
<td>$\rho^{z, m}$</td>
<td>0.8</td>
</tr>
<tr>
<td>$\rho^l$</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated Parameter Values

<table>
<thead>
<tr>
<th>Param.</th>
<th>Prior Distribution</th>
<th>Prior Mean</th>
<th>Prior S.D.</th>
<th>Post. Mean</th>
<th>Conf. Interval (90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h$</td>
<td>beta</td>
<td>0.6</td>
<td>0.15</td>
<td>0.49</td>
<td>Lower: 0.39 Upper: 0.59</td>
</tr>
<tr>
<td>$\nu$</td>
<td>gamm</td>
<td>2.0</td>
<td>1.00</td>
<td>0.31</td>
<td>Lower: 0.06 Upper: 0.55</td>
</tr>
<tr>
<td>$\chi^p$</td>
<td>gamm</td>
<td>4.0</td>
<td>2.00</td>
<td>13.85</td>
<td>Lower: 8.21 Upper: 19.26</td>
</tr>
<tr>
<td>$\eta^p$</td>
<td>beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.16</td>
<td>Lower: 0.05 Upper: 0.26</td>
</tr>
<tr>
<td>$\chi^w$</td>
<td>gamm</td>
<td>4.0</td>
<td>2.00</td>
<td>11.49</td>
<td>Lower: 7.56 Upper: 15.37</td>
</tr>
<tr>
<td>$\eta^w$</td>
<td>beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.16</td>
<td>Lower: 0.05 Upper: 0.26</td>
</tr>
<tr>
<td>$\chi^f$</td>
<td>gamm</td>
<td>2.0</td>
<td>1.00</td>
<td>1.90</td>
<td>Lower: 0.40 Upper: 3.37</td>
</tr>
<tr>
<td>$\eta^f$</td>
<td>beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.51</td>
<td>Lower: 0.26 Upper: 0.75</td>
</tr>
<tr>
<td>$\chi$</td>
<td>gamm</td>
<td>2.0</td>
<td>1.00</td>
<td>1.24</td>
<td>Lower: 0.47 Upper: 1.99</td>
</tr>
<tr>
<td>$\phi^f$</td>
<td>beta</td>
<td>0.7</td>
<td>0.15</td>
<td>0.92</td>
<td>Lower: 0.90 Upper: 0.94</td>
</tr>
<tr>
<td>$\psi$</td>
<td>norm</td>
<td>1.0</td>
<td>1.00</td>
<td>3.14</td>
<td>Lower: 2.09 Upper: 4.19</td>
</tr>
</tbody>
</table>
### Table 2. Fiscal Multiplier and Policy Effectiveness

(1) Spending Multiplier: Change in GDP (%)/Change in Government Consumption (%)

<table>
<thead>
<tr>
<th></th>
<th>M-JEM First Year</th>
<th>M-JEM Second Year</th>
<th>GIMF First Year</th>
<th>GIMF Second Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Feedback (Variable Interest Rate)</td>
<td>0.05</td>
<td>0.06</td>
<td>0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>Stabilization (Variable Interest Rate)</td>
<td>-0.03</td>
<td>-0.07</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>No Feedback (Constant Interest Rate)</td>
<td>0.08</td>
<td>0.11</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>Stabilization (Constant Interest Rate)</td>
<td>-0.03</td>
<td>-0.08</td>
<td>0.08</td>
<td>0.05</td>
</tr>
</tbody>
</table>

(2-1) Stabilization Responsiveness

<table>
<thead>
<tr>
<th></th>
<th>M-JEM First Year</th>
<th>M-JEM Second Year</th>
<th>GIMF First Year</th>
<th>GIMF Second Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Consumption Shock (Variable Interest Rate)</td>
<td>0.21</td>
<td>0.36</td>
<td>0.10</td>
<td>0.01</td>
</tr>
<tr>
<td>Government Consumption Shock (Constant Interest Rate)</td>
<td>0.31</td>
<td>0.52</td>
<td>0.12</td>
<td>0.05</td>
</tr>
<tr>
<td>Productivity Shock (Variable Interest Rate)</td>
<td>1.52</td>
<td>0.90</td>
<td>0.87</td>
<td>1.53</td>
</tr>
<tr>
<td>Productivity Shock (Constant Interest Rate)</td>
<td>0.65</td>
<td>0.24</td>
<td>0.74</td>
<td>1.16</td>
</tr>
<tr>
<td>Foreign Demand Shock (Variable Interest Rate)</td>
<td>0.02</td>
<td>0.03</td>
<td>0.37</td>
<td>0.41</td>
</tr>
<tr>
<td>Foreign Demand Shock (Constant Interest Rate)</td>
<td>0.02</td>
<td>0.01</td>
<td>0.44</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Note 1: "Foreign Demand Shock" refers to shock to foreign GDP in GIMF, and shock to Japan's net exports in M-JEM.

Note 2: Stabilization responsiveness is defined as the difference in the response of labor income tax rate between "no feedback" policy and "stabilization" policy divided by the size of the government spending shock.

(2-2) Stabilization Effectiveness

<table>
<thead>
<tr>
<th></th>
<th>M-JEM First Year</th>
<th>M-JEM Second Year</th>
<th>GIMF First Year</th>
<th>GIMF Second Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Consumption Shock (Variable Interest Rate)</td>
<td>-0.36</td>
<td>-0.35</td>
<td>-0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>Government Consumption Shock (Constant Interest Rate)</td>
<td>-0.37</td>
<td>-0.36</td>
<td>-0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>Productivity Shock (Variable Interest Rate)</td>
<td>-0.33</td>
<td>-0.35</td>
<td>-0.33</td>
<td>-0.28</td>
</tr>
<tr>
<td>Productivity Shock (Constant Interest Rate)</td>
<td>-0.29</td>
<td>-0.33</td>
<td>-0.34</td>
<td>-0.30</td>
</tr>
<tr>
<td>Foreign Demand Shock (Variable Interest Rate)</td>
<td>-0.28</td>
<td>-0.29</td>
<td>-0.16</td>
<td>-0.17</td>
</tr>
<tr>
<td>Foreign Demand Shock (Constant Interest Rate)</td>
<td>-0.25</td>
<td>-0.21</td>
<td>-0.14</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

Note: Stabilization effectiveness is defined as the difference in the response of GDP between "no feedback" policy and "stabilization" policy divided by the difference in the response of labor income tax rate between two cases.
Fig. 1: Positive Government Consumption Shock (Variable Interest Rate)

(1) Real GDP

(2) Labor Income Tax Rate

(3) Consumption

(4) Investment

(5) Inflation

(6) Policy Interest Rate

(7) Government Consumption
Fig. 2: Positive Government Consumption Shock (Constant Interest Rate)

1. Real GDP
2. Labor Income Tax Rate
3. Consumption
4. Investment
5. Inflation
6. Policy Interest Rate
7. Government Consumption

Quarter
Fig. 3: Negative Productivity Shock (Variable Interest Rate)

(1) Real GDP

( % )

Quarter

(2) Labor Income Tax Rate

( % )

Quarter

(3) Consumption

( % )

Quarter

(4) Investment

( % )

Quarter

(5) Inflation

( % )

Quarter

(6) Policy Interest Rate

( % )

Quarter

(7) TFP

( % )

Quarter
Fig. 4: Negative Productivity Shock (Constant Interest Rate)

(1) Real GDP
(\%)  

(2) Labor Income Tax Rate
(\%)  

(3) Consumption
(\%)  

(4) Investment
(\%)  

(5) Inflation
(\%)  

(6) Policy Interest Rate
(\%)  

(7) TFP
(\%)  

Quarter
Fig. 5: Negative Foreign Demand Shock (Variable Interest Rate)

(1) Real GDP

(2) Labor Income Tax Rate

(3) Consumption

(4) Investment

(5) Inflation

(6) Policy Interest Rate

(7) Net Export Shock
Fig. 6: Negative Foreign Demand Shock (Constant Interest Rate)

(1) Real GDP

(2) Labor Income Tax Rate

(3) Consumption

(4) Investment

(5) Inflation

(6) Policy Interest Rate

(7) Net Export Shock
Fig. 7: Positive Government Consumption Shock (Variable Interest Rate)
Fig. 8: Positive Government Consumption Shock (Constant Interest Rate)

(1) Real GDP

(2) Labor Income Tax Rate

(3) Consumption

(4) Investment

(5) Inflation

(6) Policy Interest Rate

(7) Government Consumption

(8) Exports
Fig. 9: Negative Productivity Shock (Variable Interest Rate)

(1) Real GDP
(2) Labor Income Tax Rate
(3) Consumption
(4) Investment
(7) Inflation
(8) Policy Interest Rate
(7) TFP
(8) Exports
Fig. 10: Negative Productivity Shock (Constant Interest Rate)

(1) Real GDP
(2) Labor Income Tax Rate
(3) Consumption
(4) Investment
(5) Inflation
(6) Policy Interest Rate
(7) TFP
(8) Exports
Fig. 11: Negative Foreign Demand Shock (Variable Interest Rate)

(1) Real GDP (%)

(2) Labor Income Tax Rate (%)

(3) Consumption (%)

(4) Investment (%)

(5) Inflation (%)

(6) Policy Interest Rate (%)

(7) Foreign GDP (%)

(8) Exports (%)
Fig. 12: Negative Foreign Demand Shock (Constant Interest Rate)

(1) Real GDP ( % )

(2) Labor Income Tax Rate ( % )

(3) Consumption ( % )

(4) Investment ( % )

(5) Inflation ( % )

(6) Policy Interest Rate ( % )

(7) Foreign GDP ( % )

(8) Exports ( % )